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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF PUBLIC WORKS
THE REPUBLIC OF CHILE

THE REHABILITATION AND CONSERVATION PROGRAM ON THE BRIDGES IN THE REPUBLIC OF CHILE (PHASE 2)

FINAL REPORT

BRIDGE MANUALS

(VOLUME 6/8)

JULY 1998

PACIFIC CONSULTANTS INTERNATIONAL

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DIVISION I	BRIDGE PLANNING
DIVISION II	BRIDGE ENVIRONMENTAL STUDY
DIVISION III	BRIDGE INSPECTION AND REHABILITATION
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DIVISION I

BRIDGE PLANNING

DIVISION I BRIDGE PLANNING

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DIVISION I BRIDGE PLANNING

CHAPTER 1 GENERAL

1.1 Introduction

"Bridge Planning" is a composite art to involve not only bridge design but also traffic, highway, waterway and other related knowledges. In broad sense, it even includes administration duties such as financing measures, land acquisition, consultations with other authorities for re-location of public utilities, etc. to assure its implementation. Thus, the job of bridge planning, for it requires a wide territory of engineerings, cannot usually be carried out but by the experienced engineers who are of course bridge specialists and further must have other related profound knowledges.

Although it is difficult to systemize all of the bridge planning procedures, this manual will provide mainly with the procedures for the structural side of bridge planning for the engineers who are not always well experienced. Particularly, the provisions for the waterway crossing requirements given in chapter 3.3.2, which is the extraction of the Japan's river act, will be a good help to understand how to take hydrological condition into the bridge planning to cross rivers. However, the manual does not detail about traffic demand and highway studies nor administration matters.

1.2 General Bridge Structure

The general features and terms of the bridge structure explained in the manual are illustrated as follows:

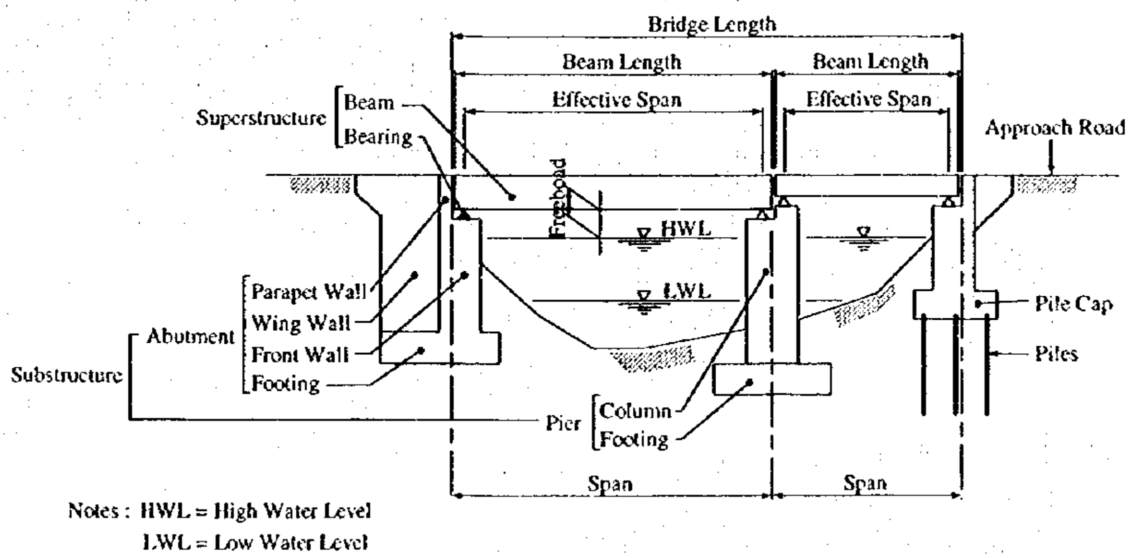


Fig. 1.1 General Bridge Structure

1.3 Bridge Life Cycle

In general, the life of bridge is considered to take a management cycle namely planned, designed, built and used as shown in the following flowchart.

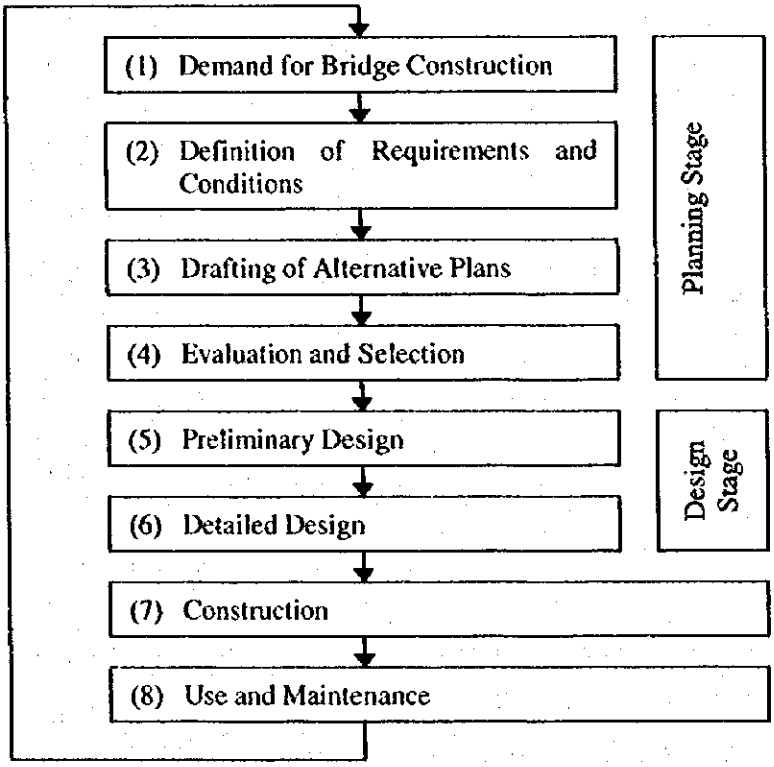


Fig. 1.2 Bridge Life Cycle

In the above cycle, the steps (1) to (4) are defined as the planning stage, and which are the very process to be discussed in this manual.

The steps (5) and (6) are recognized as the design stage to cover the activities from structural analysis up to preparation of drawings and specifications normally including construction contract documents. The step (5)-preliminary design is generally performed with less accuracy than that of detailed design to obtain outline of the project and clarify problems, which enable the authority to take early actions and corrections before detailed design sets in.

Bridge plan is materialized through the detailed design and construction. Completed bridge will be used over a long period as a public facility receiving maintenance and when it becomes decrepit, the demand for new bridge construction arises again.

CHAPTER 2 PROCESS OF BRIDGE PLANNING

2.1 General

The work of bridge planning is begun upon seizing the demand for bridge construction and takes the steps as explained in the bridge life cycle toward implementation. However, the process of bridge planning explained in this manual is not always applicable as it is to every case. By cases, different planning process will be taken: some bridges can be planned more simply but some may need another or additional consideration. Practically, the experienced bridge designers tend to perform bridge planning by taking into account various conditions simultaneously.

This chapter of bridge planning process will be useful for less experienced engineer as a check-list not to miss the essentials of planning and for advanced engineers to prepare lucid explanation and report for their planning.

2.2 Demand for Bridge Construction

Bridges are constructed for various purposes to support roads and highways at strategic points along their routes. Bridge structures are required to cross over rivers and valleys, or for grade-separation with other roads and railways.

Bridges are generally classified and separately called by purpose as follows:

(1) Road or highway bridge

General name for any bridge on roads and highways.

(2) Railway bridge

General name for any bridge on railways.

(3) Flyover or overpass bridge

Bridges for grade-separation with other roads, highways, or railways at intersections.

(4) Viaduct

Bridges to support elevated roads, highways, or railways, which are built mainly at where ground space is limited in urban area or earth-fill is difficult for ground is soft.

2.3 Definition of Requirements and Conditions

2.3.1 General

Upon receiving a demand of bridge construction plan, it is the first step to clarify all the information attending the proposed bridge plan including both of requirements and conditions. Requirements mean functions and capacities intended to the planned bridge.
Conditions mean natural environment and surroundings where the bridge is to be constructed.

2.3.2 Requirements

For the planning of road and highway bridges, generally the following information shall be clarified first, the most of which are obtained from the highway design where the bridge is proposed.

(1) Road alignments (vertical and horizontal)

Approximate location and size of bridge are initially defined in the vertical and horizontal alignments of planned road. The road alignment of the proposed bridge section and its vicinity will be sometimes modified if that is not favorable for bridge planning, for example to avoid steep grade, sharp skew, curbed alignment, etc. In case of bridge replacement, the new bridge is generally planned in parallel with the old, and approach roads are required to connect with the existing road.

(2) Cross-section of road

The cross-sectional profile of bridge generally conforms to the standard cross-section of road design. Same vehicle lane widths as that of the road section are normally applied to the bridge section, too. As regards shoulder and sidewalk, different designs are sometimes adopted according to the situation of the proposed bridge for example reducing or adding such widths from economical reason.

(3) Design vehicle loads

Design vehicle loads to be imposed on bridge must conform to the HS 20-44 load of the AASHTO's Standard Specification for Highway Bridges. Over loading provision may be considered according to the classification of road and the design traffic volume especially of heavy commercial vehicles ratio. MOP (Ministry of Public Works) applies 120 % of HS 20-44 load for the bridges on major highways and trunk roads.

(4) Affixed public utilities

Bridge, although its major function is to support traffic loads, is often requested to affix the following public utilities:

- Tele-communication cables
- Electric cables
- Water main pipes
- Gas main pipes

These public utilities are generally laid along roads under surface, but at bridges held by bridge structures.

The requests of affixing public utilities should be confirmed to each utility agency and taken into account in bridge planning if requested. The accommodation space for utilities shall be secured in the bridge cross-sectional profile and their additional weights including that of affixing devices be taken into bridge loading. Utilities are usually accommodated under bridge deck and between beams to be concealed from the external view. Affixing of electric lines needs insulated covering against electric shock risk. Affixing of water main pipes sometimes makes the bridge structural layout difficult especially in case that water pipe is too large to be accommodated between beams.

The cost of affixing public utilities is generally beared by the utility agencies in the proportion of the utility weight to the total bridge design loads.

2.3.3 Conditions

Bridges are so planned as not only to meet the prescribed requirements but also to be compatible with the surrounding environment and other site conditions. Normally, the following conditions are involved:

(1) Topography

Bridge structure is planned so as to fit in surrounding topography. Normally, topographic map and profile elevations are prepared by the plane and levelling surveys, and on which bridge structure is planned mainly for determining location, length, and spans.

(2) Geology

Also, the ground condition of bridge site will decide the structural design of bridge. General soil information such as natures and depths of typical soil layers, would be obtained by collecting previous data if available or by performing soil boring, sounding, or geophysical exploration if no previous data is available. All such information is gathered into a soil profile and which should be combined with the topographic profile for the convenience of performing planning work. Geological information is used mainly for selecting bearing stratum, and location and type of substructures in particular of foundations.

(3) Climate

The climates, contours and landscapes of Chile change much from north to south, but in west to east surface is regular in all the country. Along the coastline runs the coast mountain range, then a depression or intermediate valley, to end up in the high summits of the Andes Mountains. From Puerto Montt to the South (Patagonia), the territory is dismembered in a large archipelago that limits with the Andean Range.

Throughout the length of the country, geography varies gradually: the desert in the north, further south the desert blooms in oases. Then comes the fertile agricultural core, followed by rolling meadows and jungle. Backdrop is always present with the snow capped mountains of the Andes. But, the width of Chile is narrow, at Arica, covering a distance of only 140 km.

(4) Hydrology

Minimum height, depth, and length of bridge structure are generally decided from the hydrological conditions of waterway except the bridges planned far higher above the water level to take navigation clearance, to cross deep valley, or for grade-separation.

The most necessary hydrological information is that of flood such as rate of discharge and high water level, which can be determined by the run-off analysis assuming rainfall intensity. However, this theoretical approach is often not reliable due to complexity and lack of field data. The second-best measure is to trace the past flood marks along river basin for determining the high water level and to survey the past flood damages nearby the planned bridge for deciding the course of flood flow.

The cross-section of waterway (existing water level and river bed elevations) at the planned bridge location should be surveyed and plotted on the topographic profile together with high water level and river improvement plan if there is. After confirming the cross-sectional profile of waterway, bridge structure is planned so as to be positioned above the high water level with appropriate freeboard and over the extent of the high water level. Hydrological conditions prepared for bridge planning are subject to the approval of the River Work Department of Highway Directorate.

The hydrological survey items and the waterway crossing conditions necessary for bridge planning are detailed later in Chapters 3.2.3 and 3.3.2 respectively.

(5) Grade separation

When bridge is planned for grade separation with other road or railway, the following information of the crossing road or railway at the planned bridge location is necessary:

i. Plan and longitudinal profile
ii. Cross-sectional profile
iii. Over-head and under-ground public utilities
iv. Road or track clearance
v. Overlay and widening plan

The crossing conditions with road and railway are detailed later in Chapters 3.3.3 and 3.3.4 respectively.

(6) Construction

Construction of planned bridge should be practicable. To ensure that, the following basic information about construction is generally required, which sometimes will be a decisive factor to select bridge type.

i. Access to construction site

For such bridge sites as the access of heavy equipment is difficult due to steep terrain or densely built up, the selection of bridge type will be limited by construction method and availability of equipment.

ii. Transportation to bridge site

Modern bridge construction uses many of large precast or factory-made members such as for beams and piles, and accordingly needs more heavy equipment to erect them. The transportable size and route will be a main factor to decide the maximum span for the bridges remote from existing road.

iii. Traffic diversion

In case of re-construction plan of existing bridge, traffic diversion is usually necessary. If there is no detour way in the vicinity of the bridge, temporary bridge or the stage construction scheme is required and that raises the project cost significantly.

iv. Construction pollution

The piling work by the use of diesel hammer has been prohibited according to the area and hours in Santiago. These years, the construction work in urban area is becoming restricted for the environment conservation. Bridge plan has to consider it in selecting construction method.

2.4 Bridge Planning

2.4.1 Preparation of Base Map

Bridge plan is drafted on the base map which is prepared as follows:

i. Base map is a drawing having a topographical plan lower and a profile upper corresponding in position. Base map shall cover an area sufficient for planning both of bridge and its approach roads. Depending on the terrain and the size of the planned bridge, an area of around 100m wide by the bridge length plus 50m for each approach is a minimum idea.

ii. Add the geological information to the base map: soil profile and boring data on profile, and boring location on plan.

iii. Add the hydrological information to the base map: high water level, river bed elevations and freeboard on profile, and water flow course and banks on plan. If there is any river improvement plan, plot its finished elevations and alignments.

iv. In case of the grade-separation bridge, enter the information of the crossing road or the railway on the base map: cross-sectional elevations and clearances on profile and horizontal alignments on plan. If there is any widening or overlay plan, plot its finished alignments and elevations.

v. Plot the planned road alignments on the base map: finished road elevations on profile, and center and other lane lines on plan. In addition, enter the designed cross-sectional profile of bridge on the upper right of the base map.

2.4.2 Drafting of Bridge Plan

Bridge plan will be drafted on the base map normally taking the following procedures:

(1) Location and length of bridge

Location and length of bridge are determined on the profile of the base map by selecting the abutment location at both bridge ends.

For the bridges planned with minimum height on the high water level, the abutment location is generally so decided, according to the crossing conditions, as to minimize the bridge length from economic reason. Crossing conditions are detailed later in Chapter 3.3.

However, for the bridges planned high from the ground or from the high water level and so the abutment location is discretionary, it can be decided economically by the cost comparison between bridge and earth-fill. A sample of the cost comparison is demonstrated as follows:

i. Assume minimum three points of tentative abutment location with different earth-fill and abutment heights along an approach road. For example, suppose three earth-fill heights 4, 6 and 8m along the approach road of 4% slope and so each point is 25m apart.

ii. Estimate roughly and sum up the hypothetical costs for each point, and compare them to find the most economical location. Refer to Fig. 1.3-Economical Abutment Location and Table 1.1-Hypothetical Costs.

iii. Regarding the estimate of the superstructure cost in Table 1.1, although type and span will not have been decided yet in this stage, assume them tentatively and estimate the average unit cost per bridge surface area from the past records of project costs. For instance, PC (prestressed concrete) beam with 20~30m span may be an appropriate first assumption. If there is a possibility of steel beam likely in Sabah and Sarawak, estimate the cost in same manner.

Irrespective of the above economic study, the limit of the safe earth-fill height will be an decisive factor to decide the abutment location where the ground cannot support high fills. After all such studies, abutment is generally planned of its height ranging from around 4 to 15m.

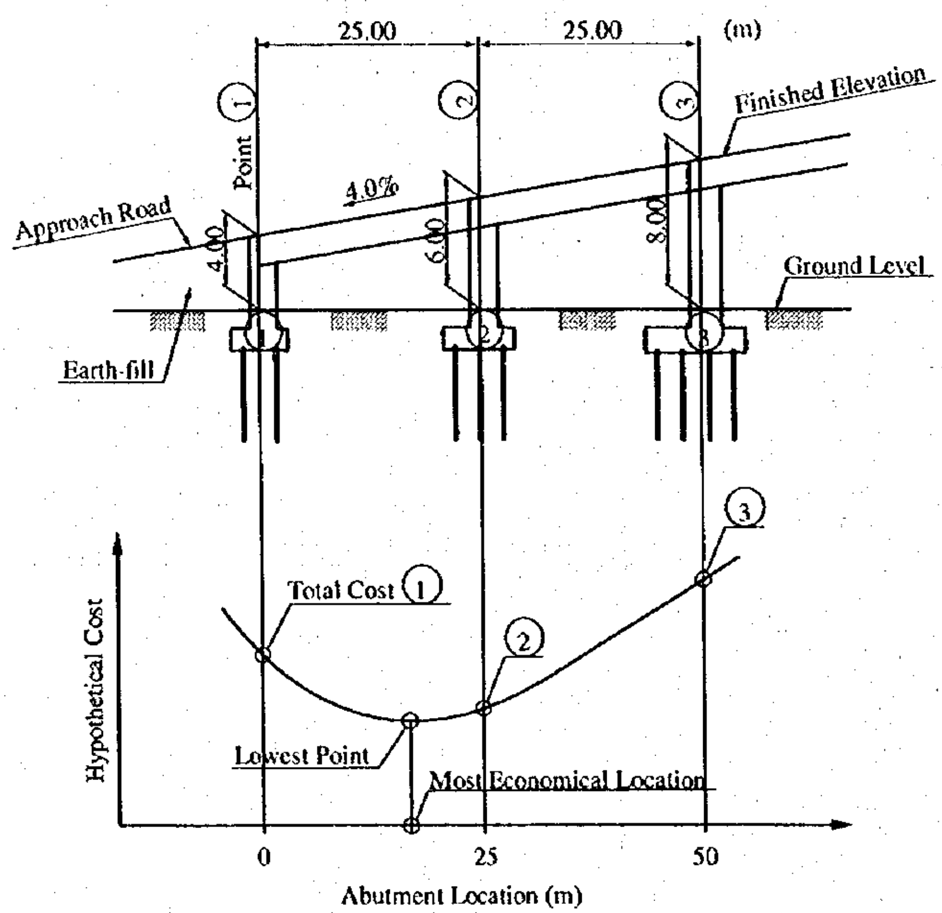


Fig. 1.3 Economical Abutment Location

Table 1.1 Hypothetical Costs

Point	①	②	③
Abutment Cost Superstructure Cost Earth-fill Cost	for Abutment ① for Section ①-③, 50m -	for Abutment ② for Section ②-③, 25m for Section ①-②, 25m	for Abutment ③ - for Section ①-③, 50m
Total Cost	①	②	③

(2) Pier location, span, and bridge type

After defining the bridge location and length, the next is to select pier location and spans as well as applicable bridge types (of superstructure) by studying the ground (topographical and geological) and crossing (of waterway, road, or railway) conditions on the base map. As spans are decided, the choice of bridge types will be narrowed down, that is, span is generally selected within the applicable range for each bridge type. The reference of bridge types and suitable span range is given later in Tables 1.5 and 1.6 of Chapter 3.4.2.

For the bridges where pier location is restricted by crossing conditions, it is so selected, according to the recommendations detailed in Chapter 3.3 - Crossing Conditions, as to minimize the interference with the crossing river, road, or railway.

However, for the bridges where pier location is discretionary, it is selected economically by comparing the costs for several span alternatives. This study holds true more for longer bridges. A sample of the cost comparison is demonstrated as follows:

i. Propose minimum three alternatives of different span arrangements and their corresponding bridge types for a certain bridge length. For example, suppose the following three arrangement cases as shown in Fig. 1.4-Economical Span Arrangement.

ii. Estimate roughly the total construction cost for each case including all the superstructure and substructure costs and compare them to find the most economical span arrangement and bridge type.

iii. In order to hold the accuracy of the cost comparison, bride type should be selected appropriate for the proposed span and be practicable in construction. The superstructure type is comparatively quick to be looked up from the standard design compared to the substructure which is usually not easy and owes much to the engineer's experience and the past similar designs. Simplified stability calculation is sometimes required to define the size of substructure especially the size and number of piles which affect the substructure cost significantly.

iv. In conclusion, the economy of selecting span and bridge type is understood as the cost balance between superstructure and substructure. That is, the cost of superstructure is generally much the higher as the longer span is. On the other hand, the cost of substructure depends more on ground condition than span and bridge type. Therefore, for such bridges as the substructure cost is small because, for instance, no pile is required owing to shallow bearing stratum, the choice of shorter span with many piers is economical, and vice versa.

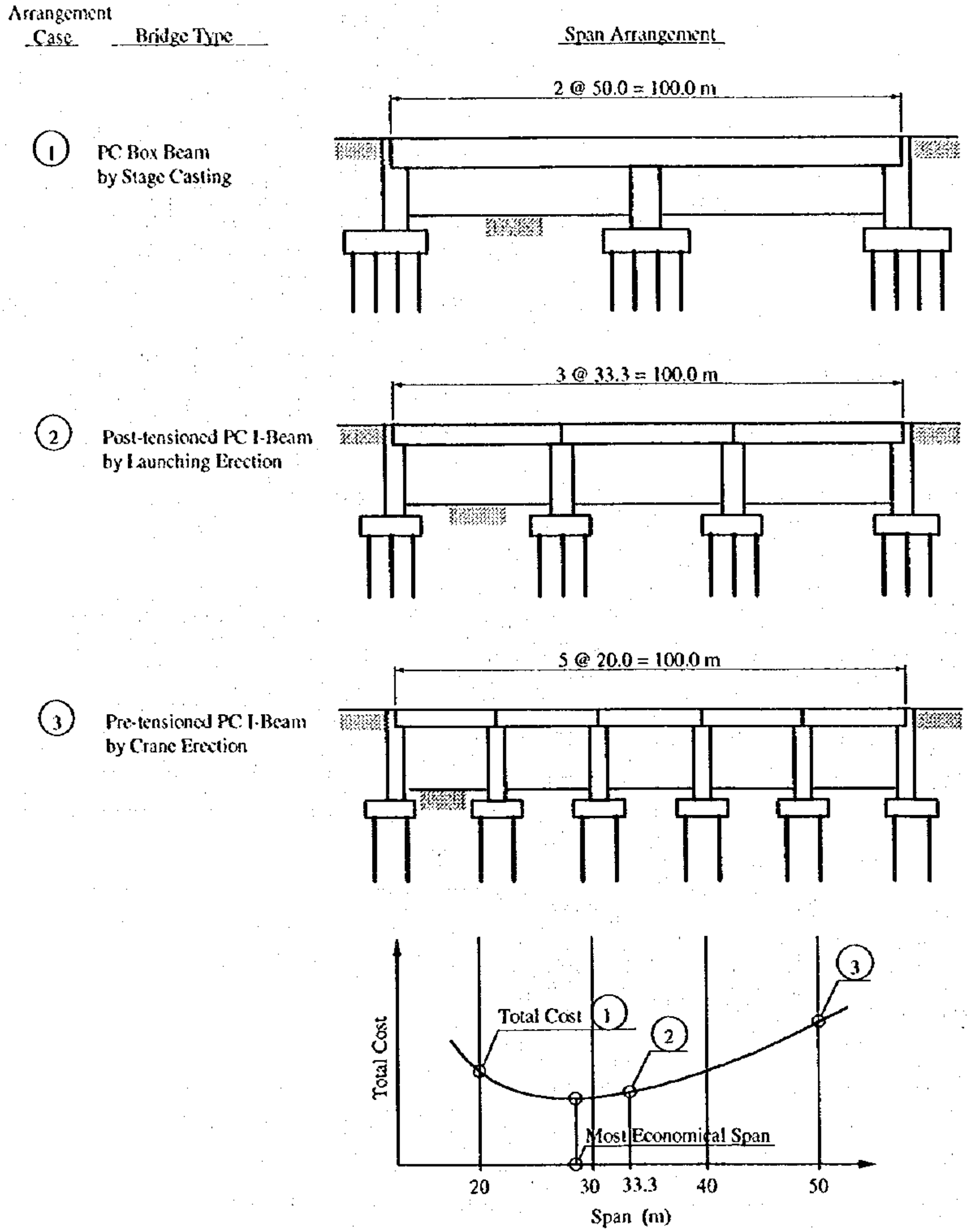


Fig. 1.4 Economical Span Arrangement

v. The above sample of cost comparison was performed among the different bridge types proposed for each span arrangement respectively. On the other hand, the most economical span for a certain bridge type can be known by performing the cost comparison under the same bridge type. For instance, PC post-tension beam is generally used in a span range of 20 to 40m and the most economical span of this type will be derived from the following comparison:

Arrangement Case	Number of Spans		Span(m)		Bridge Length(m)
①	5	×	20	=	100
②	4	×	25	=	100
③	3	×	33.3	=	100

(3) Practice of span arrangement

Multiple span bridge should be arranged in regular spans with uniform beam height as much as possible to create the view of straight, clean horizontal lines, and which also helps labor-and cost-savings in design and construction.

However, for the bridges spanning deep valley, the pier location is controlled by terrain and accordingly regular span arrangement is difficult. In Fig. 1.5, for instance, Option ① intends same span but the construction of high pier is difficult. Therefore, the irregular spans or one span option shown in Option ② and ③ will be considered as alternatives. In general, when pier height is over around 30m, the options of longer span bridges will be economically more competitive than shorter span types.

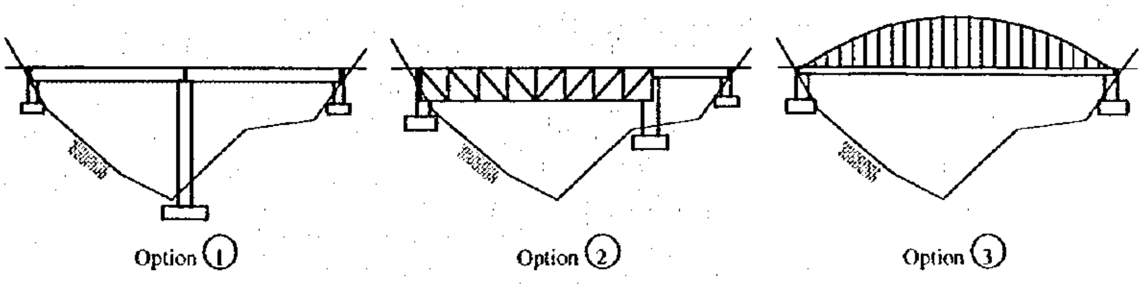


Fig.1.5 Span Arrangement for Deep Valley

2.5 Evaluation and Selection

2.5.1 General

Chapter 2.4 explained how to draft a bridge plan to meet the requirements in the given conditions. As a matter of course, drafting work is always performed to seek better plan and through this process various judgments and reasonings as well as selections will have been developed. However, such developed information will not have been logically compiled yet. For the final conclusion of bridge plan, the process of evaluation is required to justify it objectively.

The work of evaluation should start with making clear the objects of evaluation, be followed by the comparison of advantages and disadvantages, and be concluded by rating.

2.5.2 Objects of Evaluation

Bridge is a composite figure made of many components which are roughly divided into superstructure and substructure including foundation. To select such a composite figure, evaluation is required in both ways, partially and totally.

(1) Partial evaluation

This is performed to select type for a certain member part(s) or to give individual solutions of a planned bridge, and the results of that are reflected to the total evaluation.

Take an example for the selection of foundation and suppose that ground is soft alluvial deposits with intermediate sand layers and diluvial formation is about 30m deep. From this assumption it is immediately clear that this site needs some piles, but the problem is to select the type and size of piles. Several options will be suggested with advantages and disadvantages. For instance, PC spun piles may be the cheapest but uncertain in execution for the depth of bearing stratum and the existence of intermediate sand layers. Steel pile piles are reliable in construction but may be the most expensive. Bored cast-insitu concrete piles will be another possibility reliable in execution and advantageous for less noise if the site is at residential area, but the site work will be complex for large facilities and skilled techniques are required. Thus, even taking the problem of piles which is only a part of a bridge, evaluation is required to select the best.

In bridge planning, the followings are the most common objects of partial evaluation:

i. To select location, length, and spans

- Abutment location by cost comparison between bridge and earth-fills, and maximum safe earth-fill.
- Pier and span arrangement by cost comparison among several combinations of superstructures and substructures.

ii. To select foundation

- Type of foundation and construction method according to ground condition, cost, and execution reliability.
- Kind and size of piles by cost comparison among several sizes and required numbers of piles, and availability of equipment.

iii. To select substructure

- Type of abutment by its required height sometimes including comparison between retaining wall type and earth-pressure-relieved type from economy, aesthetic view and earth-fill stability.
- Type of pier by its required height and situation.

iv. To select superstructure

- Type and construction method according to span, terrain and accessibility, material and equipment (for erection) availability, cost, aesthetic view, etc.
- Construction method of deck slabs: cast-insitu or pre-cast according to accessibility and time schedule.

(2) Total evaluation

This is performed to finally select the best bridge plan as a whole. The information obtained through the partial evaluations will be combined in various ways to produce several complete bridge plans for final selection. These final plans shall be of minimum two alternatives in order to compare them but not so many suggesting that five may be maximum to clearly understand the differences among them.

i. Evaluation factors

Bridge plans should be evaluated from various aspects such as economy, construction, maintenance, aesthetics, etc. As regards safety and crossing conditions, which are usually not included in the evaluation factors, because bridges undoubtedly ought to be planned safe and to satisfy conditions.

ii. Rating

The simplest technique to assess the overall alternative plans would be to use a ranking method. A sample rating by using the method is demonstrated as follows:

① Two kinds of rating factors are used, ranking and importance. The product of the two factors is defined as the score for each alternative relative to each evaluation factor. A total score adding the scores of all evaluation factors is the conclusion of the rating, and normally the alternative plan scored the highest will be the most desirable.

② Ranking factors will be given by whole number with respect to the order of desirability among the alternatives. The rank of 1 is assigned to the least desirable alternative and a rank of n (equals the number of alternatives) is assigned to the alternative that is the most desirable.

③ Importance factors will be given by weighing priorities among the evaluation factors. The assignment of importance factors is voluntary, and with which the policy of bridge plan can be considered in the result of evaluation.

④ Supposing a sample rating of three alternatives, where the first priority is given to economy and the other importance factors are weighed equal, the following result is obtained. In this assumption, the highest total score will be 30 and the lowest 10.

Evaluation Factor	king Factor	Importance Factor	Score
Economy	1 , 2, ③	4	12
Construction	1 , ②, 3	2	4
Maintenance	1 , ②, 3	2	4
Aesthetics	①, 2, 3	2	2
		10	22

⑤ It is noted that the above ranking method cannot distinguish incremental differences among alternatives. One way to remedy this is to establish the ranking scale on the basis of relative difference, but that is too hypothetical to give factors properly.

iii. Evaluation table

Total evaluation is the summary of all the information obtained through the planning process and which should be clearly explained to the public or to the parties concerned for approval. Evaluation results should be understandable to third party, so that the use of table is recommended for better presentation. Fig. 1.6 shows the example.

Alternative Plan		① (Naming)			②			③		
Illustration (Profile)		(Figure)								
Evaluation Factor	Importance Factor	Comment	Ranking Factor	Score	Comment	Ranking Factor	Score	Comment	Ranking Factor	Score
Economy	4	(Comments)	3	12		1	4		2	8
Construction	2		2	4		3	6		1	2
Maintenance	2		2	4		1	2		3	6
Aesthetics	2		1	2		3	6		2	4
Conclusion & Total Score	10			22			18			20

Note: Scores shown are sample only.

Fig. 1.6 Evaluation Table

2.5.3 Scope of Evaluation

Evaluation is performed to figure out the best bridge plan under a certain situation or scope, and within the scope all alternative plans come out and conclusion is made. The scope depends on purpose, location, and site condition of bridge plan, but it is generally established conforming to the policy of the client (government department). If bridge plan is a part of highway project, the scope will be decided in the coordination with the highway plan.

(1) Evaluation under fixed bridge length

Bridge planning is started from the basic matters to decide location and length and followed by foundation and substructures. Normally, the comparison of superstructure types as well as spans is highlighted as the main object for the final selection. In such case, most substructures and foundations have been already decided by partial evaluations, accordingly the total evaluation will be played under the fixed bridge length, the differences of substructures and foundations will not be emphasized, and the cost of approach road construction will not be included in economic comparison. This is the simplest and most common evaluation to decide only bridge type and spans.

(2) Evaluation among different bridge length

Bridge location is normally determined along the road alignment. However, in the course of bridge planning, modification of road alignment is sometimes suggested in the vicinity of the bridge location for more favorable bridge plan. Evaluation arrives at the common procedure if road alignment is reviewed regardless of bridge types. However, if road alignment is different in relation to bridge types, total evaluation will become complex: bridge alternative plans must be compared in different location and bridge length, and cost of approach road should be included in economic comparison.

(3) Scope of economic evaluation

It is ideal for economic evaluation to estimate the total life cost covering design, construction, right-of-way acquisition and maintenance costs. However, because design cost is so small against construction cost and maintenance cost is difficult to estimate, economic evaluation is often performed with only the initial cost of construction and right-of-way acquisition.

CHAPTER 3 ENGINEERING FOR BRIDGE PLANNING

3.1 Principles for Bridge Planning

The followings are the common suggestions useful in bridge planning:

(1) Road alignment to minimize bridge cost

In general, bridge cost is much higher than road cost per length. To minimize total project cost, road alignment needs the review from the bridge engineer's view although it is selected normally considering traffic strategy, right-of-way availability, obstacles, ground condition, and other many factors. Attention shall be given to the location of bridge and its approach roads. Even after deciding road alignment, sometimes bridge design can be much improved by minor changes of the bridge location and the alignment of approach roads.

(2) To meet requirements of bridge

Bridge shall be planned to meet the requirements expected to the planned bridge such as of width, length, height, and loading capacity. In particular, the requirements of crossing waterway, highway, and railway shall be carefully determined after due consultation with their administration agencies.

(3) Safety and economy of bridge structure

Bridge structure must be planned safe but at the same time it is required to achieve economical design, construction, and maintenance. The two concepts of safety and economy seems to be conflicting, and taking equilibrium between them is a major problem to be solved in bridge planning. Because bridge is an important public facility, it seems to be a right way that the first priority should be given to safety and the second to economy.

The criteria for safety of structures is generally given by design specifications or codes, which is a necessary condition in bridge design but not a sufficient. To harmonize safety and economy in bridge planning, it requires the profound knowledges of an experienced engineer. However, the drawing or the completed bridge given due such consideration will convince the people's eye that the structure is functional, and safe, too.

(4) Easier and faster construction

When there are more than two prospective alternative plans and they are of alike cost, it is then recommended to study their construction methods and select easier one.

In case that a new technique is proposed, it is recommend to respond such challenge as much as possible after careful study for its reliability for the good of the progress of technology.

(5) Standardization of structures

Bridge planning is in principle performed individually to select the most suitable design according to each site condition. However, when a number of bridges similar in size and type are planned, such as for a series of over-bridges along a highway, the standardization of structures will often save cost and time both in design and construction. For instance, in case that the spans of the overbridges fluctuate a little, it is more economical and practical to apply a standard beam of same size and span to all bridge sites despite accompanying somewhat construction losses.

(6) Traffic safety and comfort

The traffic safety and comfort on bridges depend not only on the road geometries and alignment but also on the existence of structures on the bridge surface. In view of that, the following measures are recommended:

i. Adopt deck type bridge rather than through type except the cases that the under-bridge clearance is limited. However, through type is more economical than deck type for longer span range.

ii. Prefer continuous beam bridge to simple beam to reduce expansion joints which may cause the vehicle running shock and become to be a big maintenance burden.

(7) Easier maintenance

The maintenance troubles of bridges are frequent on the secondary members such as expansion joints and bearing shoes rather than on the primary members. Therefore, continuous beam bridge, because it has less such troubles, is more favorable for maintenance. In particular, the reduction and the easy maintenance of expansion joints should have been considered from the planning stage. Repair or replacement work of expansion joints on bridges will become a major cause of traffic interference.

(8) Aesthetic consideration

Bridges must serve for the public to carry traffic safely, and they have to be constructed and maintained with reasonable cost. That is the primary function of bridges and can be designed by applying physical science. On the other hand, bridges exist long time on ground exposing to the public eye, so that bridges cannot help having the ornamental function as well. The bridge design successful in pleasing the people's eye, is not necessarily obtained only by the use of physical techniques. Because bridge design is a process of human creation, it is natural to seek beauty in the view of bridges.

3.2 Field Surveys

3.2.1 Topographic Survey

(1) Survey method

Topographic survey is carried out to prepare topographic map which is necessary as the base map for bridge planning. The survey method is generally to use plane-table surveying or aerial photogrammetry. The area of topographic map for bridge planning is regional and the scale is comparatively large, so the plane-table surveying is normally used. If the existing photographic map covering the proposed bridge site is available, it may be utilized by magnifying the scale but that needs the complementary and correction surveys by plane-table surveying.

(2) Scale

The scale of topographic map suitable for bridge planning ranges 1/100 to 1/500. The scales 1/200, 1/300 or 1/400 are generally used.

(3) Contour

In principle, topographies have to be indicated by contours, the interval of 1m is preferable. The planimetric map having no contours is sometimes used although it is unfavorable, but at least point contours should be shown to find elevations.

(4) Road center line

Road center line, if it is available at site, should be surveyed and shown on the topographic map. It is useful to find the planned bridge location on the map and can be used as a datum line in planning work.

(5) Profiles

Longitudinal and lateral profiles are preferably prepared by the leveling surveying along the road center line. Alternatively, profile can be also prepared from the contours of the topographic map and that may be usable considering less accuracy.

3.2.2 Geological Survey

(1) Survey method

The geological survey for bridge planning is performed putting stress on obtaining the general subsoil information of bridge site rather than detailed soil tests. The survey is normally carried out from data collection and field reconnaissance, and followed by boring, test-pit digging, or geophysical exploration if considered necessary.

(2) Data collection

This is performed at early stage of the survey to collect the existing geological data around the site. Major data sources are the geological map issued by the National Geology Office and the previous boring or geophysical data of the vicinity. If such existing data is available, the general geological condition of site can be often supposed from those data and so special field survey may not be required. Thus, the execution of field survey depends on the data collection.

In addition, the existing bridges and buildings will be another useful data source by studying their foundations about type, size, depth, and whether settlement and tilt are seen or not.

(3) Field reconnaissance

This is a visual survey to judge the subsoil conditions from the outcrops of rocks and strata. The survey is carried out by walking along the existing roads and rivers in the survey area while observing the outcrops to make a field reconnaissance map.

Landslide traces, obstacles, terrain and ground condition which seem to be troubles for construction, will be also surveyed in this occasion.

(4) Soil boring

i. General

Boring survey is the most popular soil investigation method to obtain the underground stratification and the engineering characteristics of strata. The method bores a hole into ground by boring machine, collects samples and carries out in-situ tests through the hole. Soil boring generally performs the following surveys:

- Discrimination of stratification
- Observation of cored soils
- Sampling and laboratory soil test
- Water level in bore
- In-situ test in bore: standard penetration test, vane shear test, lateral loading test, pore water pressure test, geophysical exploration, etc.

Survey results should be carefully compiled by using the prescribed forms such as boring log and soil test data sheets, because these boring data will be the basis and repeatedly referred for designing and construction.

ii. Application of Standard Penetration Test

The result of standard penetration test "N-value" is the most important information widely used for the design of foundations. Many design factors as shown in Table 1.2 can be estimated from N-value.

Table 1.2 Design Factors Estimated from Standard Penetration Test

<table>
<tr><th>Sandy Soil</th><th>Clayey Soil</th><th>Construction</th></tr>
<tr><td>-Relative density
-Internal frictional angle
-Coefficient of bearing capacity
-Void ratio</td><td>-Consistency
-Uniaxial compression strength (undrained)</td><td>-Judgment on possibility of piling penetration
-Judgment on effect of soil improvement
-Study of excavation method</td></tr>
<tr><td colspan="2">-Bearing capacity of soil
-Coefficient of ground reaction
-Bearing capacity of piles</td><td>-Judgment on land slide</td></tr>
</table>

The Meyerhof's suggested relations of N-value to relative density and internal frictional angle is given in Table 1.3 and the Terzaghi-Peck's of N-value to consistency and uniaxial compression strength in Table 1.4.

Table 1.3 Meyerhof's Relation of N-Dr- ϕ for Sandy Soil

N-value N	Density of Sand	Relative Density Dr	Internal Frictional Angle ϕ (degree)	Static Cone Penetration Test Value qc(kg.f/cm^2)
< 4	very loose	< 0.2	< 30	< 20
4 ~ 10	loose	0.2 ~ 0.4	30 ~ 35	20 ~ 40
10 ~ 30	medium	0.4 ~ 0.6	35 ~ 40	40 ~ 120
30 ~ 50	dense	0.6 ~ 0.8	40 ~ 45	120 ~ 200
> 50	very dense	> 0.8	> 45	> 200

Table 1.4 Terzaghi-Peck's Relation of N-Consistency-qu for Clayey Soil

N-value N	Consistency of Clay	Uniaxial Compression Strength qu (kg.f/cm^2)
< 2	very soft	< 0.25
2 ~ 4	soft	0.25~0.50
4 ~ 8	medium	0.50~1.00
8 ~ 15	stiff	1.00~2.00
15 ~ 30	very stiff	2.00~4.00
> 30	very hard	> 4.00

For selecting the bearing stratum for bridge foundation according to N-value , although there are many exceptions to design and site condition, the following values are generally suggested as a standard:

Sandy Soil: N > 40

Clayey Soil: N > 30

3.2.3 Hydrological Survey

Hydrological survey is vital to planning the bridges which cross rivers and channels. From bridge site, the following information should be collected and analyzed:

(1) Condition of river course

Condition of river course is a decisive factor to determine the crossing location and direction, the bridge length, and the protection against erosion and scouring. Major survey and analysis items include the followings:

i. Meandering reach, curved reach, or straight reach
ii. Historical change of meandering and bank erosion
iii. Pattern, size, and movement of sand bars
iv. Change of longitudinal river bed elevations such as aggradation or degradation of sediment
v. Area of flood plain and width of main stream during flood

(2) Condition of major floods

It is important for bridge planning not to worsen the capacity of waterway for flood flowing by bridge construction. Flood discharge should be passed smoothly and safely at bridge. To determine the design discharge of flood and the required opening of bridge, it is necessary to survey and analyze the past major flood records on the following points:

i. Flood water level, area, and duration at bridge
ii. Flood discharge and velocity of current
iii. Debris, sediment, and floating logs

(3) Design discharge

JKR has the guideline for the hydrological design for the bridges crossing rivers and channels, in which the following return periods for the estimation of design discharge are specified:

i.	For bridges to cross rivers and drainage channels:	100 years
ii.	For sewerage culvert:	50 years

(4) Meteo-hydrological condition

Meteo-hydrological condition of bridge site and river basin is also a necessary factor for determining design discharge, high water level, design wind velocity, construction method and schedule. Major items of this survey are as follows;

i. Seasonal variation of temperature, relative humidity, and wind velocity
ii. Seasonal variation of rainfall
iii. Seasonal variation of water level and discharge

(5) River improvement plans

Any river improvement plan, whether it is on-going or a future plan, should be investigated and entirely taken into account for bridge planning so that the bridge construction should not become any obstruction to the river improvement plan.

3.3 Crossing Conditions

3.3.1 General

Bridges are constructed to cross existing land space, most are public spaces such as rivers, roads, railways, etc. and where the bridge structures must exist long time after being constructed. Therefore, bridge plan is required to have due consultations with the competent authorities of such space for approval.

The crossing condition required in bridge planning is different depending on planning location and purpose, and governed by various regulations relevant to land use. The following regulations may be concerned:

Land Use	Concerning Regulation
- River and flood control reservation	River and Flood Control Act
- Roads and Railways	Right-of- Way Act
- Environment conservation	Natural Environment Protection Act
- National park	Park Law
- Historical preservation	National Historical Preservation Act

In addition to the above, urban and local development plans are also involved in bridge planning, although these conditions should have been consulted in the road planning stage.

This chapter explains the general crossing conditions for river, road, and railway, because most bridges are planned to cross them.

3.3.2 Waterway Crossing

The figures and equations suggested in this section are based on the Manual for River Works in Japan.

Fig. 1.7 shows the general concept of river cross-section and bridge layout.

(1) Location and direction of crossing

i. Cross river at its straight reach.

In numbers of rivers in Chile, bank erosion has occurred more at the curved reaches than the straight. Although small meandering occurs even in straight reaches by the movement of sand bars, it is far better to select bridge site at the straight reach compared to the curved. Further, it is important to investigate the historical change of river course and bridge site should be selected at where the change of river course is small.

ii. Cross river in perpendicular to its flow.

The bridges crossing rivers with skew direction often cause erosions and scours at around bridges. Skew bridge will produce asymmetric turbulence in river flow and that makes the bank protection against erosion very difficult.

Therefore, the crossing at straight reach with right angle is the most recommendable. If it is unavoidable to cross river at curved reach or with skew direction, protection shall be provided not only at around abutments but also to the adjacent river banks with sufficient length.

(2) Waterway width and freeboard

i. Lay abutments outside of waterway.

If bridge opening is shorter than the waterway width, flow will be constricted at the bridge, and that causes backwater effect on upstream. This phenomenon will endanger the bridge by incurring severe erosion and scouring. Therefore, it is necessary to design the bridge opening wider than the waterway width.

Although it varies depending on water depth, the design discharge and the required waterway width have a general relation as follows:

Design Discharge (m3/s)	Waterway Width (m)
300	40 ~ 60
500	60 ~ 80
1,000	90 ~ 120
2,000	160 ~ 220
5,000	350 ~ 450

ii. Minimum freeboard on high water level (HWL)

The freeboard between HWL and the top of dike for the rivers having compound cross-sections, shall be not less than the following values:

Design Discharge (m3/s)	Freeboard (m)
less than 500	0.5
500 ~ 2000	1.0
over 2000	1.5

For the rivers having single cross sections, the freeboard is recommended to take at least 0.6 m.

The clearance between HWL and the soffit of bridge beam shall be decided by adding the allowance of 0.5m to the above-mentioned freeboards. See Fig. 1.8.

(3) Minimum span length

i. Span length has a direct relation to the possibility of clogging the bridge opening with floating logs or debris. For this phenomenon, minimum span length is defined by the following hydrological span length in relation to design discharge.

$L = 20 + 0.005Q$ where, L = Hydrological span length (m) measured in perpendicular to flow
Q = Design discharge (m^3/s)

ii. However, if there is far less possibility of floating logs and debris so that clogging rarely occurs, the minimum span length can be reduced to the following values:

$Q < 500\ m^3/s$ and $W < 30$ m	L = 12.5 m
$Q < 500\ m^3/s$ and $W \geqq 30$ m	L = 15 m
$500 \leqq Q \leqq 2000\ m^3/s$	L = 20 m

where, W = waterway width (m)

iii. Pier location close to bank

Pier should not be laid on the slope of bank nor at the foot of bank slope. It is recommended for the piers planned close by bank to take at least the following distance from the toe of bank slope.

Design Discharge(m^3/s)	Distance (m)
less than 500	5
over 500	10

For where it is difficult to take the above distance, sufficient bank protection should be provided on the foot of bank slope and around the pier against possible local scouring.

iv. Impediment rate of pier width to waterway

The existence of piers in waterway is the biggest impediment to water flow imposed by bridge construction. The smaller pier width is, the better water flows. There is a guideline to control the total pier widths in a waterway by the impediment rate to the waterway width:

		Impediment Rate
Desirable	:	less than 3 %
Maximum	:	5 %

The pier width shall be measured in perpendicular to flow direction at high water level, and the waterway width shall be the width of high water level.

(4) Abutment design

i. Invert-T type abutment

There are many examples in Chile that bank seat type and pile bent type abutments are damaged by local scouring. Many protections provided in front of such abutment are washed away by flood and piles are exposed.

Therefore, it is recommended to adopt the invert-T type abutment instead of bank seat and pile bent types.

ii. Embedding depth of footing

Footing shall be embedded into river bed. Where the scouring risk is high, it shall be deepened below the anticipated scour depth. (Fig. 1.8)

iii. Parallel to flow

Abutments shall be laid in parallel to flow.

(5) Pier design

i. Oval or round shape for pier column

The existence of piers in waterway unavoidably brings about turbulence in flows and which is a major cause of the local scouring around piers. To lighten this effect of piers, it is recommended for the cross-sectional shape of the pier columns to be oval or round which disturbs water flow much less compared to rectangle. It is also recommended that a pier have only a single column, but do not have double or multiple columns which rather induce severer turbulence in closely standing columns.

Where flow is not stable or curved, round shape is more adaptable to the change of flow than oval.

ii. Embedding depth of footing

Footing shall be embedded into river bed deeper than the anticipated scour depth. A guideline of the embedding depth of footing is given as follows (Fig. 1.8):

Location of Pier	Embedding Depth
① Low water channel and the part of high water channel within 20m from the top of the slope of low water channel:	More than 2m below the river bed of low water channel
② High water channel beyond 20m from the top of the slope of low water channel:	More than 1m below the river bed of high water channel

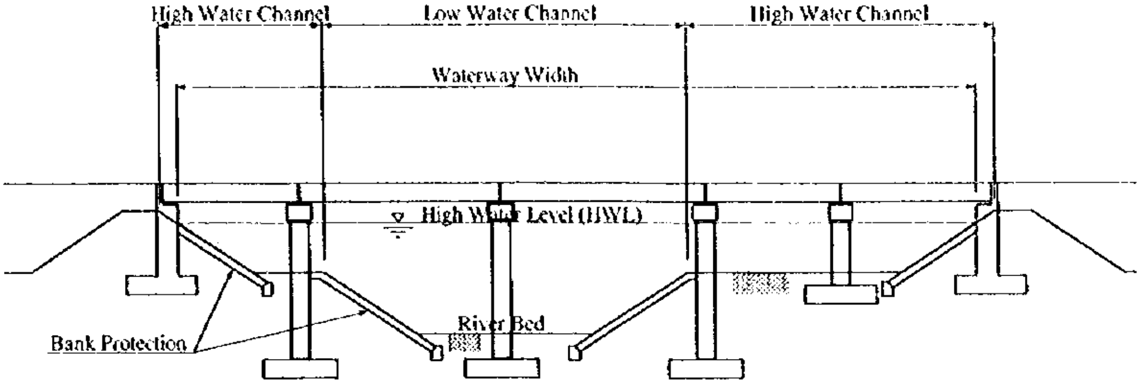


Fig.1.7 General River (Compound) Cross-section and Bridge Layout

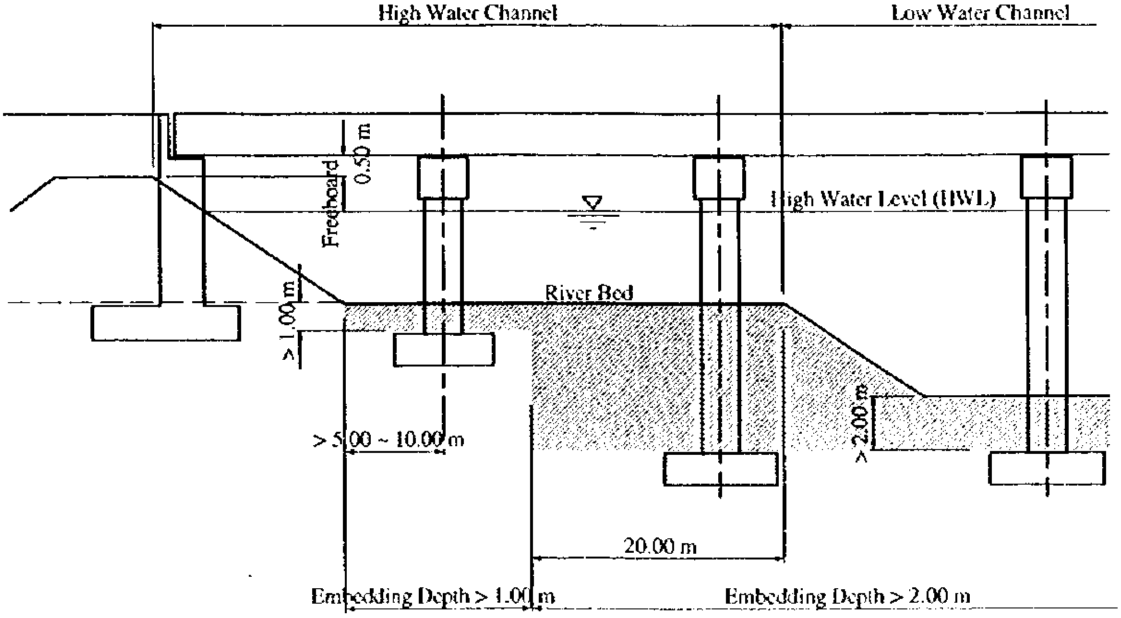


Fig.1.8 Freeboard and Embedding Depth

(6) Bank protection

Bank protection is required to protect the slope of bank from the erosion which may be caused by the turbulent water flow induced by the construction of piers.

i. Covering area

Bank protection shall be provided both on high water bank and low water bank, from the top to the toe of bank slope, for the extent of 10m up - and down - stream from the side of bridge including the underneath of bridge.

For skew bridges, additional covering area is required as shown in Fig. 1.9 to cope with asymmetric flow turbulence.

ii. Embedding depth

Bank protection shall be embedded into river bed not less than 0.5 ~ 1.0m for small rivers and 1.0m for large rivers. Where scouring risk is high, it shall be deepened below the anticipated scour depth.

iii. Foot protection

The toe of bank protection shall be protected against scouring with gabion packs or stones.

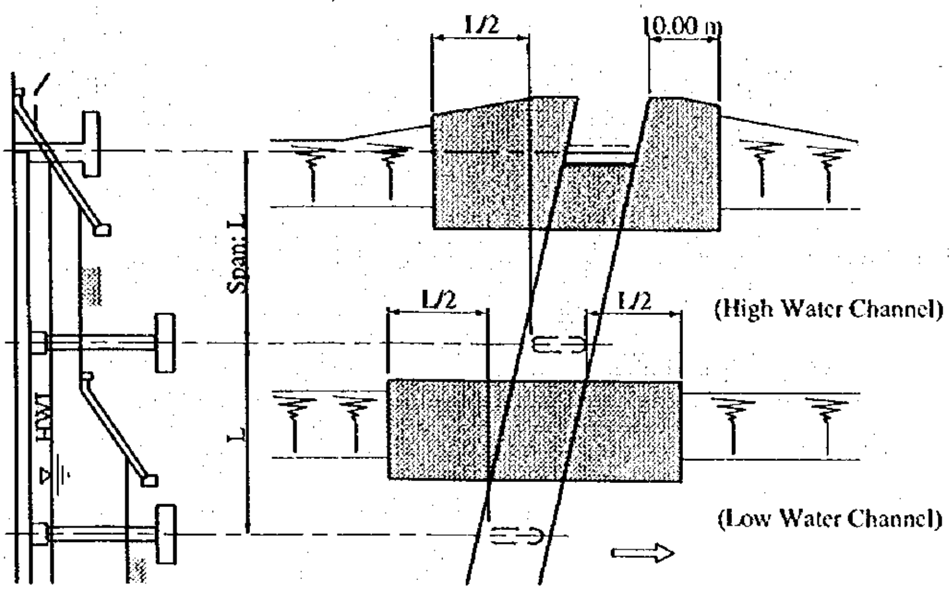


Fig. 1.9 Area of Bank Protection

(7) New bridge near existing

Where a new bridge is constructed near to an existing one, the effect of one structure on flows striking the other should be considered. To minimize this effect, the location of two bridges should be compatible in flows. In principle, the piers of a new bridge should be aligned with those of an existing bridge along flow lines.

Fig. 1.10 shows a guideline how to determine pier locations and spans of a new bridge planned to be parallel with an existing bridge, according to the distance between two bridges.

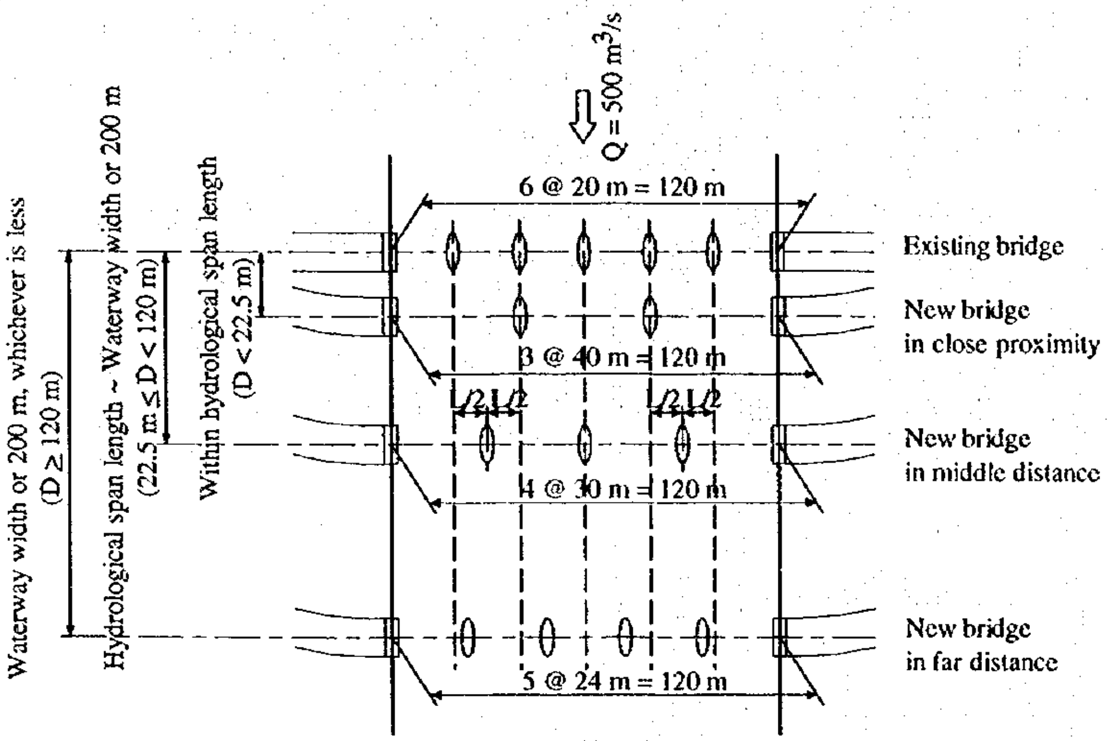


Fig. 1.10 New Bridge near Existing

In the figure, the following river conditions are assumed:

Design discharge	Q = 500 m3/s
Waterway width	W = 120 m
Hydrological span length	L = 20 + 0.005 x 500 = 22.5 m

i. For close bridges within hydrological span length;

- New bridge piers to be located exactly on the alignments extended in parallel with the flow lines from the corresponding existing bridge piers.
- In addition, the new bridge span shall not be less than the hydrological span length.

According to the above provisions, in the figure, the new bridge span in for the close bridge has no choice but to become 40 m doubling the existing bridge span, because the existing span of 20 m is more than the hydrological span length of 22.5 m.

ii. For middle distance bridges of more than the hydrological span length and up to waterway width or 200 m whichever is less;

- New bridge piers shall be located exactly on the alignments extended parallel to the flow lines from the corresponding existing bridge piers, or on the middle point of such alignments. The pier location on middle point is allowed on condition that the lateral space of middle point shown as L/2 in the figure is not less than the hydrological span length.
- In addition, the new bridge span shall not be less than the hydrological span length.

The location of new bridge piers in the middle distance shown in the figure will not be acceptable, where L/2 (20 m/2 = 10 m) is less than the hydrological span length of 22.5 m due to the first provision mentioned above. In this case, a 40.0 m span is required the same as the close case.

iii. For the far distant case of over waterway width or 200 m whichever is nearer;

- The location of new bridge piers will not be conditioned by the location of existing bridge piers.
- However, new bridge spans shall not be less than the hydrological span length.

The location of new bridge piers in far distance shown in the figure can be selected free from the location of existing bridge piers, but the span of 24 m is not less than the hydrological span length of 22.5 m.

3.3.3 Roadway Crossing

(1) Information of crossing road

As previously mentioned in Item(5)-Grade separation of Chapter 2.3.3, the following information of the crossing road is required for bridge planning:

i. About existing road:

- class and grade
- cross-sectional profile
- right-of-way
- clearance limit
- longitudinal profile

ii. About future plan

- designated, or not designated to the roads of city planning
- sidewalk plan, or not
- overlay and widening plan, or not

iii. About public utilities

(2) Consultation items

The following items are to be consulted with the competent authority of the crossing road:

i. Bridge length and spans
ii. Location of abutments and piers
iii. Embedding depth of foundations
iv. Under-bridge clearance
v. Diversion road
vi. Construction method (includes protection of existing road and traffic)

(3) Clearance limit

In Chile and also in Japan, a clearance height of 5.0m above the existing road surface under the soffit of the planned bridge beam seems to be recommended from the following reasons.

Reason 1: The road geometric design act specifies the clearance to be 4.70m. In addition this, an allowance of 0.3m is considered for future overlay.

Reason 2: The legal vehicle size is 3.80m. On the other hand, bridges need a space of minimum 1.0m under bridge beam for repainting work as well as a margin of 0.2m.

(4) Location of abutments and piers

i. General

Abutments and piers are prohibited inside of roadway. It is favorable for the traffic of the crossing road to have sufficient lateral margins between roadway and abutment, and not to have a pier on median strip.

However, the following cases are technically and economically very difficult to avoid a pier on median strip:

- Crossing road is very wide having six lanes or over.
- Bridge is skewed to crossing road with over about 50 degrees even if it has only four lanes or less.
- Crossing road is separated into up and down lanes.
- Frontage road and/or waterway run in parallel to crossing road.

When a pier is designed on median strip, it is recommended to consider collision load of vehicles for the design of pier.

ii. Lateral margin

If a pier is put in median strip, the median needs to be widened at least for the pier width so as to maintain the original lateral space. Even in case that median cannot be widened sufficient, a minimum lateral margin of 0.5m is required between the pier and the clearance limit of the crossing road as shown in Fig. 1.11. Guardrail or autoguard will be installed in the lateral margin.

Footing of pier, as shown also in Fig. 1.11, shall be preferably not extended beyond the median width to avoid uneven settlement on roadway, and embedded more than 1.0m to secure the space for underground public utilities.

iii. Special lateral margin for expressway

The crossing with expressway, where vehicles can run in high speed, needs greater lateral margin for abutments and piers not to be visual oppression against drivers. It is recommended to take minimum 3.0m for massive structure like abutment and thick pier and 1.5m for slender structure like thin pier (pier width is less than about 1.0m).

3.3.4 Railway Crossing

(1) Information of crossing railway

Like the road crossing, the following information of the crossing railway is required beforehand:

i. About existing railway:

- class and grade
- rail-gauge and cross-sectional profile
- right-of-way
- clearance limit
- electrified or not

ii. About future plan

- electrification plan, or not
- double-tracking plan, or not
- elevating plan, or not

(2) Consultation items

The following items are to be consulted with the competent authority of the crossing railway:

i. Bridge structural type
ii. Bridge length and spans
iii. Embedding depth of foundation
iv. Location of abutments and piers
v. Under-bridge clearance
vi. Construction method (includes relocation and protection of existing railway facilities)
vii. Consignment construction, or delegation of supervisors
viii. Installation of guard fence

(3) Clearance limit

The clearance limit of railway is different depending on the type and kind of railways. The railway of Chile has been developed based on the European gauge and is now in progress of electrification. Fig. 1.12 shows the clearance of the Chile National Railway.

However, in recent years new commuter railway system is going to be constructed in urban area. To cross with such new system, clearance limit should be confirmed by individual consultation.

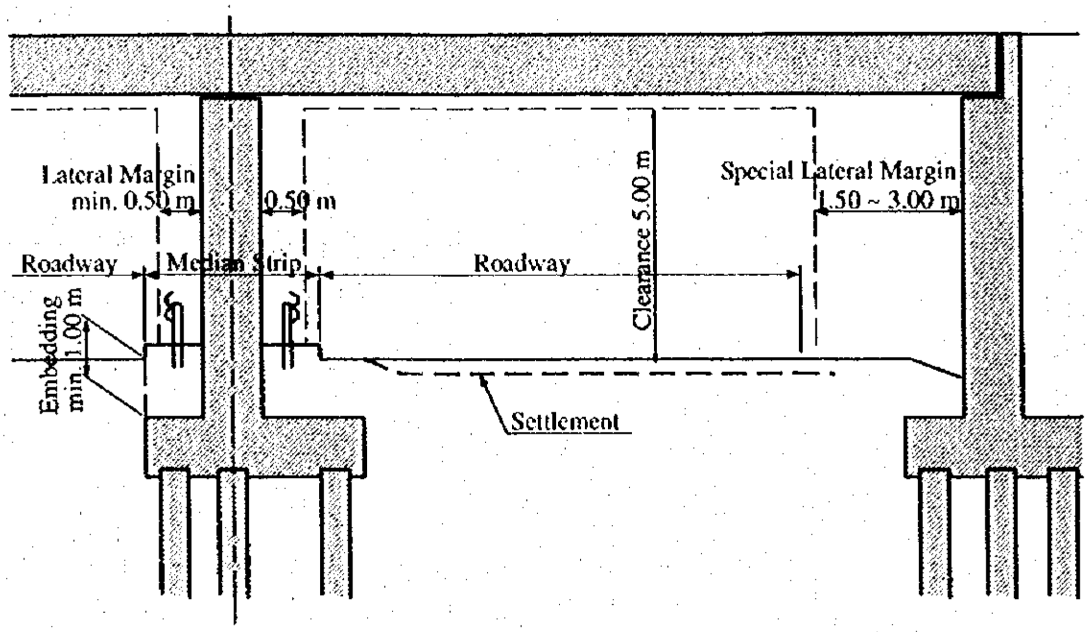


Fig. 1.11 Clearance for Road Crossing
(Note: Clearance shall be checked to meet the current MOP practice.)

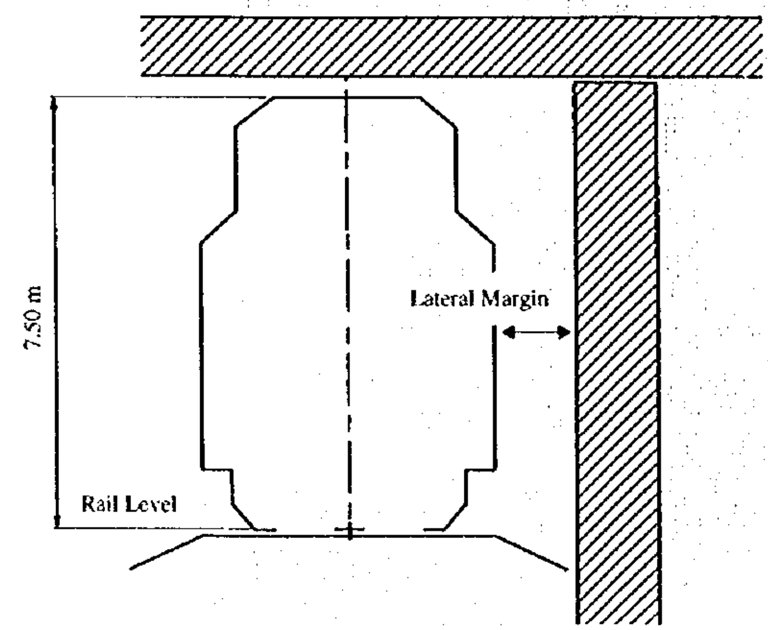


Fig. 1.12 Clearance for Railway Crossing
(Note: Clearance shall be checked to meet the current Chile National Railway practice.)

3.4 Bridge Structure Type

3.4.1 General

There are many factors to be considered in the selection of a structure type. One of the most important is the section of the country in which the bridge will be built. For various reasons there seem to be preferred bridge types in certain sections of the country. Proximity to the steel mills and the cost of freight may well control the choice between a concrete or a steel bridge. The experience of the local contractors is a big factor, and offering a structure type which is strange to them can only result in higher prices. If the area is remote, every effort should be made to minimize the necessary labor on the job so that a large number of men will not have to be imported at a very high cost.

It should be obvious that most of the discussion of this chapter is concerned with moderate-sized bridges. When a truly large structure is to be built, there are many other influences which come into play and its design becomes a very special exercise. The truly monumental bridge will dominate its environment. It will cost a great deal of money and take a great deal of time to design and build.

3.4.2 Superstructure

(1) Concrete structure

Concrete is a very versatile material and lends itself well to complicated configurations. It can be formed into smooth sweeping curves or the intricate details of statuary. It may be precast and prestressed (decreasing the weight) and made into large beams which may be set across long gaps without falsework supports. Or it may be cast in place and post-tensioned. Concrete is very heavy and its use ensures a high dead load factor. When poured in place, it requires forms and falsework which are often inconvenient to traffic. The size and weight of beams which may be transported on the highways is limited. This curtails plant production and often forces the use of forms and falsework which may be undesirable.

Concrete (prestressed) bridge types and their normal span range are given in Table 1.5.

Table 1.5 Prestressed Concrete Bridges and Suitable Span Range

Bridge Type	Structural Shape	Construction Method	Span Range (m) 20 40 60 80 100 120 140 160 180 200	Beam Hight -Span Ratio	Curved Structure
Pre-tensioned Hollow Slab		Crane Erection		1/24	×
Pre-tensioned I-Beam		Crane Erection		1/18	×
Post-tensioned I-Beam		Crane Erection Launching Erection		1/15	×
Continuous Hollow Slab		Fixed Staging Travelling Staging		1/22	○
Continuous Box Girder		Fixed Staging Travelling Staging		1/20	○
		Canti-lever Erection		1/18 ~ 35	○
Rigid Frame		Fixed Staging Canti-lever Erection		1/17 ~ 49	×
		Fixed Staging Canti-lever Erection		—	×
Cable Stayed		Canti-lever Erection		1/40 ~ 100	×

(2) Steel structure

In the late 1960s, the fabrication of structural steel underwent some very great change. Welding took over and almost completely displaced the long-serving rivet. Welding has many quickly recognized advantages in saving weight, labor, and simplifying details - resulting in much more economical steel structures.

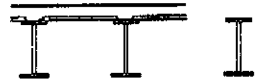
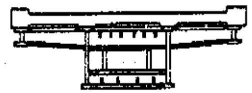
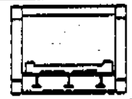
With the rise in use of welding, there has also been an increase in the use of high-strength bolts, usually for field splices. Bolted joints are often used to connect welded members. This is to simplify the field work and make the erection quicker and easier.

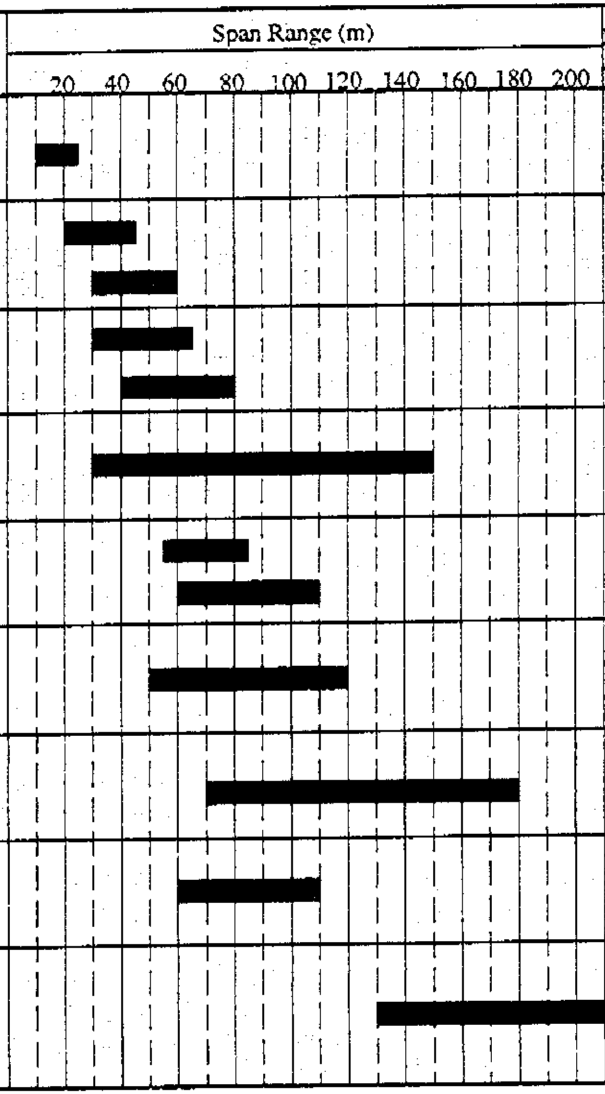
Welding has made the hybrid girder possible. This is a girder which combines a number of different strengths of steel to match the stress levels in a member. This can result in very trim, clean-looking girders without the changes of flange thickness throughout the span length.

Steel bridges which need to be painted to prevent corrosion are natural subjects for the use of varied colors. Bridge color should conform to the general desire for compatibility. The color or colors selected should harmonize well with the surroundings. Soft greens, tans, and browns are natural earth colors and fit well. Where the structure is to be minimized, gray colors against the sky and dark colors against deep shadows serve to swallow a structure.

Steel bridge types and their normal span range are given in Table 1.6.

Table 1.6 Steel Bridges and Suitable Span Range

Bridge Type	Structural Shape	Structural Form	Span Range (m)	Beam Hight -Span Ratio	Curved Structure
Rolled H-Beam				1/20	×
Welded Plate I-Girder		Simple Girder Continuous Girder		1/17 1/18	○
Welded Plate Box-Girder		Simple Girder Continuous Girder		1/22 1/23	○
Orthotropic-Deck Plate Girder		Simple Girder Continuous Girder		—	○
Truss		Simple Truss Continuous Truss		1/9 1/10	×
Arch		Langer Girder		1/6.5	×
		Lohse Girder		1/6.5	×
		Tied Arch		1/6.5	×
Cable Stayed				1/40 ~ 100	×



3.4.3 Substructure

(1) Abutments

Abutments, mostly made of concrete, are located at both ends of a bridge not only to support superstructure but also to withstand the earth-pressure from the back. In general, stability of abutment is secured by the combination of own weight and backfill on rear footing. As abutment become high, wall thickness will be reduced to save concrete volume in compensation for reinforcing with steel bars.

(2) Piers

Piers, mostly made of concrete, are located intermediately between both abutments to support superstructures. Piers rarely receive maldistributed earth pressure. Type and shape of piers are selected according to the conditions of bridge site in particular of the crossing conditions.

3.4.4 Foundation

(1) General

Foundation is a structure made of concrete, steel or timber, and built into ground as a part of substructure to transmit loads from superstructure to ground. In broad meaning, surrounding ground (bearing stratum) is regarded as a part of foundation. Foundation is classified by construction method and depth as shown in Table 1.7.

(2) Spread foundation

Spread foundation is generally constructed with shallow and comparatively wide concrete footings which are supported directly on ground.

Spread footing is generally used where the bridge site meets the following ground conditions:

i. Supporting ground lies shallow within about 5m from ground surface.
ii. Bearing strength of the supporting ground is appraised more than 30 of N-value by standard penetration test in case of sandy soil and more than 20 for clay.
iii. Such supporting ground develops in a depth more than 1.5 times the designed footing width (shorter side) under the bottom of footing.

iv. When ground water level is high, draining and cutting off measurers are available.

v. For foundations in waterway, there is less possibility of scouring, or countermeasures against scouring are available.

Table 1.7 Foundation Types and Construction Depth

Foundation Type		Construction Depth (m)	Diameter or Side (m)	Ground Condition: Soft and Weak	Ground Condition: Intermediate Hard Layer	Ground Condition: Intermediate Gravel Layer	Ground Water: High Level	Ground Water: Artesian over 2 m from Ground	Frictional Support	Construction in Water	Batter Pile	Environmental Condition: Low Vibration & Noise	Environmental Condition: Less Effect on Neighboring Structures	Environmental Condition: Existence of Poisonous Gas
Spread Footing		0 – 10	> 1.50	×	○	○	△	×	×	△	–	○	○	△
Driven Piles	RC Spun Pile	5 – 20	0.25 ~ 0.50	○	×	×	○	○	○	△	○	×	×	○
Driven Piles	PC Spun Pile	10 – 25	0.30 ~ 1.00	○	△	×	○	○	○	△	○	×	×	○
Driven Piles	Steel Pipe Pile	15 – 60	0.30 ~ 1.50	○	○	△	○	○	○	△	○	×	△	○
Driven Piles	Inside Drilling Method	10 – 25	0.40 ~ 1.20	△	○	△	○	×	△	△	△	○	○	○
Cast-in-Place Concrete Piles	Reverse Circulation Method	15 – 90	0.80 ~ 1.50	○	○	×	○	×	△	△	×	○	○	○
Cast-in-Place Concrete Piles	All Casing Method	10 – 40	0.80 ~ 1.50	○	○	△	○	×	△	×	△	△	○	○
Cast-in-Place Concrete Piles	Earth Drilling Method	10 – 25	0.80 ~ 1.50	×	○	×	○	×	△	×	×	○	○	○
Caisson	Open Caisson	5 – 50	> 2.00	○	△	△	○	△	×	△	–	○	△	○
Caisson	Pneumatic Caisson	10 – 35	> 4.00	△	○	○	○	○	×	△	–	○	△	×
Steel Pipe Sheet Pile Foundation		15 – 60	> 3.00	○	○	△	○	○	×	○	–	×	△	○

○ : practicable △ : difficult × : unpracticable

(3) Pile foundation

i. General

Where spread footing cannot be found on rock, or on dense granular or stiff cohesive soils within a reasonable depth, pile foundation is the most often used. For locations where the scouring risk is high or unacceptable settlement is anticipated by the use of spread footings although soil condition would permit the use, pile foundation may also be used as a countermeasure.

ii. Pile types by supporting manner

Pile foundation is classified as end-bearing, friction, or a combination of both according to the load transferring manner. End-bearing pile derives major portion of support capacity from the resistance of bearing stratum. Friction pile derives major portion of support capacity from the friction resistance along the side of the embedded pile. The bearing capacity of combination end-bearing and friction pile is derived as the sum of the resistance from the pile tip and from the friction of embedded shaft.

It is recommended to use end-bearing piles as much as possible. In case that the use of friction pile is unavoidable because bearing stratum exists deep for instance more than 60m below, the long-term consolidation settlement of the pile group should be considered in design. In this regard, friction piles are not recommended for the statically undetermined structures like continuous beam and rigid frame bridges because such structures are easily affected by uneven support settlements.

iii. Pile types by material and construction method

Pile foundation is also classified by construction method as driven and bore piles. Driven piles have various kinds made of timber, precast concrete, or structural steel sections.

Timber piles are limited in length and rarely used nowadays except small, less important constructions.

Precast concrete piles, the early type of which was RC (reinforced concrete) square pile cast at field, are nowadays a factory-made product and the most commonly used for the foundations up to around 30 m in depth. The piles are reinforced with reinforcing bars or prestressing steel, centrifugally compacted to form circular cross-section, and so called commonly RC or PC spun piles. PC spun piles are more used than RC piles because PC piles are more durable against cracks and can be driven deeper than RC piles despite small cost difference between them. The market size of PC piles varies 30~80 cm in diameter.

Steel piles may be pipe, H- or rail-section. Steel pile piles offer higher resistance against driving impact and accordingly can be penetrated deeper than PC piles. The pile, for they are expensive, are generally used for where PC piles cannot be constructed because bearing stratum is deep or hard intermediate layers exist. For corrosion of steel, the margin of 0.02 mm/year is generally considered to steel thickness under normal environment.

Steel H- or rail-piles are conveniently used for temporary construction and often pulled out to re-use several times.

Bore piles are constructed by placing reinforcing steel cage and concrete into pre-drilled holes. According to the soil condition and the desired pile depth, the methods of drilling and maintaining hole are selected. Generally either wet or dry drilling, water or slurry, temporary or permanent metal casing will be used as necessary to produce sound concrete foundation shafts free of defects. Bore piles are advantageous in urban and neighboring construction owing to their characteristics of less noise and vibration compared to the driven piles, but the method needs skilled techniques and high quality control for the complexity of construction operation. Bore piles will be studied as an alternative to steel pile piles for planning deep foundation.

iv. Batter piles

Where the lateral resistance of soil is considered not to be adequate against horizontal loads, or when increased rigidity of the entire structure is required, batter piles are often used to save piles. However, batter piles are not recommended where settlement of compressible soil and so negative skin friction loads are expected, and for bore piles due to their difficulty of construction except all casing method. Instead, it is recommended to increase the number or the diameter of piles.

v. Spacing of piles

The following minimum center-to-center pile spacings are recommended to decide the size of foundation.

For end-bearing piles	:	2.5 times pile diameter/width.
For friction piles	:	3.0 times pile diameter/width preferably, but not less than 2.5 times.

3.5 Preliminary Cost Estimate and Construction Plan

3.5.1 Preliminary Cost Estimate

(1) General

Cost estimating is a procedure to break down an object of work into its component parts such as number of spans, substructures, or a cubic meter of concrete thereby making each part more sensitive to accurate measurement of quantity and estimate of its cost.

For a government department (MOP), the cost of a bridge project will include the costs of administration, surveys, design, right-of-way acquisition, construction, supervision, and financing. For a consulting engineer, the cost will depend on its definition in his contract with the client. For a contractor, the cost will include the actual cost of construction to which an allowance for contingencies and profit is added to produce the contractor's bid.

Cost estimate may be classified by purpose as:

- Preliminary estimate,
- Comparative estimate, and
- Detailed contractor type estimate.

The preliminary estimate will be performed at the planning stage to establish the viability of a project and to earmark funds. The comparative estimate serves at the design stage of the project development and it is used for the engineer's estimate. The detailed or the contractor type estimate is used by contractors. The more detailed and accurate the estimate, the more costly and time consuming the estimation process becomes.

(2) Preliminary cost estimates

These estimates are the first made for a project in the planning stage and are used to bracket the probable cost within a rather wide range. They must be based on limited and only general definition as to scope and detail. For example, a bridge plan would be compared as to terrain, length, height, width, soil condition, etc. with the previous projects having similar characteristics, from which an approximation of quantities and cost could be made. This level of estimation may be prepared for the accuracy within 20~30 percent of final cost.

However, if additional accuracy is required for more detailed cost comparison of alternative plans or financing plan by the owner, the simplified unit cost method is recommended. The method involves the use of unit prices from previous projects applied to the quantities for a new project by grouping cost items into several major items. Here the quantities for the new project are known (at least approximately) and the previous unit costs are taken from a project or projects selected because of their general similarity of cost-controlling conditions, where a certain degree of accuracy can be obtained without extensive adjustments or detailed analyses. The unit costs for estimating bridge project cost are commonly grouped into the following major items:

Cost Item	Quantity Measurement Unit
i. Superstructure	
- Pavement (include curbs and rails)	surface area (m^2)
- Expansion joints	size and length (m)
- Main beams (include erection work and diaphragms)	
PC precast beam	type, size, and number of beams from standard design (pieces)
PC box girder	concrete volume per bridge surface area from previous project data (m^3/m^2)
Steel girder	steel weight per bridge surface area from previous project data (ton/m^2)
- Deck slab	concrete volume (m3)
- Bearing shoes	capacity and number of shoes (pieces)
ii. Substructure	
- Abutments and piers	concrete volume (m3)
- Excavation and temporary cofferdam	excavation volume (m^3)
- Foundation	
Spread footing	be included in abutment/pier concrete volume.
Piles	type, size, depth, and number of piles (total pile length : m)
iii. Approach road	
- Road earth-fills	earth volume (m^3)
- Pavement	surface area (m^2)
iv. Other works	
- Temporary staging	surface area (m^2)
- Traffic detour-way	length or surface area (m or m^2)
- Bank protection	surface area (m^2)

The unit costs used in this method are considered to include all direct, indirect, and corporate indirect costs. With this method, accuracy is expected to be within 10~20 percent range.

Significant error may occur if unusual construction techniques and temporary facilities are involved and are not properly compensated for in the unit costs applied. This is a reason why the preliminary cost is sometimes far below the contractor's bid cost.

3.5.2 Preliminary Construction Plan

(1) Objectives of planning

The main objectives of construction plan are:

i. to envisage how the construction will be carried out, in what order and with what method and resources; reducing the construction to a number of manageable activities.

ii. to anticipate potential difficulties and risks to overcome them, so that their effects can be minimized. This is the major objective of construction planning, because civil engineering is a high risk business and the planning is fraught with uncertainty.

iii. to schedule resources (men, equipment, materials and money) to enable optimum use.

iv. to provide a basis for predicting and controlling time and cost.

(2) Planning process

Planning is the mental activity of working out what has to be done, how, by when, by whom, and with what. Planning techniques assist in the analysis of plan organizing information, and in which the plan is communicated to others. Taken together these two elements of planning produce the plan a strategy and tactics for the execution of the project in terms of activities, time, quantities, resources, and perhaps costs. The plan is expressed as charts and reports.

Planning depends on data. Without reliable data, planning can only process best guesses. As each construction project is different, all construction projects are a learning process and this learning process enables the plan more accurate as the project progresses. New data can be used to refine or revise the plan.

(3) Planning hierarchy

Before starting to prepare any plan, it is vital to decide who the plan is for and what level of detail is required. Table 1.8 lists the people who may require or prepare a construction plan, summarizes what they will need to know, and gives appropriate time-scales.

Table 1.8 Planning Hierarchy

Plan drawn up			Primary purpose of plan	Scope of plan	Scope of programme	Time-scale	Unit	Level of detail
	For	By						
Clients	Government department	Project director	Administrative planning	A project overview from identification of need through feasibility study, preliminary design, detail design, land acquisition, and construction period.	Outline project programme	Entire project	Month	Low
		Project director	Financial planning	A project overview from project conception to implementation including appointment of consultant and contractor, design and documentation periods, and construction.	Outline project programme	Entire project	Month	Low
Managers	Project manager	Project manager	Co-ordination of design and construction	Design period, documentation, letting contracts, and construction period.	Outline and broad details	Project design and construction	Week	Low/ medium
	Contractor	Staff	Tender plan	All activities within construction period in sufficient detail to enable contractor to prepare the tender.	Construction programme	Construction period	Week	Medium
	Contractor's or Engineer's Representatives	Staff	Resource planning	Every activity, major items of plant, dates of key material deliveries and site movement.	Short-term programme	Months	Day	Medium/ high
	Foreman	Staff	Disposition of plant and manpower	Every operation with the actual plant, manpower and supervisors employed.	Weekly programme	Weeks	Half-day	High

(4) Project duration

There are two ways to determine how long the project will take:

i. It is imposed by external considerations of the time available, and designer or contractor then has to devise a plan to meet this requirement, or

ii. It is built up from a detailed analysis of the work to be done and the resources available, using estimates of the time required for each activity.

The examples of externally imposed considerations are: (1) it is difficult to attempt building piers in deep waterway in high water season, (2) asphalt paving work will be avoided in rainy season, or (3) the client may often have an economic or administrative need for fast construction, or require a project to be constructed in stages for budgetary reason.

The examples of detailed analysis of the work and the resources are: (1) the output of a construction operation is determined by the capacity of a key plant or equipment or by the work sequences; this is most common in bridge construction, or (2) it is also common that contractors tend to assess the combination of resources most likely to complete the work at minimum direct cost; then the duration of the operation is calculated from the volume of work in this way.

(5) Planning tools

Four techniques are commonly used in construction planning: bar chart, line-of-balance, linear programme, and network analysis.

Bar Chart

The bar chart is easy to draw, easy to understand, and best used for straightforward, well-understood construction work with simple relationships between the activities. Main disadvantages are that it neither show relationships between activities nor relate activities to location.

Line-of-balance

Line-of-balance was derived from manufacturing industry, and has been found to be effective in planning work that is truly repetitive. Line-of-balance has been found to be difficult to use on projects which require a large number of operations to construct each identical unit. The problems arise from the difficulty of showing all the information on one chart, especially when using the technique to monitor progress. However, it is an excellent means of relating resources, activity durations and the general pace of work.

Linear programme (or time-chainage chart)

Linear programming is a specialized technique for linear work. This is a basic tool of the construction of a large canal and it is especially useful in tunnelling. Like line-of-balance, this is a simple two-dimensional graphical technique and can show clearly only a limited amount of information and a limited degree of complexity.

Network analysis

Network analysis is a logical and analytical technique. It is most effective when used for complicated projects, especially those with external constraints and complex interrelationships. The technique is based on drawing the logical relationships between construction operations, and establishing which operations have the most crucial effect on the project duration. The technique is known as the critical path method (CPM), and a version which incorporates a statistical method for calculating the probability that a project will be completed on a specific date is called the programme evaluation and review technique (PERT). Network analysis has a good and comprehensive logical basis, lends itself easily to computer processing, and can be used as an effective control tool.

It is of fundamental importance to note that the level of detail of the plan and the choice of technique are related. For example, the overall programme for a large and complex project should be drawn by a network. However, for an simple activity "piling work", obviously network analysis does not work well. Instead line-of-balance programme should be used.

(6) Planning components

Planning tools aim to express the work to be done to a time-scale; some also include resources and perhaps cost. The other major factor in construction control is "quality" which is undertaken by separate techniques from the planning tools. However, quality is related to time and cost through the skill and judgment of construction management.

The major components of planning techniques are:

- **activities:** this means a work to be done for example preparing a drawing, materials to be ordered, piles to be driven, or concrete to be placed.

- **activity duration:** the time required for the completion of each activity.

- **project time-scale:** the time structure of the project; it is usual to give each week or month a number (this makes calculation easier).

- **event:** an occurrence at a specific point in time; for example, the start and end of construction.

- **work method:** the plan must be expressed in some logical way, indicating the sequence of operations, and which activities and events are interrelated; this may be implicit (as with bar charts) or explicit (in network analysis, where work method is usually called logic).

- **resources:** generally include men, machines, materials, and money, and even such essentials as managerial skill.

- **costs:** what the work has or will cost, often derived directly from the unit costs of the individual resources.

3.6 Environmental Impact and Aesthetic Consideration

3.6.1 General

The term "environment" is meant to be interpreted broadly as the whole complex of physical, social, cultural, economic, and aesthetic factors which affect individuals and communities and ultimately determine their form, character, relationship, and survival. The definition "environmental impact" is any alteration of environmental conditions or creation of a new set of environmental conditions, adverse or beneficial, caused or induced by the action or set of actions under consideration. The attention given to environmental conditions will vary according to the nature, scale, and location of the proposed action or actions. Attention would be given to those factors most evidently affected, such as the effects on the resource base, including land, water quality and quantity, air quality, public services and energy supply, as well as other environmentally critical areas.

Generally, impacts can be categorized as either primary or secondary. This distinction is important for consideration of alternatives and ways to minimize adverse impacts in performing impact analysis. One way to describe the distinction is that project "inputs" generally cause primary impacts and project "outputs" generally cause secondary impacts. Primary impacts are generally easier to analyze and measure, while secondary impacts are usually more difficult to measure. Secondary impacts may, in fact, be more significant than primary impacts.

3.6.2 Impacts of Highway and Bridge Project

(1) General

Bridges are a part of highway, accordingly the environmental impacts of the bridge construction should be discussed in the environmental problem of the highway construction.

Highway construction has impacts in a number of areas, the most noteworthy of which are aesthetics, air quality, circulation and traffic patterns, noise, socioeconomics, water quality, and wildlife. Highway may stimulate or induce other actions (secondary impacts), such as more rapid land development or changed patterns of social and economic activities. Impacts associated with secondary action may often be even more substantial than the primary impacts associated with construction. For example, the effect on population and area growth associated with the construction of new highways may be among the more significant impacts.

(2) Aesthetics impacts

Of general concern relative to aesthetics are such impacts as: (1) blocking viewlines along visual corridors (such as valleys, stream courses, and streets); (2) blocking viewlines to landmarks in the community from residential, recreation, and commercial areas that benefit from view; (3) bridges or elevated highway out of scale with adjacent urban development; (4) visual distraction and displeasing glare visible in recreational and residential areas; and (5) unattractive contrast between existing vegetation and revegetated or landscaped areas, between natural landforms and engineering features, and between urban or existing development patterns and highway features.

(3) Air quality impacts

Air quality impacts include: (1) dust and/or particulate matter on vegetation and structures surrounding the construction site or along roads: (2) tire and exhaust particles coating roadside vegetation and structures; (3) increase in severity of existing smog conditions due to an increase in automobiles traveling through the area; and (4) generation of vehicle fumes and odors (such as from exhaust emissions, or tire and brake rubber).

(4) Noise impacts

Noise impacts generally involve the area within sound of the traffic such as: (1) disturbance of surrounding passive recreational activities requiring quiet and serene conditions for their enjoyment; (2) disturbance of educational, health care, and cultural activities or institutions particularly sensitive to noise, such as schools, churches, hospitals, sanitariums, auditoriums, and theaters; (3) disturbance to operation or patronage of commercial activities requiring or benefiting from quiet surroundings; and (4) disturbance to surrounding residential development.

(5) Socioeconomic impacts

Socioeconomic impacts include: (1) removal of residential, commercial, and industrial land uses and displacement of both residents and jobs; (2) removal of structures or sites of scenic, architectural, archaeological, or historic significance; (3) loss of site having unique potential or suitability for commercial or industrial activities; (4) loss of taxable private land revenues; (5) relocation costs to displaced residents greater than compensation paid; and (6) severance of interpersonal ties of displaced residents to former neighborhood/community (family ties, ethnic bonds, or neighborhood friendships).

(6) Water quality impacts

Water quality impacts involve one or more of the following: (1) turbidity and silting of adjacent streams and reservoirs caused, for the most part, by the erosion of the raw soils exposed during construction and maintenance operations (the primary impact of these effects generally involve increased operating costs or shortened life of affected reservoirs and channels; damage or elimination of fish and other aquatic life; and possible damage to buildings, roads, and bridge foundations); (2) watershed modification caused by the impingement of the road system and its construction on estuaries, marshes, wooded swamps, and streams – in particular, in estuaries disturbance of natural flows can affect ecological determinants such as sedimentation patterns, mixing of fresh and salt waters, nutrient flows, shellfish beds, fish and wildlife, and local vegetative patterns; (3) highway runoff contamination caused by runoff containing oil, fuel, tar, pesticides, fertilizer, deicing salts, animal and human wasted, and the products of combustion which can affect water quality, wildlife, and roadside vegetation; (4) sanitary wastes from temporary and permanent waste disposal facilities (Note: Waste disposal is accomplished through portable toilets during construction and permanent rest areas after construction); in either case, raw or inadequately treated discharges can have an impact on local water systems; and (5) contamination of surface and ground water supplies and recharge areas by polluted fill material, where the use of polluted fill material can affect the concentrations of biological, physical, chemical, and radiological contaminants in water supplies.

(7) Wildlife impacts

Wildlife impacts would generally include: (1) loss or degradation of unique or highly productive wildlife, fish or shellfish habitats; (2) division of wildlife ranges and migratory patterns; (3) displacement of wildlife to other ranges; (4) impairing or blocking migration and/or movement of aquatic biota; and (5) visual disturbance of wildlife on adjoining lands.

(8) Circulation impacts

Circulation impacts include: (1) blocking or impairing access along existing street patterns crossed by the highway, such as access to public and private services of residents and patrons within the service area, reinforcing or creating physical barriers between social groups, congesting through-street traffic by diverting traffic from dead-end or rerouted streets, and disrupting public transit routes; (2) dividing single land uses or resource areas such as agricultural operations, recreation areas, wildlife ranges or habitats; (3) increasing truck and construction equipment traffic on public roads during construction; (4) providing new or improved access to previously inaccessible or relatively inaccessible public and private lands; (5) providing or improving access to relatively undeveloped areas outside urban centers, thus inducing commercial and industrial operations to locate outside urban centers; and (6) increasing traffic traveling through the area and thus causing an increased demand for travel related services.

3.6.3 Aesthetic Consideration

(1) General

A bridge should never usurp its role as a part of the highway. It should always look as though it thoroughly belonged to the rest of the highway. It should be completely compatible with its surroundings. The bridge belongs in that location.

Giving a bridge a retiring personality is not always easy. A designer must subdue any impulse to make his structure stand out as a monument to his design prowess. A bridge which stands out when it should be merely a part of the highway often develops into an eyesore. The designer must be careful lest he be carried away by transient public fads.

Designs, which rely for their beauty on good proportions, clean lines, and an honest approach to function, have worn better with time. So will the structure built in the future if they have basic excellence built into them: good balance, trim proportions, clean lines, interesting but not fancy forms. The bridge designer should never forget the projected 100-year life for his structure. If he wants his critics of eight or ten decades hence to admire his work, he had better make it a basically excellent design. He must walk the fine line between uninteresting starkness and overdone decoration.

High fills have blocked the view of many attractive canyons, when the beauty of many deep canyons would be enhanced by the slim framework of a well-designed bridge. Fills and culverts have their place when they will not destroy natural beauty. But, where there is such beauty, consider a bridge rather than a culvert and fill. As a practical matter, the apparent economy of a culvert at the base of a huge fill may prove false if debris plugs the culvert and the water backs up and floods the country above the road. Such short-sighted economy can generate lawsuits.

(2) Aesthetics of structures

It is important that the bridges be completely compatible with their surroundings. They should look like they belonged there. As soon as they have had a chance to weather a little, they should look like they had always been there a completely natural and acceptable part of the landscape. This often means that attention should be given to the characteristics of prominent buildings nearby or other landmarks with which the bridge must fit. Compatibility is the key.

Beauty in a structure comes from its basic design. Beauty starts with the first concepts of the structure and from there proportion, form, and general design must follow to achieve a pleasing result. Beauty in this context, coming from well-proportioned, carefully planned design, is not expensive. Even though the owner may not wish to spend any extra money for aesthetics, the designer still may create a good-looking structure by his careful handling of proportion, shape, and light and shadow.

(3) Number of spans

The number of spans is the first important decision that has critical aesthetic effects. Unless a structure is part of a grade-separation where the span arrangement is dictated by the intersecting roadways, the number of spans to be used in a bridge is one of the first determinations for the designer to make. If the structures is easily visible as a whole, an odd number of spans will be found to be more pleasing than an even number.

(4) Balance of span and height

The length of spans depends upon the length of the bridge and its height above ground. The ground, the piers, and the bridge deck create a series of generally rectangular shapes. If the piers are close together, these rectangles may be higher than they are wide and look crowded. The arrangement is generally better when the rectangular areas are longer in a horizontal direction – generally, the longer the better. The cost of longer spans is a factor, so the designer must balance the aesthetic tastes against the money available to build the bridge.

Structures which are high above the ground look thinner and more graceful. It is possible to have a deep, heavy structure that looks delicate and graceful if it is high enough above the ground. For structures which cannot be high in the air, every effort must be made to make the superstructure as thin as possible or at least to create an illusion of thinness. Concrete superstructures can be made thinner by prestressing. Rounding the corners, sloping the outside faces of girders, building a longitudinal ledge to develop a shadow area on the lower part of the girder – all of these are useful tools in creating the illusion of a thin superstructure.

It is often difficult to design a thin steel superstructure economically for a reasonably low short span. Shallow steel girders become uneconomically heavy. Problems of erection or traffic may override cost to make short steel spans desirable. Some steel box designs produce attractive, thin superstructures for long spans.

(5) Artistic techniques

i. An attractive structure is produced by the harmony of all of its elements. The use of a number of details which are attractive in themselves does not guarantee a pleasing overall effect. This is what makes aesthetics an art rather than a science. The satisfactory end result depends upon the taste and innate ability of the designer to combine all of the details artistically.

ii. There are some details which may help the overall effect. Sloping the exposed area of the front faces of the abutments in toward the roadway will produce a pleasing dynamic effect in a short structure which seems to launch it across its span. Tapering the piers so they are smaller at the bottom than at the top will tend to decrease the feeling of heavy attachment to the ground and make the structure appear to float. On the other hand, for very tall piers, tapering from the ground to a thinner neck high in the air seems to release the superstructure from its solid ties with the ground, and this also makes it appear to float. Modern highways are avenues of speed and flowing movement. The bridges should carry out that feeling, emphasizing the horizontal lines and playing down the verticals which tend to interrupt the flow.

iii. Piers have been made round, square, or rectangular. There are many interesting shapes which can be developed out of these basic forms which, with some of the tapering effects, can add considerable interest.

iv. Attractive designs are not necessarily fancy designs. There is a strong appeal to very simple plain shapes and forms. As noted earlier, there is also an economic appeal in that they are cheaper to build. Contractors are notoriously unaesthetic when they come to build forms or fabricate shapes which vary from the straight, square, and simple. Nevertheless, fancy shapes do cost more money and the designer should be constantly seeking the plain, easier-to-build solutions.

v. It cannot be stated too often that the successful and artistic bridge must fit its site, and be completely compatible with its surroundings. It is imperative that the designer be familiar with the site and have a feeling for the environment of his structure. There have been examples of designs which were totally unsuited for their locations because the designer did not take the trouble to visit the site and see just how and where his structure would fit into the landscape.

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DIVISION II

BRIDGE ENVIRONMENTAL STUDY

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CHAPTER 1   GENERAL

1.1 Introduction

Global attention and concern have recently been focussing increasingly on the pollution and destruction of the Earth's environment, the environment on which mankind depends for its very existence, seen.

Many countries formerly felt that environmental protection and development were incompatible and that to escape from poverty, their most pressing problem, priority had to be given to development, even at the cost of environmental destruction. Today, they address environmental problems, such as pollution in major cities and the destruction of tropical forests, very seriously, the need to take account of environmental considerations in development projects is understood and determined efforts are being made to tighten environmental laws and strengthen agencies charged with protecting the environment.

1.2 Objectives of the Manual Guideline

For the implementation of Road and Bridge development projects, careful environmental consideration should be carried out from the early stages of project planning with a long-term perspective in order to accomplish a well-balanced development. As such development project are implemented based on the decision making process of the country, it is necessary to conform to the country's laws, rules and regulations related to environmental consideration.

However, such rules and regulations are not properly enforced. The policies and structures for environmental consideration vary. Therefore, when undertaking the environmental consideration, it is necessary to take into account of the country's policies and structures and to understand the country's awareness of environmental problems, while holding sufficient discussions with the people concerned in flexible manner.

If environmental consideration is not sufficiently undertaken for implementing a development project and, if careful attention is not paid to the management of the surrounding natural resources, the base of the development might be jeopardized and the development might be halted. The base of people's livelihood or even their subsistence can be also threatened. It is necessary to try to ensure the sustainable development by harmonizing the development project with natural resources and the base of the residents in the area.

The Manual guideline describes screening and scoping procedures at the preparatory study stage to deal with the negative impacts of a development project on the environment of the project site and its surrounding area. The process of environmental consideration in a project cycle is shown in Figure 2.1.

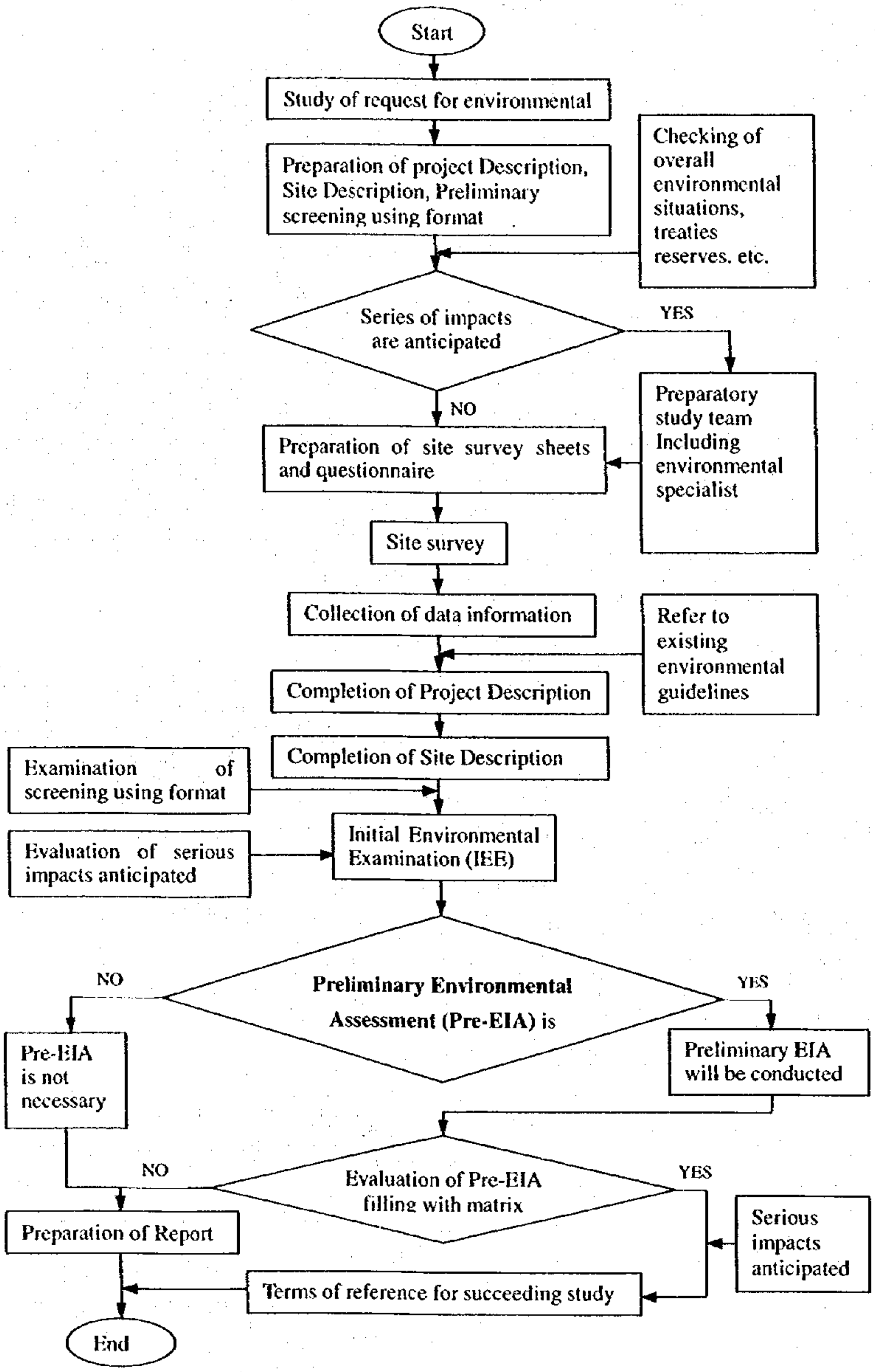

Figure 2.1 Procedure of Environmental Consideration for Road and Bridge Projects

A development project begins with its finding and formulation. At each stage of the cycle, a series of environmental considerations, such as preliminary environmental survey, an Initial Environmental Examination (IEE), Preliminary Environmental Impact Assessment (Pre-EIA), Environmental Impact Assessment (EIA) and the design of environmental protection measures take place. Environmental monitoring is then conducted with project implementation. Through this process, sustainable development can be attained.

1.3 Focus to the Balanced Development

Whatever projects would be proceeding, environmentally balanced development is vitally important. Today tendency that many development projects have being worked for the prevention of environmental degradation, and for environmental improvement, focussing on the five points listed below. The Manual guideline will continue, and intensify, these endeavors.

(1) Taking account of environmental considerations in its review of the environmental factors of a development project, this emphasizes the following:

a) Harmony between development and the environment, in a perspective of sustainable development;
b) Resolving environmental issues by means of a continuing dialogue with the development agencies
and its country concerned; and
c) Considering environmental factors at the earliest possible stage of the process.

(2) Expansion and enhancement of environmental projects

Principal purpose is environmental improvement or some of the components of which contribute to environmental improvement, and will continue this approach.

(3) Systematic gathering and coordination of environmental information

(4) Closer links with other agencies

(5) Considerations Institutional arrangements making it possible to give greater emphasis to environmental

1.4 Character of the Manual Guideline

(1) The goal of environmental consideration is to help countries themselves manage their own development in an environmentally sound way. This Guideline Manual, therefore, cover those

environmental items, which should be considered by the development, body at the stages of project planning and preparation. Intending development bodies are advised to utilize the Guideline Manual fully to enhance the quality of their projects.

(6) The Guideline Manual have been prepared to ensure that consideration of environmental factors items. It will make necessary improvements on and ongoing basis, in the light of experience of their use, relevant research findings, etc.

1.5 Criteria to be Employed

For proceed of the environmental consideration study on the road and bridge development project, the following criteria for environmental consideration should be employed to fulfil balanced development related with existing environmental components.

(1) Socio-economic environment:

A project shall not be carried out in such a way as will unacceptably adversely affect the existing human environment.

(2) Natural environment (flora and fauna, etc.):

a) Legislation and rules stipulated in international conventions, etc. must be strictly complied with.
b) A project shall not be carried out in such a way that it will have a considerable adverse effect on the habitat of the principal flora and fauna of the area.
c) Measures must be taken to protect rare and endangered species of flora and fauna in the area.

(3) Environmental pollution (air pollution, water pollution, noise, vibration, offensive odours, etc.):

a) The country has regulatory environmental standards, such as emission standards; those standards are to be strictly observed.
b) The country has administrative guidelines, such as environmental standards, measures adopted must not militate against the attaining and maintaining of those standards.
c) The country has no such standards; standards adopted in international organizations are to be referred.

CHAPTER 2. INITIAL ENVIRONMENTAL EXAMINATION

2.1 General

The aim of Initial Environmental Examination (IEE) is to examine the overall impact on the environment of road and bridge development and those of rehabilitation projects. And the objectives of IEE are:

a) To examine and select the best from the project options available:
b) To identify and incorporate into the project plan appropriate abatement and mitigating measures:
c) To predict significant residual environmental impact;
d) To determine the significant residual environmental impacts predicted:
e) To identify the benefits of the project reflect to the community.

2.1.1 Establishing the Need for the Project as an Important Concept

In planning of Road and Bridge project, it is important to establish clearly the need for the project. An explanation of why the project has been proposed indicates the aim of the project and helps to maintain direction during planning. A "Need for the Project through project and site description" also highlights the Socio-economic or other benefits that will accrue from the project

2.2 Project Description and Site Description

2.2.1 Basic Concept

To conduct screening and scoping of the potential environmental impacts that may be caused by a development plan or project, it is essential to fully understand the "project description" and "site description" at the earliest stage.

Project description includes the contents and features of the project, such as its background, objectives, location, executing agency, number of beneficiaries, scale, structure, construction method, operation and maintenance, etc..

Site description includes the present conditions of the natural and social environment and pollution in and around the project area.

In particular, if the project site includes such areas as follow, they should receive special attention:

a) Areas requiring soil conservation (high-risk areas of erosion, salinization, etc.).
b) Arid and semiarid areas subject to desertification.

c) Natural forests.

d) Water sources.

e) Habitats of value for the protection and conservation and/or sustainable use of fish and wildlife resources (wetlands, mangrove, swamps, coral reefs, etc.)

f) Areas of unique interest (historical, archaeological, cultural, aesthetic and scientific).

g) Areas of concentrations of population or industrial activities where further industrial development or urban expansion could create significant environmental problems.

h) Areas of particular social interest to specific vulnerable population groups (e.g., nomadic people or other people with traditional life styles).

It should be borne in mind that the above items must be thoroughly studied in each project step.

2.2.2 Project Description and Site Description

The project description and the site description should be clarified in the formats shown in Tables 2.1. However, at the project finding and preparatory study stages, sufficient information for the project description and site description may not be available. Thus, during the preparatory work prior to the preparatory study in the host country, the formats of Tables 2.1 and 2.2 should be filled in as complete as possible using all available information. The additional necessary information should be supplemented during the field surveys.

Table 2.1 Inspection format for Project description

Project No. and Name: Location: Region: Province:

Item		Description
Background		
Objectives		
Executing Agency		Ministry of Public Works (MOP)
Beneficiaries		
Project Components		
	Existing bridge structure Bridge length, width Other specific features	Slab( ), Beam( ), Abutment( ), Pier( ), Foundation( ) Length(m), Width(m) Carriage way width (m), Side walk width (m)
	Project Type	( ) Replacement, ( ) Repair
	Road Type	( )Urban / ( )Rural area, ( )Plain area /( )Mountain area ( )Paved / ( )Unpaved
	Existing traffic volume	Year/month/day / / Day of the week( ) ( ) Cars/hour, ( )Cars/day
	Road width/lanes	Existing Width =(m) Nos. lanes = ( )
	Road structure	( )Embankment / ( )Elevated / ( )Others: Cutting of original ground
	Supplemental facilities	
Others		River name:

Table 2.2 Inspection format for Site description

Project No. and Name: Location: Region: Province:

Item		Description	
Social environment			
Inhabitants: Residents, Indigenous people. Their views on the project, Others	Upperstream: Left bank area:	Right bank area:	
	Downstream: Left bank area:	Right bank area:	
Landuse and facilities: Urban area, Farm land, Others, Historic & cultural site, Scenic spot, Hospitals and other facilities	Upperstream: Left bank area:	Right bank area:	
	Downstream: Left bank area:	Right bank area:	
Economy: Commerce, Agriculture, Forestry, Others	Upperstream: Left bank area:	Right bank area:	
	Downstream: Left bank area:	Right bank area:	
Transport: Bus terminal, etc.			
Natural environment			
Topography, (Feature of river bank area) Steep slopes, Soft ground, Wetland	Upperstream: Left bank area:	Right bank area:	
	Downstream: Left bank area:	Right bank area:	
Geology, (Feature of river bank/bed): Outcrop, stone, Gravel, sand/ Fault, Soil type, etc.	Left bank area:	Right bank area:	
Hydrology, (Feature of river flow, Water level, flood level)			
Fauna & Flora / habitats, Rare species /community, etc.,			
Environmental Pollution			
Complaints: Population of the upmost concern			
Measures taken: Institutional measures, Compensation			
Others			

2.3 Environmental Components

Road and Bridge project mostly same as other related infrastructure projects has basically various environmental components to be contacted through the beginning of implementation stage to operation maintenance stage. These environmental components may classify 3 categories of Socio-economic, Natural and Pollution. The list of environmental components for the Road and Bridge project can be identified as follows.

(1) Socio-economic Environmental Components

(a) Inhabitants
Residents, Indigenous people
Land Acquisition, Relocation and Resettlement

(b) Landuse and Facilities
Urban area, Farm land, others
Historic and Cultural site
Scenic spot
Hospital, School, Church and other Public Facilities

(c) Economy
Commerce, Industry, Agriculture, Forestry, Fishery

(d) Transport
Railway, Railway station, Bus terminal, others

(2) Natural Environmental Components

(a) Topography
Features of Topographic Land Form
Features of River and Bank Area
Slope Gradient
Ground Surface Feature
Wetland, Swamp, others

(b) Geology
Geological Features of Land, Fault
Features of River Bank and Bed
Ground Surface of Outcrop, Stone, Gravel, Sand
Soil Type, others

(c) Hydrology
Features of Surface Water, River, Swamp, Lagoon and Lake

Water Flow, Water Level, and Flood Level, Discharge Pattern
Features of Groundwater

(3) Environmental Pollution

(a) Complaints: Population of the up-most concern
Air Quality
Water quality
Noise and Vibration
Odour

2.4 Project Activities for Road and Bridge Project

Project activities related on the Road and Bridge construction and rehabilitation project has various items to be fulfilled. To begin with Pre-construction stage, and through construction stage to operation maintenance stage, there are various activities may arise. These activities are always interacting with those of Environmental Components. The items of project activities regarding to each implementation stages can be identified as follows.

(1) Pre-construction Stage

Access roads
River and Stream Crossing
Route and Site Surveying
Boring Test
Site Clearing and Burning
Earthworks and Drainage alteration
Equipment
Waste Disposal and Recovery
Land Acquisition
Resettlement and compensation

(2) Construction Stage

Access Roads
River and Stream crossings, Detour Route
Earthworks Drilling and Blasting
Demolition

Building Relocation
Reclamation
Quarries
Drainage Alteration
Erosion Control
Pilling
Structures and Surfacing, Paving
Equipment
Transportation
Landscaping
Revegetation
Labour Force
Utilities
Waste Disposal and Recovery

(3) Operation and Maintenance Stage

Equipment
Transportation and traffic
Pedestrian Traffic
Waste Disposal and recovery
Accidents
Landscape

(4) Consequent Project

Amenities
Utilities
Transportation

2.5 Environmental Characteristics and Components

From each relevant project activity there may be several potential environmental effects. This section defines each of the major categories where effects are felt (i.e. Socio-economic, natural) as listed as follows in the section 2.5.1. It describes in more detail under the headings of the broad environmental characteristics.

The environmental effects described for each of the components listed should be used as a guide only. The list of components is not exhaustive and provision is made on the matrix for screeners to add relevant components. Environmental effects other than those described as followings may occur also.

2.5.1 Socio-economic Environmental Components

Item: 1. Resettlement

Description:

Resettlement due to occupancy of land (transfer of rights of residence and/or land ownership)

Causes of Impacts

1) Land acquisition for road and bridge construction

Possible Environmental Impacts

1) Loss of living foundation of inhabitants to be resettled social and cultural inadaptability to the new settlement site may occur.
2) Conflict between permanent residents and resettlers over social and economic burden
3) Deterioration of living standard after resettlement due to the poor compensation system in some countries or the status of illegal occupants

Useful Factors for Evaluation

1) If the following conditions are involved, resettlement will be difficult:
    a) The inhabitants live on the special environmental resources of the site.
    b) The inhabitants are currently well off.
    c) Favorable relocation site is not available in the vicinity.
2) Careful consideration is needed if racial or tribal problems exist

Related Subjects for Study

1) Population of the inhabitants to be resettled and their economic condition
2) Condition of the resettlement site
3) Past cases of resettlement

Measures

1) Resettlement site selection considering the wishes of the inhabitants
2) Meetings with the inhabitants and provisions of necessary information
3) Improvement of living and economic conditions of the resettlement site
4) Compensation
5) Job training and guidance

Item: 2. Economic Activities

Description:

Loss of bases of economic activities, such as land, and change to the economic structure

Causes of Impacts

1) Loss of arable land and forests
2) Land reclamation and change in land use
3) Change of industrial structure following the inflow and outflow of population and goods resulting from the road construction

Possible Environmental Impacts

1) Effects on the regional economy because of a decrease in agriculture and forestry production due to loss of arable land and forests, change of population distribution caused by alternate land use, change of commercial activities and job opportunities
2) Inconvenience in accessing between both sides of the route
3) In self-sufficient areas, although cash income would increase by the adoption of cash crops, malnutrition might result.
4) Rise in land value along the route would widen the gap between the rich and poor.

Useful Factors for Evaluation

1) Increase in land use value along the route would make it difficult for industries having low value-addition to survive.
2) In self-sufficient areas, the effect on the economy caused by the inflow of people and commodities would be significant.
3) If important industries exist in the site, the effect of relocation on the local economy and employment may be significant.

Measures

1) Alternate route selection
2) Sufficient compensation to the land owners
3) Securing of substitute

Related Subjects for Study

1) Local economy and industry
2) Future plans of the area such as a regional development plan

Item: 3. Traffic and Public Facilities

Description:
Impacts on schools, hospitals and present traffic conditions, such as increased traffic congestion and accidents

Causes of Impacts
1. Replacement of transport means by road traffic
2. Emergence and increase of vehicular traffic

Possible Environmental Impacts
1) Depression or extinction of the existing traffic and transport facilities owing to the emergence of mass transport introduced by the new road
2) Increase in traffic accidents, traffic jams and other traffic problems caused by an increase in traffic
3) Effect of noise caused by vehicles on schools, hospitals, religious spots and other public facilities. The possibility is higher in an urban area.

Useful Factors for Evaluation
1) Local traffic and transport facility conditions, especially the conditions along the access roads to the existing route should be considered carefully.
2) It is necessary to refer to the regional development plan or city planning.
3) Careful consideration should be given to schools, hospitals, religious spots and other public facilities in the area.

Measures
1) Examination of the project contents
2) Rehabilitation of the existing traffic system, especially along the access route
3) Installation of safety facilities
4) Environmental protection measures for public facilities

Related Subjects for Study
1) Land use and traffic conditions
2) Future land use plan, transportation plan
3) Higher level regional development plan
4) Distribution of the public facilities

Item: 4. Disintegration of Communities

Description:
Community split due to interruption of area traffic

Cause of Impacts
1) Interruption of existing route by the construction of new roads
2) Interruption of traffic of inhabitants and commercial distribution

Possible Environmental Impacts
1) Inconvenience in daily activities of inhabitants and effect on economic activities
2) Creation of detached territories or isolated areas

Useful Factors for Evaluation
1) In case isolated areas are created, the effect is obvious and countermeasures should be considered.
2) Careful consideration is needed if there are communities having long existing customs or traditions and that are tightly united in their social activities.

Measures
1) Securing of alternative routes
2) Creation of new community centers
3) Sufficient compensation

Related Subjects for Study
1) Social structure of the region
2) Transportation system, distribution of goods, and regional economy
3) Higher level regional development plan

Item: 5. Cultural Property

Description:
Damage to or loss of the value of churches, temples, shrines and archaeological remains and other cultural assets

Causes of Impacts
1) Damage to and/or loss of historical assets and cultural property by land reclamation for road construction

2) Increase in traffic of people owing to the development of road
3) Noise and air pollution caused by vehicles

Possible Environmental Impacts

1) Increase possibility of theft due to construction activity and activated traffic, and damage to or vanishing of a unique culture by the flow of different cultures and the loss of opportunity for academic research
2) Damage to tourism business opportunities, which depend on cultural property
3) Aggravation of inhabitants' feeling caused by the loss of precious cultural assets in the area

Useful Factors for Evaluation

1) Impacts would be critical when the cultural property is recognized historically and culturally important from global viewpoints or is unique to the area.
2) Countries with longer histories may have more cultural property to preserve.
3) Careful consideration should be given to officially register cultural assets.
4) Careful attention should be paid to buildings and other facilities in unique communities.

Measures

1) Reexamination of the traffic routes and contents of the plan
2) Preservation or relocation of cultural property
3) Meetings with the inhabitants and provisions of necessary information

Related Subjects for Study

1) Laws and regulations concerning preservation of cultural property
2) Local history and folklore
3) Preservation or relocation plans and measures

Item: 6. Water Rights and Rights of Common

Description:

Obstruction of fishing rights in rivers, water rights and land use rights

Causes of Impacts

1) Occupancy of arable land and forests for road construction
2) Obstruction or alteration of fishing grounds if the roads traverse rivers or pass by coastal areas
3) Increase in traffic

Possible Environmental Impacts

1) Effect on the people who have utilized the common land in case the route passes through the common land. The effects may extend to the culture and industry of the area.
2) Occupancy of the fishing ground would affect fishery. Easy access to forests may cause illegal entry and logging.

Useful Factors for Evaluation

1) Special attention should be paid to old communities likely to have common forests or land.
2) Careful attention should be paid when the route passes through fishing ground.
3) Water rights or land use rights may exist if water intake facilities, navigation facilities and charcoal-burner sheds exist.

Measures

1) Alternate route selection and reexamination of project components
2) Provision of new common land
3) Meetings with inhabitants and provisions of necessary information
4) Sufficient compensation

Related Subjects for Study

1) Local history and folklore
2) Type of land ownership, e. g., by laws or custom

Item: 7. Waste

Description:

Generation of construction and demolition waste, debris and logs

Causes of Impacts

1) Generation of debris and construction waste due to the construction of roads
2) Generation of general waste following the use of the roads and an increase of economic activities

Possible Environmental Impacts

1) Exposed waste may diminish aesthetic values and affect vegetation. It may also cause the pollution of soil and water.
2) Dumping from vehicles would affect aesthetic values along the route and cause sanitary problems.

Useful Factors for Evaluation

1) The volume of debris can be estimated from the scale of excavation.
2) A large amount of demolition waste may be produced when the project includes the demolition of buildings.
3) Disposal of debris would become a critical problem in urban areas.

Measures

1) Establishment of proper waste collection system and disposal system
2) Securing of sufficient waste disposal site
3) Careful construction plan and management

Related Subjects for Study

1) Study on volume of waste, physical and chemical characteristics of the waste
2) Land ownership and land use to determine a suitable disposal site
3) Laws and regulations concerning waste disposal

Item: 8. Hazards (Risk)

Description:

Increase in risk of landslides, cave-ins and accidents

Causes of Impacts

1) Cut and fill and land reclamation for road construction
2) Insufficient drainage
3) Decrease in rainwater intrusion owing to the paving of road surfaces

Possible Environmental Impacts

1) Damage to and collapse of the road surfaces as a result of poor flood water drainage.
2) In case of impermeable paving, surface runoff caused by heavy rain will cause soil erosion and flooding.
3) Large-scale cutting would change the balance of the soil and create land cave-ins or upheavals.
4) Landslides and similar failures might damage land and houses and threaten the lives of inhabitants.

Useful Factors for Evaluation

1) Probability of landslide is high in areas having steep hills of soft soil with high porosity.
2) Careful attention should be paid if villages exist in the vicinity.
3) Careful attention should be paid in areas having intense rain in a short time period.

Measures

1) Alternate route selection
2) Adequate drainage work
3) Protection of the slopes
4) Monitoring and maintenance system

Related Subjects for Study

1) Topographical and geological surveys
2) Meteorological study
3) Case study of past natural disasters

2.5.2 Natural environmental components

Item: 1. Topography and Geology

Description:

Change of valuable topography and geology by excavation and land reclamation

Causes of Impacts

1) Cut and fill, and excavation of underground for road construction

Possible Environmental Impacts

1) Topography and geology would be altered by cut and fill. It may bring about landslides or soil erosion.

Useful Factors for Evaluation

1) Careful attention should be paid in the following types of areas:
   a) Areas which have important topography and/or geology,
   b) Areas of steep hills of soft soil with high porosity,
   c) Areas which have rainfall of high intensity
2) Urban areas have little concern with this problem.

Measures

1) Alternate route selection
2) Examination of the construction method
3) Restriction of land use in the vicinity

Related Subjects for Study

1) Topographical and geological survey
2) Landslide sites
3) Land use

Item: 2. Soil Erosion

Description:

Topsoil erosion by rainfall after land reclamation or vegetation removal

Causes of Impacts

1) Exposure of topsoil caused by land reclamation or removal of vegetation for road construction
2) Rainfall and flood during construction

Possible Environmental Impacts

1) Loss of topsoil by surface runoff or wind may affect growth of plants and animals, agriculture and forestry.
2) Sediment would create water turbidity and affect aquatic life and river discharge in downstream areas.

Useful Factors for Evaluation

1) Probability is high under the following conditions:
    a) Steep topography with sandy soil.
    b) Heavy or intense rainfall, or strong wind.
    c) Scarce vegetation coverage

Measures

1) Protection against soil erosion, e.g., vegetation cover, slope protection
2) Alternate route selection
3) Examination of construction method and schedule

Related Subjects for Study

1) Soil, topographical and geological surveys
2) Meteorological study
3) Land use

Item: 3. Groundwater

Description:

Change of the distribution of groundwater by large-scaled excavation

Cause of Impacts

1) Disruption of groundwater flow by large-scale excavation or tunnel construction which would alter the distribution of groundwater and bring about turbidity of groundwater
2) Decrease of groundwater recharge function due to change of outflow rate by clear cutting of vegetation
3) Extraction of a large quantity of groundwater because of an increased water demand for the

Possible Environmental Impacts

1) Lowering of the groundwater level and the exhaustion of wells which may affect the groundwater use in the project site
2) Land degradation on alluvial or clayey soil layer due to the lowering of the groundwater level
3) Water pollution during the construction and saltwater intrusion in the coastal areas, which would deteriorate the water quality and affect the water use

Useful Factors for Evaluation

1) Shallow wells, which use unconfined groundwater, are susceptible to the impacts.
2) Particular attention should be paid if the groundwater level has a tendency to decline or land degradation has already progressed in the area.
3) Careful attention should be paid to saltwater intrusion when the project site is located near the sea.

Measures

1) Alternate route selection
2) Use of construction methods adopting conservation measures of groundwater
3) Development of alternative water source

Related Subjects for Study

1) Hydrogeological survey, e.g., determination of aquifer
2) Pumping tests
3) Water use

Item: 4. Hydrological Situation

Description:
Change of river discharge and riverbed condition due to the inflow of drainage or landfill

Causes of Impacts
1) Hydrological regime would be altered by the construction of structures, such as piers, when the route passes over lakes and rivers.

Possible Environmental Impacts
1) Alteration of riverbed would change the habitat condition of aquatic life and affect fishery.
2) Navigation and tourism may be affected by the change of water depth, flow and flow rate.

Useful Factors for Evaluation
1) Careful attention should be paid to the habitats of valuable aquatic life.
2) Particular attention is required if the communities in the area utilize the water for navigation, fishery and tourism.

Measures
1) Alternate route selection
2) Compensation for fishery

Related Subjects for Study
1) Aquatic life
2) Water use

Item: 5. Coastal zone

Description:
Coastal erosion and sedimentation due to landfill or change in marine condition

Causes of Impacts
1) Excavation and dredging for the construction of piers when the route passes through the coastal zone
2) Increase or decrease in sediment supply to the surrounding marine area owing to the change in tide

Possible Environmental Impacts

1) Damage to and loss of mangrove forests and/or coral reefs caused by altered coastal topography, coastal erosion and extinction of tideland due to the change of littoral drift, which would affect tourism and fishery
2) Impacts on natural environment, including an increase in risk of coastal disaster, resulting from the depression of the wave dissipation effect by natural coast

Useful Factors for Evaluation

Impact will be significant if the project site has:

1) Precious nature, such as mangrove forests and coral reefs,
2) Excellent fishing field and other business field,
3) Tourism utilizing the sea and the coast,
4) High risk of disaster, such as high tide.

Measures

1) Alternate route selection
2) Installation of wave dissipation revetment and breakwater
3) Artificial nourishment
4) Compensation for damage in fishery

Related Subjects for Study

1) Valuable natural environment, e.g., mangrove forests, coral reefs
2) Fishery and related industries
3) Industries which utilize the coastal zone

Item: 6. Fauna and Flora

Description:

Obstruction of breeding and extinction of species caused by change of habitat condition

Causes of Impacts

1) Removal of vegetation and extinction of habitats of animals due to the construction of roads and related facilities
2) Generation of exhaust gas and noise from running vehicles
3) Disruption of migratory routes and habitats of animals by the existence of roads and related facilities

Possible Environmental Impacts

1) A decrease in useful creatures for human activities or extinction of valuable species
2) Livelihood of people, including the hunting of animals and collection of forest products, would be threatened and the recreational value would be decreased.
3) Decrease of natural enemies and extinction of other species may result in an outbreak of other animals, pests and harmful insects.

Useful Factors for Evaluation

Particular attention should be paid in the case of following:

1) The site includes vulnerable ecosystem, such as primary forests, swamp and mangrove forests.
2) There are species peculiar to the region.
3) Many people make their living by hunting and use of animals.
4) There are endangered or rare species listed in the Red Data Books by the International Union for Conservation of Nature and Natural Resources (IUCN).
5) There are bilateral and multilateral conventions on wildlife.

Measures

1) Relocation of plants and animals
2) Sufficient compensation
3) Careful route selection
4) Careful construction designing
5) Protection measures for fauna and flora

Related Subjects for Study

1) Existing vegetation, topographical and geological survey
2) Distribution of animals
3) Affiliation of conventions concerning wildlife protection
4) Livelihood of inhabitants

Item: 7. Landscape

Description:

Change of topography and vegetation by land reclamation. Deterioration of aesthetic harmony by appearance of structures

Causes of Impacts

1) Change of topography and vegetation by construction, and appearance of roads and piers

Possible Environmental Impacts

1) Damage to the value of the scenery by the change of landscape, which may have cultural values or close relationship with the life of local people (e.g., religious importance)
2) Tourism and local people's life may be affected by the damage.

Useful Factors for Evaluation

1) Particular attention should be paid to the landscape that has cultural values from an international viewpoint
2) The particular meanings or roles of the landscape (religious object, tourist attraction, etc.) in the area should be studied.

Measures

1) Reexamination of the project contents
2) Landscape architecture

Related Subjects for Study

1) Folklore
2) Livelihoods of the inhabitants
3) Tourism

2.5.3 Environmental Pollution

Item: 1. Air Pollution

Description:
Pollution caused by exhaust gas and toxic gas from vehicles and factories

Causes of Impacts

1) Exhaust gas from construction equipment and vehicles, and dust generated by earthwork
2) Exhaust gas from running vehicles

Possible Environmental Impacts

1) Exhaust gas and dust would affect the health of people, plants and animals along the route.
2) If the amount of the exhaust gas is enormous, nitrogen oxides and sulfur oxides may contribute to acid rain, and carbon dioxide to the global warming.

Useful Factors for Evaluation

1) If houses are densely built in the area, the impact will be larger.
2) If dry and wet seasons are separated, the impact will be greater during the dry season.
3) If the number of vehicles increases significantly, special attention should be paid.
4) If the gradient of slope is large, the concentration of exhaust gas from running vehicles will be higher.

Measures

1) Dust prevention by sprinkling water or chemicals during construction
2) Alternate route selection
3) Reexamination of construction methods

Related Subjects for Study

1) Urban planning and regional planning
2) Distribution of public facilities
3) Distribution of fauna and flora
4) Air quality standard and regulations on emission of pollutants

Item: 2. Water Pollution

Description:
Pollution by inflow of silt, sand and effluent into rivers and groundwater

Causes of Impacts

1) Disturbance of sediments by construction of piers when the route passes over lakes, stream and rivers
2) Erosion caused by the change of vegetation and topography
3) Use of herbicides to the roadbed; flush out of dust and oil on the road surface during rain

Possible Environmental Impacts

1) Effect on aquatic life by water pollution or turbid water
2) Contamination of water by herbicides would affect the aquatic life and the health of inhabitants who use the water.

Useful Factors for Evaluation

1) Careful consideration should be given when habitants or businesses in the downstream area use the water.
2) Particular attention should be paid if important aquatic species exist.

Measures

1) Careful construction planning and management
2) Compensation to the people and business concerning the water use
3) Creation of habitats for valuable aquatic species
4) Study on maintenance methods, such as clearing grass without herbicides

Related Subjects for Study

1) Water use and watershed use industries
2) Valuable aquatic species

Item: 3. Soil Contamination

Description:

Contamination of soil by dust and chemicals, such as herbicides

Causes of Impacts

1) Dispersion of paving materials, such as asphalt emulsion, during construction
2) Spreading herbicides for maintenance
3) Exhaust gases and dusts from running vehicles

Possible Environmental Impacts

1) Enlargement of the impacts through such a process that heavy metals in dust and chemicals in herbicides accumulated in soil are absorbed in plants under a certain condition, and leak out into water system
2) Effects on vegetation by contaminated soil with paving materials
3) Health hazards to the inhabitants who use the groundwater, which is contaminated through penetration

Useful Factors for Evaluation

Careful consideration is required in the following cases:

1) There is arable land along the route.
2) There are sources of drinking water in the vicinity.
3) Groundwater is utilized in the area.

Measures

1) Careful construction planning and management
2) Roadbed maintenance without herbicides

3) Restriction on land use in the proximity

Related Subjects for Study

1) Land use
2) Water use

Item: 4. Noise and Vibration

Description:

Noise and vibration generated by vehicles

Causes of Impacts

1) Operation of construction equipment and vehicles for construction and detonations
2) Operation of vehicles

Possible Environmental Impacts

1) Effect on hospitals and schools by noise, and the disturbance of sleep by vehicles operating at night, especially in urban areas
2) Obstruction of breeding of cattle and dispersion of wildlife
3) Cracks in buildings on soft ground caused by vibration

Useful Factors for Evaluation

Impact would be significant under the following conditions:

1) There are facilities, which require calm circumstance, or densely populated areas.
2) There is important cattle industry.
3) There are habitats of valuable wildlife.
4) There is weak ground such as filled land or clayey soil layer.

Measures

1) Reexamination of the project contents
2) Use of low noise and vibration construction equipment
3) Careful construction planning and maintenance considering time and period of the work
4) Installation of acoustic walls and buffer zone
5) Compensation for damage to livestock

Related Subjects for Study

1) Geological survey
2) Land use, distribution of inhabitants and public facilities, living condition of inhabitants

3) Habitats of valuable wildlife

2.6 Screening

2.6.1 Basic Concept of screening

Basically screening is the first judgement in the process of environmental consideration and should commence at the initial stage of the project, such as project finding. Through the screening process, the evaluation of whether or not the IEE/Preliminary Environmental Impact Assessment (Pre-EIA) is required for a project should be based on appropriate ideas and views for harmonizing the sustainable development with the residents' livelihood and surrounding environment by taking into consideration the project features and its environment, but not on the quantitative standards.

2.6.2 Screening Methods

(1) Outline

As for the procedures for screening, it describes the following cross-sectional viewpoints:

a) Can the project adversely affect the sustainability of production which depends mainly on natural resources?
b) Will the project significantly affect people's health?
c) Will the project lead to a deterioration or loss of valuable living resources and their habitats ?
d) Will the project have an unreasonable impact on the livelihoods and subsistence of the people concerned ?

Based on the above viewpoints, the screening method should be examined in detail. If there are laws or regulations concerning the environmental impact assessment for the project, it is necessary to discuss to make better environment considerations in accordance with the laws and regulations by referring to the guidelines.

On the other hand, if there are no such laws or regulations, it may be possible to formulate a standard with respect to the project scale and the land-use conditions for evaluating whether the development project requires an environmental impact assessment or not.

It is considered to be more effective, therefore, to formulate certain ideas and viewpoints with qualitative expressions for evaluating screening.

(2) Screening of Road and Bridge Projects

Based on the above consideration, the following concepts are established in the preliminary environmental survey:

a) The development project should be planned in such a way as to provide society with sufficient benefits while securing the areas' sustainable development and growth without being detrimental to the lives and existence of the residents.

b) The development project should be planned in such a way as to maintain harmony with the natural environment, while avoiding significant damage to the existing environment, and preserve valuable natural environmental assets.

The examination of screening should be conducted from practical viewpoints for each environmental item based on the above concepts. The results of the examination should be clarified by using the screening format as shown in Table 2.3 and should be included in the preparatory study report.

The evaluation result of each environmental item should be noted on the format whether or not environmental impacts exist. As the overall evaluation, the conclusion and the reason for evaluating whether or not EEE/Pre-EIA is required should be described briefly on the format.

The guidelines should be applied for all environmental impacts that may be caused by the project implementation not only in the project area but also in any area that may be directly or indirectly affected during the construction and after the operation of project facilities.

Table 2.3 Format for Screening

Project No. and Name: Location: Region: Province

No.	Environmental component	Identification of activities	Description of activities	IEE evaluation	Remarks (Reason)
Socio economic Environment					
1	Land and Property	Land aquisition Resettlement	Transfer of right of land ownership compensation Transfer of rights of residence / compensation	Yes or No Yes or No	
2	Economic	Economic activities	Loss of basis of economic activities, such as land, and change of economic structure	Yes or No	
		Employment	Increase or decrease of employment opportunity	Yes or No	
3	Traffic and Public facilities	Traffic	Impact on present traffic conditions, increase of traffic congestion	Yes or No	
		Public facilities	Impacts on schools, hospitals caused by increase of traffic volume	Yes or No	
4	Communities	Disintegration of communities	Community split due to interruption of area traffic	Yes or No	
5	Amenity	Amenities	Increase or loss of existing amenities	Yes or No	
6	Historical and Cultural	Historical assets	Damage or loss of the value of historic or archaeological remains	Yes or No	
		Cultural properties	Damage or loss of the value of cultural assets	Yes or No	
7	Vested rights	Water rights and rights of common	Obstruction of fishing rights, water rights, or other rights of common	Yes or No	
8	Waste	Waste	Generation of construction and demolition debris	Yes or No	
9	Hazards	Risk and damage	Risk of accidents, traffic damage	Yes or No	
Natural Environment					
10	Land	Topographic feature /river bank and bed	Changes of valuable topographic land form condition	Yes or No	
		Geological condition	Changes of geological condition	Yes or No	
		Land use	Change of original land use	Yes or No	
		Soil erosion	Topsoil erosion by rainfall after earth work and vegetation removal	Yes or No	
11	Surface water	Hydrological feature	Changes of flow variation	Yes or No	
		Water use	Change of existing water use	Yes or No	
		Water quality	Change of water quality	Yes or No	
		Floating debris	Floating obstacles	Yes or No	
		Flood affection	Flood affected area	Yes or No	
12	Species and their population, habitat	Terrestrial vegetation /flora	Obstruction of valuable species and their community, habitat	Yes or No	
		Terrestrial wildlife /fauna	Obstruction of breeding and extinction of species, communities, habitat	Yes or No	
		Aquatic flora	Obstruction of valuable species	Yes or No	
		Aquatic fish fauna	Obstruction of breeding and extinction of species, communities , habitat	Yes or No	
13	Aesthetics	Landscape	Changes of topography and vegetation due to reclamation. Deterioration of aesthetic harmony by structure	Yes or No	
Pollution					
15	Atmosphere	Air pollution	Pollution caused by exhaust gas or toxic gas from vehicles	Yes or No	
16	Water	Water pollution	Pollution by inflow of silt, sand and effluent into rivers	Yes or No	
17	Noise and vibration	Noise and vibration	Generation by construction machinery and traffic vehicles	Yes or No	
Overall evaluation			Is Preliminary EIA necessary for the project implementation?	Need of Pre-EIA?	