2.3 Physical Conditions and Engineering Survey

2.3.1 Topographic Survey

(1) Topography of the Study Area

The valley between Kratie and the mouth of the Mekong River, with a length of about 520 km, is called the Lower Mekong Basin or the Mekong Delta. Phnom Penh and its surroundings, located at some 300 km from the mouth of the Mekong River, is the area called the Four Faces where the Mekong River meets the Tonle Sap River and separates to the Tonle Bassak River. In the rainy season, the water level of the Mekong River rises to approximately 10 m in height. As a result, the water of the Mekong River pours into the Tonle Sap Lake through the Tonle Sap River. In the dry season, the water of the Tonle Sap Lake drains into the Mekong River through the Tonle Sap River. The floodwater, accordingly, shows complex movements in Phnom Penh and its surrounding area.

Along the channels of the Mekong River and the Tonle Bassak River, natural levees are distributed on both banks of those rivers. These natural levees, of which the height ranges from 6 to 8 m above sea level, are not flooded during the rainy season. A vast back marsh, at its height of 2 to 4 m, expands east and west outside of the natural levees. And in these back marshes, there are various permanent lakes along the old river channels. In parallel with the back marshes, there are wide flood plains at a height of 4 to 6 m. Most of plains are flooded in the rainy season and are not flooded in the dry season.

Lands near study area are dominantly use for agriculture and residential area expand along the national road No.1 and No.11. Elevation of the national road No.1 is around 8.5 m above MSL on the west bank and approximately 8.8 m above MSL on the east bank. Elevation of residential area where reclaimed from flood field is 6 to7 m approximately.

(2) Topographic Survey

The topographic survey was carried out in two survey stages comprised of five work items. The survey quantity and the scale of drawings being produced for each work item are shown in Table 2.3.1.

Table 2.3.1 Survey Quantity and Scale of Drawings

Work Items		Survey Quantity	Scale of Drawings
Topographic Survey			
	Centerline Survey	5.529 km	Included in Plan Survey
	Profile Survey	5.529 km	Horizontal; 1/2000, Vertical; 1/200
	Cross Section Survey	10.7 km	1/200
	Plan Survey	0.823 sq.km	1/2,000
Bathymetric Survey			
	River Cross Section Survey	11 cross sections	1/200

(3) Survey Issues

The topographic survey was implemented from the middle of May 2005 to the end of August 2005. All the field works were completed before the water level of the Mekong River started to rise.

During the implementation of the survey, the locals of Otdam Village of Preak Khsay Ka Commune informed the survey team that there were some unexploded ordnances (UXOs) at the survey area. The UXOs were left after the civil war (from 1979 to 1983) between the Khmer Rouge and the Vietnamese troops in the study area. During the fight, two arsenals which were located around Sta. 2+600 and Sta. 3+300 at the survey area were bombed and bombshells were scattered at surrounding areas.

Benchmarks and station pegs as the control points along the route will be installed prior to the implementation of topographic survey including Global Positioning System (GPS) survey. UXOs were searched at survey area from Sta. 2+600 to Sta. 3+700 by using UXO Detector prior to the survey.

(4) Method of Topographic Survey

1) Geodesic Datum and Mean Sea Level (MSL)

The following geodesic data was applied for the topographic survey.

- Geodesic Datum : WGS 84 (World Geodesic System 1984)
- Ellipsoid : GRS 80 (Geodesic Reference System 1980)
- Semi-Major Axis : a = 6378137.000 m
- Reciprocal Flattening : 1/f = 298.257222101

MSL of Ha Tien in Viet Nam was used for the topographic survey.

2) Reference Points for Coordinate and Elevation

Reference point for coordinate (Point ID No. 1401) which is maintained by the Geographic Department of the Ministry of Urban Planning and Land Management was set up in Peam Mo District Office in Prey Veng Province. The properties of the reference point are as follows:

- Latitude : 11° 19′ 04.208012″
- Longitude : 105° 16′ 51.764925″
- Height (reference only) : 6.3834 m above MSL

Reference point for elevation which is used to observe the water level of the Mekong River is located at Neak Loeung Hydrology Station. The height of the reference point is 7.592 m above sea level (refer to Photograph 2.3.1).

3) GPS and Traverse Survey

Before starting the GPS survey and traverse survey, seven concrete station pegs for control points were installed in the ground and the coordinates were measured by GPS (refer to Photograph 2.3.2). In addition, 9 concrete station pegs for Temporary Control Points were installed and they were measured by the Total Station.

Coordinates of the Control Points were converted from the geodesic coordinates to Universal Transverse Mercator (UTM) Zone 48. UTM was converted into the local plane coordinates in order to use the Total Station. Coordinates and elevation of the Control Points and Temporary Control Points were measured by traverse survey using Total Station and Auto Level.

Source: Photo by JICA Study Team

Photograph 2.3.1
Reference Point for Elevation

Photograph 2.3.2
Station Peg

4) Centerline Survey

Bamboo pegs were installed at every 50 m and each turning point for the centerline survey along the road alignment. All of coordinates of pegs along the centerline were measured by the Total Stations.

5) Profile Survey

Every ground level at changing points of the geographical features and land uses were measured by the profile survey. The elevation of bamboo pegs which were installed every 50 m along the centerline were also measured. Total Station and Auto Level were used for profile survey.

6) Cross Section Survey

Cross sections were set with right angles to the center lines at the 50 m intervals on the centerline. Grand heights at 50 m width along the cross sections from the both side of centerline were measured by the same method of profile survey.

7) Plan Survey

The plan survey was carried out to measure the coordinates and the ground height of such land features as pond, building, house, road, channel, river, grave and so forth within 50 m from the centerline on both sides.

8) Bathymetric Survey

The bathymetric survey consists of the river cross section survey and mapping. The river cross survey was carried out at the main stream of the Mekong River referring to the coordinates of Control Points installed for the topographic survey.

The range for river cross section survey was 250 m each to the upstream and downstream parallel to the centerline of project route and at an interval of 50 m, 11 sections in total. Coordinates of the survey points were measured GPS along each river cross section every 50 m. The depth of the riverbed was measured using a 20 kg steel weight attached to 30 m string.

2.3.2 Soil and Geotechnical Survey

(1) Outline of Geomorphological and Geological Condition

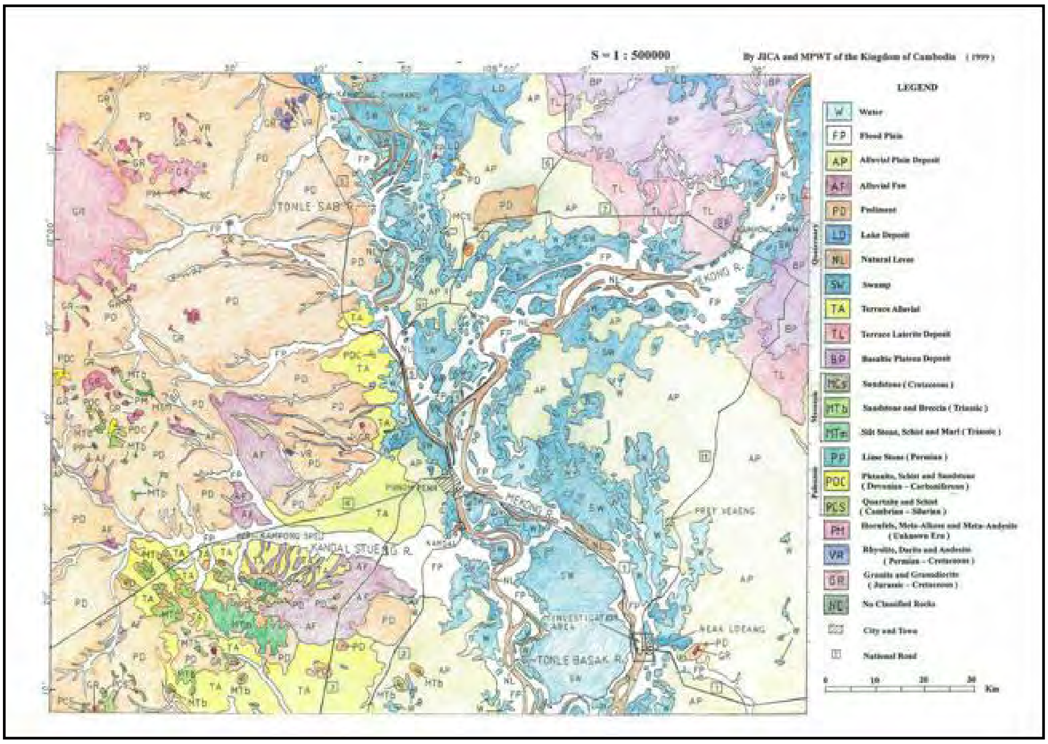
1) General Geomorphology

Along the Tonle Bassak River, a network of irrigation canals, so called Colmatage, was constructed in historical ages. At both banks of these canals, the floodwater forms sedimentation of fertile soil. Till now, four large modern Colmatages were constructed between Phnom Penh and Neak Loeung. These Colmatages drain the water of the Mekong River with fertile soil into the Tonle Bassak River in the rainy season.

Outside of the back marshes and flood plains, 8 to 10 m high alluvial plains, including peneplains, expand in all directions. These alluvial plains are not flooded in the rainy season except the lowland along the small river channels. On these alluvial plains, 20 to 50 m high-eroded hills are scattered. They are covered with thick residual soil. At the west bank of the Tonle Bassak River, low mountains 200 to 500 m in height spread north and south.

These mountains are distributed about 150 km from Phnom Penh to the Vietnam border. They consist of wide pediments and are covered with thick residual soil. Alluvial terraces and alluvial fans are distributed widely along the mountains.

The total length of the route, including the approach road and bridge structure, are 5.4 km and 1.6 km respectively. The approach road the right bank of Mekong River which is about 700 m in length crosses two natural levees which are each 100 m in width. The old river channel which is 4 km in length and from 100 to 200 m in width is distributed from the south to the north along the Mekong River. The old river channel is closed by soil deposits at the upstream and the downstream. At present, the old river channel is used for dry field. There is a sub-river channel which is 150-250 m in width and 4 km in length in the western part of bridge planed. This channel is shallow and passable in dry season. Also, there is an extensive sand bar between sub-river channel and main channel of Mekong River. It has maximum width of 800 m and length of 4 km in the island. In the main channel of Mekong River, maximum depth in the rainy season is about 30 m and width is about 600 m. Small-scale erosion is founded in left bank. A natural levee of about 100 m in width is distributed in the south north in left bank along the main channel. The flood plains and the back marsh are distributed outside of natural levees. After the bridge route crosses a natural levee and the flood plains, approach road in the east side (total length 3.1 km) runs through the back marsh to the south north by the length of about 2 km. Geomorphological and geological map of Phnom Penh is illustrated in Figure 2.3.1.



Source: MPWT

Figure 2.3.1 Geomorphological and Geological Map of Phnom Penh

2) Geological Conditions

The basement rocks of Mekong Delta areas consist of metamorphic rock, sandstone and limestone of the Paleozoic. These basement rocks are covered with conglomerate, sandstone and mud stone of the Mesozoic. These formations are distributed in mountain areas located in the west banks of the Tonle Sap River and the Bassac River. Also, these formations are penetrated through by volcanic rocks such as rhyolite, dacite and andesites of the Paleozoic or the Mesozoic and igneous rocks like granites of the Mesozoic. Among these rocks, granites are distributed most widely and are found in mountains of the west bank of the Tonle Sap River. Granites are formed the pediment in theses areas. Very wide basaltic plateau of the Tertiary and the Quaternary is located in the northeastern region. At the front of basaltic plateau, wide terraces of laterite are found.

In the study areas, alluvial and diluvial deposits of the Quaternary are widely distributed. The Quaternary deposits consist of unconsolidated sandy soil and clayey soil and are founded on natural levees, flood plains and marsh areas. Thickness of Quaternary deposit in downstream of Lower Mekong Basin of Mekong Delta is estimated about 200 meters. According to soil investigation in Phnom Penh City, the thicknesses of alluvial and diluvial deposit are from 40 to 50 meters and from 150 to 160 meters respectively.

(2) Geological Survey

1) Soil Boring

Geological Survey including soil boring and laboratory test were carried out in the study area. Survey item and quantity of soil boring are shown in Table 2.3.2

Table 2.3.2 Summary of Drilling Work

Item	First Stage (2004)	Second Stage (2005)	Total
Number of boreholes (location)	5	3	8
Total of drilling length (m)	212	160	372
Standard Penetration Test (time)	212	160	372
Un-disturbed sample (sample)	10	4	14

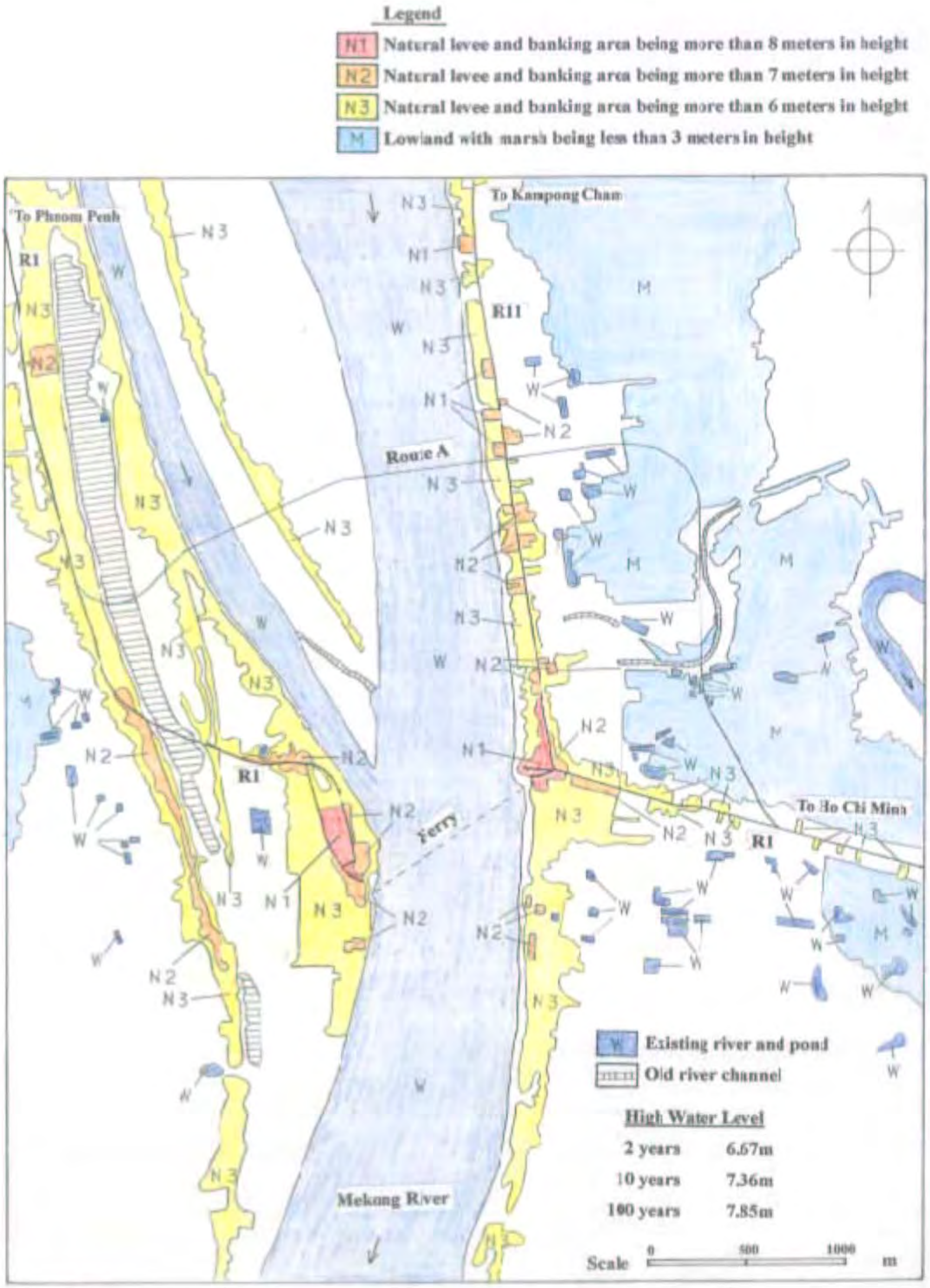
The location map and boring logs are shown in Appendix 2.3.

2) Ground Conditions

According to soil exploration, the formation is divided into 2 layers which are alluvial and diluvial deposits. Soil profile of study area is shown in Figure2.3.2. The thickness of alluvial formations in proposed bridge route is 40 m in right bank, and 15 to 20 m in left bank. Right bank is too thick as compared with left bank. This formation consists of sandy soils (AS) in right bank and cohesive soils including organic soils (AC) in left bank. This difference originates in the geomorphic surface where a lower diluvium is plateau on the left bank side and valley on the right bank. Namely, course sand has deposited on the right bank which is valley because the velocity of flood flow is high. Contrary to this, silt and the clay of fine grain have deposited because it is low on the plateau.

Among the alluvial formations, clay which is the latest deposit is distributed in both side of Mekong River. The thicknesses of alluvial formations in right and left bank are approximately 5 m and 20 m respectively. These cohesive soils are soft layers and average of “N value” (Standard Penetration Test) is 4-5. Especially, the proposed approach road passes on poor ground in the back marsh in left bank about 2 km or more. Furthermore, the thickness of organic clay or peat may be distributed. Alluvial gravel (AG) as basal gravels are distributed in the bottom of alluvial formation and the boundary layer between alluvial formations and diluvial formation are formed the surface of unconformity.

The upper of diluvial formations are mainly cohesive soils (DC). Thicknesses of these soils are 20 m in right bank and from 20 to 40 m in right bank. This formation is hard clay and average of “N value” is more than 20. Diluvial sand layer (DS) is distributed below DC. DS are divided into 2 layers that are the upper sand layer (DS1) and lower sand layer (DS2). DS1 that is 1 to 5 m in thickness is consolidated; however, it is weathered partially. DS2 is consolidated and “N-value” is more than 50. This formation is steady and is the optimum bearing stratum for bridge foundations. DS2 layer is in the depth of about 60 m from the ground.



Source: Prepared by JICA Study Team

Figure 2.3.2 Geomorphological Map of the Study Area

3) Soil Conditions

The geological profile is constructed based on five drilling logs surveyed in 2004 and three drilling logs in 2005. Also, geological formations in the study area are classified into 15 formations, based on the geological profile.

Standard penetration test was carried out on 182 samples at three locations along the optimum route of the study road: NBHNo.6, NBHNo.7 and NBHNo.8. N value of each geological formation is tabulated in Table 2.1.3. N values of more than 50 and penetrations of less than 30 cm are shown as conversion N values to 30 cm in length.

Banking Soil (BS) shows low N value because it consists of soft sandy silt. Alluvial Hard Clay (ACH) shows very high N value since it contains iron oxide. Alluvial Clay (AC 1 and AC 2) shows low N value. Organic Clay (AO 1 and AO2) shows high N value, because it contains a small quantity of organic material or peat in the form of the thin layer or dot. N values of Alluvial Sand (AS) increase by depth. The upper part of Alluvial Sand (AS) in 5 m thickness shows low N value because of the weathered sand. Alluvial Gravel (AG) shows high N value. Diluvial Clay (DC 1 and DC 2) shows high N value compared with Alluvial Clay. Some of this clay is weathered and its strength is not homogeneous. Diluvial Gravel (DG 1 and DG 2) shows low N value because of soft matrix except DG 2 at NBHNo.6. Diluvial Clay (DC 3) shows high N value because of the existence of consolidated clay. Diluvial Sand 1 (DS 1) shows high N value except some weathered sand. N values of Diluvial Sand 2 (DS 2) consistently show 50 or more. This sand is the densest consolidated sand amongst all formations. The soil characteristics of each layer are shown in Table 2.3.3.

Table 2.3.3 Soil Characteristics of Each Layer

Classification			Characteristics			Standard Penetration Test (N-Value)		
	Symbol	layer	Color	Thickness	Consistency	Max	Min	Av.
Alluvial Formations	BS	Banking Soil (Silt)	Dark brown-Liver	2-3m	Soft	4	2	3
	ACH	Alluvial Hard Clay	Dark Brown	5-6m	Stiff -Hard	18	11	15
	AC1	Alluvial Clay 1	Dark brown-Grayish Brown	3-7m	Soft-Medium- Stiff	10	2	4
	AO1	Organic Clay 1	Dark brown-Grayish brown	3-5m	Soft-Medium	8	3	5
	AC2	Alluvial Clay 2	Yellowish grey-Yellowish liver	2-15m	Very soft-Soft- Medium - Stiff	10	0	4
	AO2	Organic Clay 2	Dark yellowish brown-Gray	2-3m	Very soft-Soft- Medium	7	0	5
	AS	Alluvial Sand	Dark gray	10-40m	Loose- Medium dense- Dense- Very dense	41	6	19
	AG	Alluvial Gravel	Yellowish brown	2-2.5m	Dense-Very dense	60	26	44
Diluvial Formation	DC1	Diluvial Clay 1	Yellowish brown	10-18m	Medium- Stiff- Hard-Very hard	36	7	16
	DG1	Diluvial Gravel 1	Brown	2m	Dense	30	22	26
	DC2	Diluvial Clay 2	Yellowish brown-Brown	5-8m	Medium- Stiff- Hard-Very hard	32	8	22
	DG2	Diluvial Gravel 2	Yellowish brown	2-3m	Dense- very dense	45	28	28
	DC3	Diluvial Clay 3	Brown- Yellowish brown	10-11m	Hard- Very hard	86	16	39
	DS1	Diluvial Sand 1	Yellowish brown	1-5m	Dense- Very dense	56	18	33
	DS2	Diluvial Sand 2	Bluish brown	>13m	Very dense	106	62	77

Note: SPT numbers over 50 are Conversion N Value to 30 cm in length for the standard of penetration test. Results of Soil data and description are in Appendix 2.3.
Source: Prepared by JICA Study Team

(3) Results of Laboratory Test

1) Number of test items and Standard

Test items, quantities and standards are shown in Table 2.3.4

Table 2.3.4 Laboratory Test Results

Test Item	First Stage (2004)	Second Stage (2005)	Total	Standard
Water content (piece)	33	34	67	ASTM D2216
Specific Gravity (piece)	33	34	67	AASHTO T100
Liquid Limited (piece)	33	34	67	ASTM D4318
Plastic limited (piece)	33	34	67	ASTM D4318
Unit Weight (piece)	33	34	67	AASHTO T265
Grain Size Analysis(piece)	33	34	67	AASHTO T27/T88
Unconfined Compressive Test (piece)	9	6	15	AASHTO T208
Consolidation Test (piece)	10	6	16	ASTM D2216

Note: AASHTO: American Association of State Highway and Transportation Officials, ASTM: American Society for Testing and Material
Source: JICA Study Team

2) Physical Characteristic of Soil

Physical Characteristic of each layers are shown in Table 2.3.5

Table 2.3.5 Physical Characteristic of Each Layer

Layer	Specific Gravity	Water Content (%)	Grain Size Analysis					Atterberg's Limits			Unit Weight (t/m^3)
			Clay (%)	Silt (%)	Sand (%)	Gravel (%)	Classifi-cation*	LL (%)	PL (%)	Ip	
BS	2.686	28.74	50.09	43.52	6.39	0.00	CL	35.68	18.86	16.82	1.826
ACH	2.682	25.07	76.82	20.60	2.43	0.15	CL~CH	46.14	19.91	26.23	2.024
AC1	2.617	37.88	66.50	31.92	1.58	0.00	ML~CH	43.50	22.05	21.45	1.765
AO1	2.617	72.39	70.29	27.18	2.52	0.01	OH~OL	45.08	23.26	21.82	1.512
AC2	2.594	45.75	55.38	40.81	3.72	0.09	CL~ML	39.37	22.13	17.24	1.693
AO2	(2.600)	(70.00)	-	-	-	-	(OH~OL)	(45.00)	(23.00)	(22.00)	(1.500)
AS	2.625	31.27	15.16	21.37	63.46	0.01	SM	-	-	-	1.826
AG	(2.800)	(20.00)	-	-	-	-	(GM)	-	-	-	(2.100)
DC1	2.666	25.52	58.71	30.20	10.53	0.56	CL	34.60	17.13	17.47	1.983
DG1	2.698	29.24	-	-	-	-	(GM)	-	-	-	1.968
DC2	2.643	21.40	47.43	24.70	26.04	2.13	CL	30.25	15.54	15.01	2.018
DG2	(2.800)	(20.00)	-	-	-	-	(GM)	-	-	-	(2.000)
DC3	2.636	18.43	44.70	29.19	24.06	2.05	CL~ML	33.27	14.32	18.95	2.083
DS1	2.669	19.49	12.00	21.50	56.19	0.31	SM	21.92	14.52	7.4	2.033
DS2	(2.700)	(20.00)	-	-	-	-	(SM)	-	-	-	(2.100)

Note: All value is average, ( ):Estimated, Classification, *: Unified soil classification, Ip: plastic index (LL-PL)
Source: JICA Study Team

3) Dynamic Characteristics of Soil

Dynamic laboratory tests were carried out by using the undisturbed samples. Results of unconfined compressive test and consolidation test are shown in Table 2.3.6

Table 2.3.6 Dynamic Characteristics of Soil

Layer	qu (kgf/cm^2)	C (kgf/cm^2)	mv (m^2/MN)	Cv (m^2/s)	Cc
ACH	0.91	0.46	0.136	9.83×10^{-8}	0.320
ACH	0.87	0.44	0.102	1.99×10^{-7}	0.320
AC1	0.63	0.32	0.805	5.07×10^{-7}	0.621
AC1	1.24	0.62	0.150	8.28×10^{-8}	0.128
AO1	0.72	0.36	0.245	3.45×10^{-8}	0.649
AO1	0.86	0.43	0.183	1.81×10^{-7}	0.188
AO1	0.46	0.23	0.225	7.71×10^{-7}	0.214
AC2	0.53	0.27	0.213	4.07×10^{-8}	0.407

Note: qu: Unconfined compressive strength, C: Cohesion(=1/2・qu), mv: Coefficient of volume, Cv: Coefficient of consolidation, Cc: Coefficient of compressibility

Source: JICA Study Team

4) Soil Constants for Design

Based on the soil exploration, soil constants for design are shown in Table2.3.7

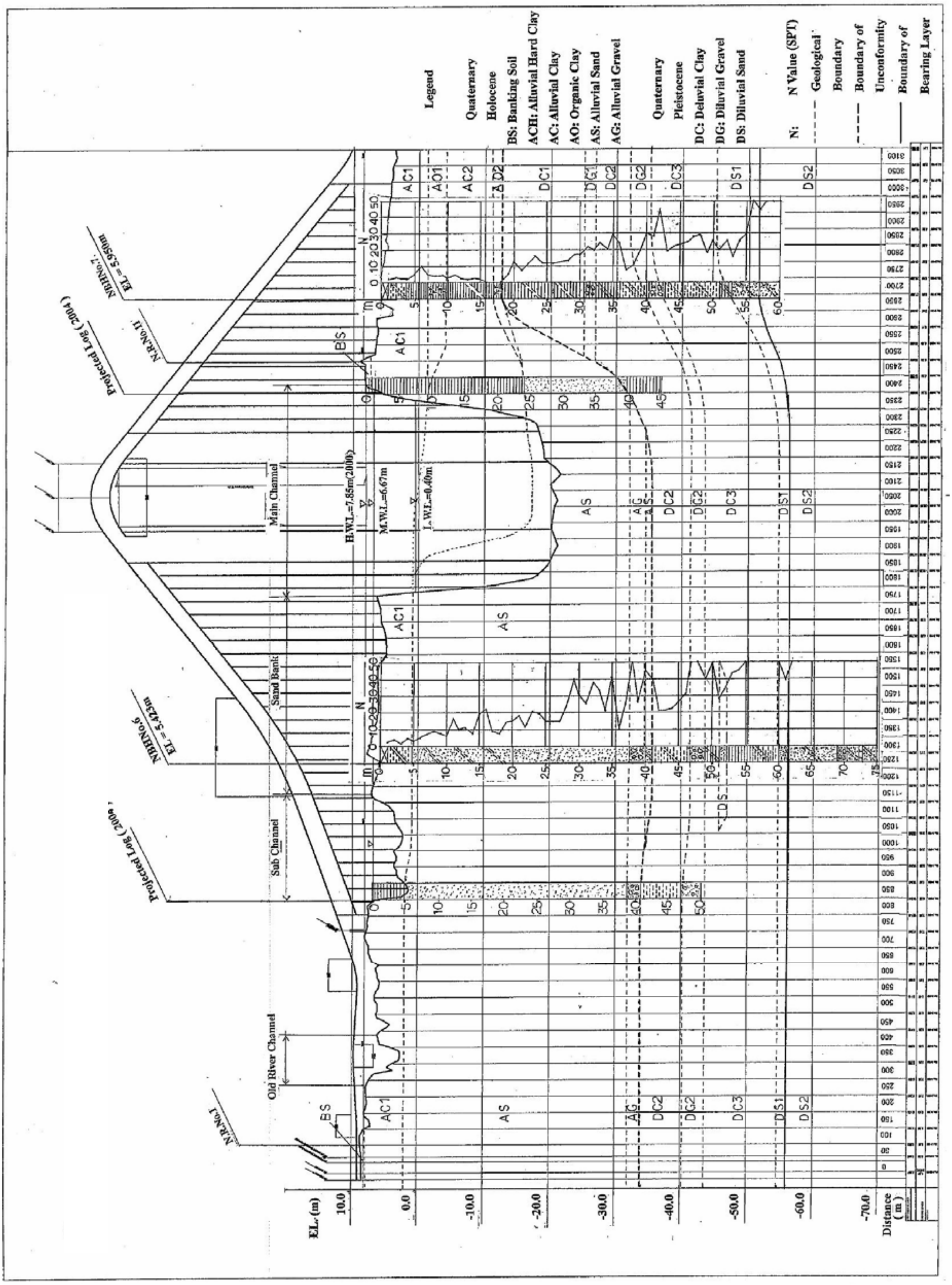
Table 2.3.7 Soil Constants for Design

	Symbol	layer	N-Value	Unit Weight (t/m^3)	Cohesion ($C:kgf/cm^2$)	Angle of Internal Friction (ϕ °)
Alluvial Formations	BS	Banking Soil (Silt)	3	1.826	0.2	0
	ACH	Alluvial Hard Clay	15	2.024	0.45	0
	AC1	Alluvial Clay 1	4	1.765	0.32	0
	AO1	Organic Clay 1	5	1.512	0.34	0
	AC2	Alluvial Clay 2	4	1.693	0.27	0
	AO2	Organic Clay 2	5	(1.500)	0.33*	0
	AS	Alluvial Sand	19	1.826	0	32**
	AG	Alluvial Gravel	44	(2.100)	0	41**
Diluvial Formation	DC1	Diluvial Clay 1	16	1.983	1.07*	0
	DG1	Diluvial Gravel 1	26	1.968	0	35**
	DC2	Diluvial Clay 2	22	2.018	1.47*	0
	DG2	Diluvial Gravel 2	28	(2.000)	0	36**
	DC3	Diluvial Clay 3	39	2.083	2.6*	0
	DS1	Diluvial Sand 1	33	2.033	0	37**
	DS2	Diluvial Sand 2	77*	(2.100)	0	45**

Note: ( ) : Estimated, *: Estimated by C=N・1/15, (ϕ =0), ** : Estimated by $\varphi=\sqrt{15N}+15$ (N>5, $\phi \leqq 45$, C=0)

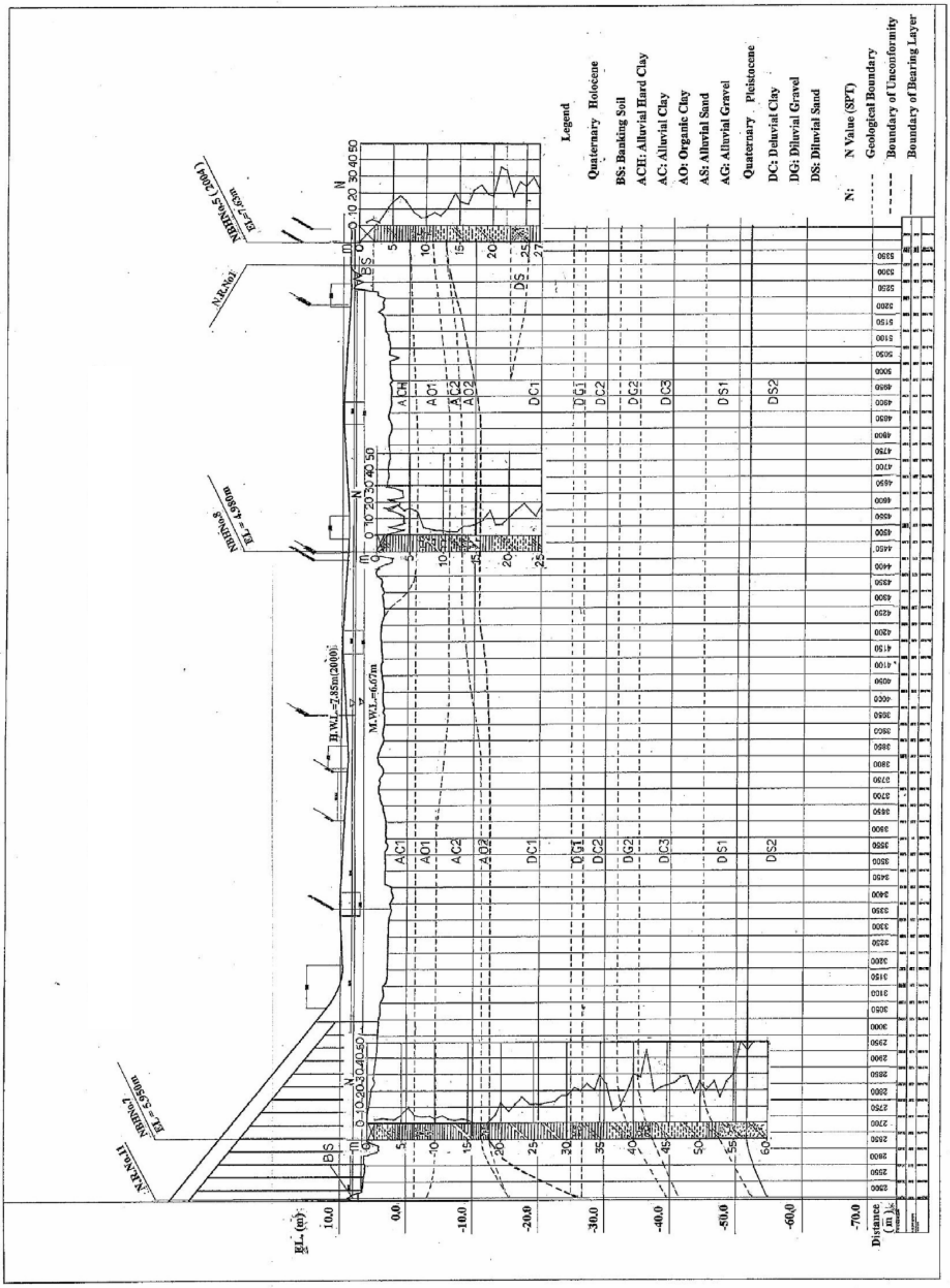
Source : JICA Study Team

Summary of laboratory test are shown in Appendix 2.3.



Source: JICA Study Team

Figure 2.3.3 (1) Geological Profile along the Optimum Route



Source: JICA Study Team

Figure 2.3.3 (2) Geological Profile along the Optimum Route

(4) Recommended Additional Survey and Laboratory Tests

Geotechnical issues at the study area are summarized as follows:

1) Further Drilling Works

Drilling surveys at the sandbank in the river and the west bank were carried out in this feasibility study. However, at the basic design stage, further drilling works should be carried out at the proposed location of the substructures of the bridge.

The approach road passes over the old river channel of 150 m on the right bank. Along this old river channel, the thick soft layer is expected to spread. Further drilling works, accordingly, should be carried out along this soft layer. Furthermore, on the west bank the approach road passes over the back marsh of 2 km. The back marsh consists of soft alluvial clay and organic clay. Drilling works, accordingly, should be carried out to obtain an accurate distribution of the soft layers.

2) Analysis of Consolidation Settlement for Embankment.

The consolidation settlement is a critical issue for the embankment work. The laboratory test should be appropriately designed and carried out to study the soft layer samples.

3) Study for Embankment Material.

A small hill with height of 150 m is located 10 km away from the study area. This small hill consists of granites and grano-diorite of the Mesozoic. At present, fresh hard rocks are utilized as a quarry and weathered rocks and their residual soils are utilized as a borrow pit. These materials are suitable for aggregates and embankment materials. Accordingly, the laboratory tests are required including CBR test for these materials.

4) Issues Relating to Dispersive Clay.

Dispersive clay, mainly alluvial clay, consists of the flood deposit and is found in most parts of the Lower Mekong Basin. Also, it is practically utilized for embankment soil. However, it causes piping or slope failure on the embankment. Inside of the dispersive clay, clayey material dissolves in pure water or rainwater without chloride. As a result, it causes piping in the soil. It is, accordingly, essential to distinguish dispersive clay from non-dispersive clay by chemical analysis (dispersive clay contains a considerable amount of sodium ions). Recently the Bureau of Reclamation in United States (USBR) has finalized a laboratory test manual for dispersive clay. So, the laboratory tests for materials should be carried out based on this manual.

2.3.3 Hydraulic Conditions

(1) General Features of the Mekong River

The Mekong River, the longest river in South-East Asia with a length of about 4,200 km, originates in the Chinese Tibetan plateau and flows through six countries in Asia, including China, Myanmar, Thailand, Lao PDR, Cambodia and Vietnam, and then flows into the South China Sea at the south eastern tip of the Indochina peninsula.

The Mekong River enters the lowland in Cambodia and flows into the Mekong flood plain from downstream of the Kampong Chum extending 60 km wide between Phnom Penh and Neak Loeung. Directly after the confluence with the Tonle Sap River, the Main River divides into the Bassac River and Mekong River for its outflow to the sea through Mekong Delta. The Tonle Sap River reverses direction into the Tonle Sap Lake during the flood season. The Tonle Sap Lake which extends over 300 km from Phnom Phen behaves as a natural reservoir for Southern Cambodia and Vietnam Delta by decreasing the flood peak during the flood season and increasing low water flows in the dry season.

A catchment area of the Mekong River is 795,000 km^2. Of this area, upstream of Phnom Penh is 663,000 km^2, and the area of the Mekong River Basin (20% of the whole catchments area) in Cambodia is 155,000 km^2 which is composed of the Mekong River Main Stream Basin (61,337 km^2), the Sap River Basin including the Great Lake or the Tonle Sap Lake (79,310 km^2) and the Bassac River Basin (14,248 km^2).

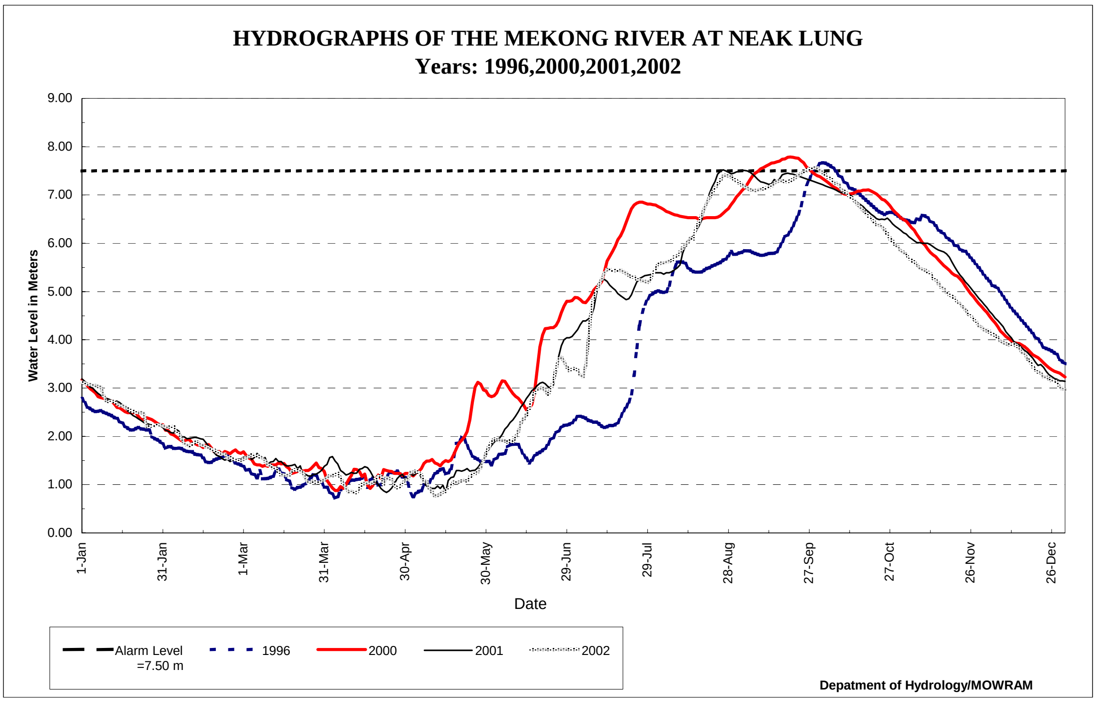
(2) Water Level of Mekong River

1) Monthly Variation of Water Level

Lowest water level of the Mekong River starts at the end of the dry season around April and continues to June. Water level goes up gradually when the rainy season begins and it reaches maximum high-water level around August or September.

The variation of monthly mean water level changes greatly in each year. Especially at the time when a water level begins to rise in the beginning of rainy season, in June or July the difference between monthly average maximum water level and that of the minimum water level is larger than other months.

At Neak Loeung Station, the range of the highest water level is 6 to 8 m above MSL. The high water level of more than 7 m continues for about two months from mid August to mid October, while the lowest water level less than 1 m above MSL continues for three months from March to May. The Hydrograph of Mekong River at Neak Loeung from 1996 to 2006 is shown in Figure 2.3.4.



Source: Department of Hydrology, MOWRAM

Figure 2.3.4 Hydrographs of Mekong River at Neak Loeung (1996 to 2003)

2) Historical Water Level

Table 2.3.8 shows historical annual maximum water level and annual minimum water level at Kampong Cham, Chruoy Changvar and Neak Loeung.

The tendency of the water level at Chruoy Changvar and Neak Loeung is parallel so that their high water level matches each other. However, the high water level at Kampong Cham shows some different data compared with other locations.

Table 2.3.8 Maximum Water Surface Level of 1996, 2000, 2001 and 2002 Floods

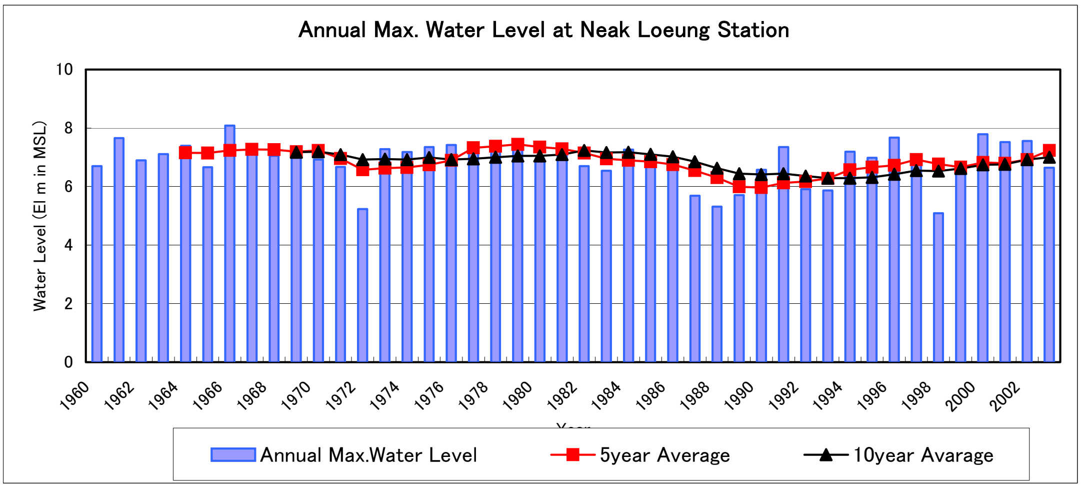
(Unit: El. meters in MSL)

Flood	Neak Loeung St.	Chruoy Changvar St.	Kampong Cham St.
1996 Flood	7.67	9.92	**15.18**
2000 Flood	**7.79**	**10.13**	14.98
2001 Flood	7.52	9.69	15.16
2002 Flood	7.56	9.82	14.98

Source: Prepared by JICA Study Team

3) Long Term Tendency of Water Level

Based on the annual maximum water level data at Neak Loeung Gauge Station from 1960 to 2003, the historical annual maximum water levels in these 43 years are plotted as shown in Figure 2.3.5.

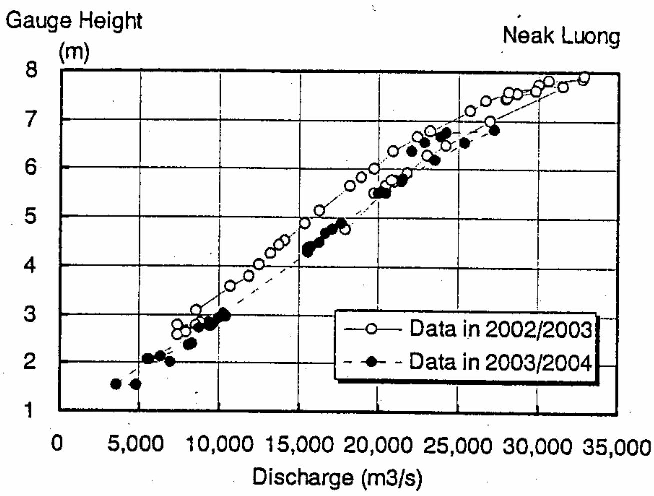


Source: Prepared by JICA Study Team

Figure 2.3.5 Annual Maximum Water Level at Neak Loeung (1960 to 2001)

(3) Discharge

Discharges at Neak Loeung gauge station are shown Figure 2.3.6. Maximum discharge at the flood time is 33,000 m^3/sec with about 8 m above MSL and minimum discharge in the dry season is 3000 m^3/sec.

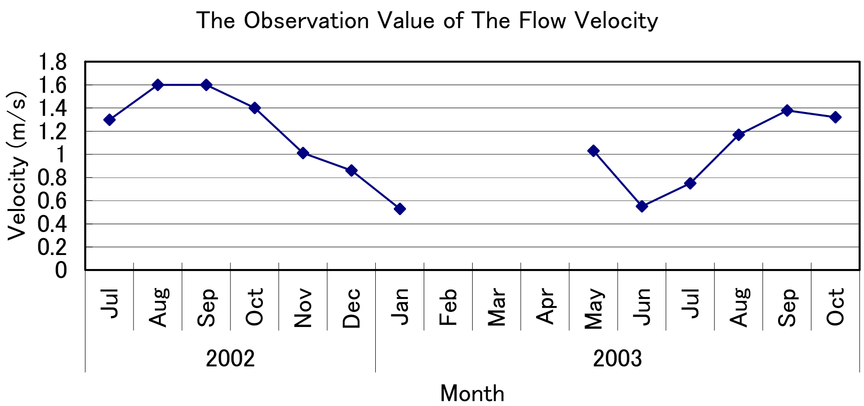


Source: The Study on Hydro-meteorological Monitoring for Water Quantity Rules in Mekong River Basin

Figure 2.3.6 Discharge at Neak Loeung Station

(4) Flow Velocity

Average flow velocity in Mekong River is shown in Figure 2.3.7. Maximum flow velocity at the flood time is 1.6 m/sec and minimum flow velocity is 0.5 m/sec.



Source: The Study on Hydro-meteorological Monitoring for Water Quantity Rules in Mekong River Basin

Figure 2.3.7 Flow Velocity at Neak Loeung Station

(5) Characteristics of Past Floods

The flood situations in recent years are as follows:

- The flood event of the 2002 monsoon season was very similar to that encountered in the previous three years.
- According to the 2002 image record, the extent of the flooded areas started to increase gradually from July to September.

- The peak flood conditions were recorded over most of the study area on September 20, 2002. Then the flood range became smaller gradually up to January, 2003.
- In terms of flood extent and severity of flood damage, 1999 is considered an average year. In contrast, the 2000 floods resulted in extreme inundation of the floodplains of the Mekong, Bassac and Tonle Sap rivers. During that year, the entire country experienced more rainfall than normal.
- In 2001, the study area again experienced extreme inundation, and with peak in flooding conditions during the month of September. Comparing RADARSAT-1 image analysis results for the peak floods in 1999, 2000 and 2002, the peak flood for 2001 was the most extensive.
- The largest total inundated area of all flooding zones occurred during the 2001 peak period and covered over 1.5 million ha of land. The peak flood of 2002 was the second largest in recent years in terms of the percentage of flooded areas (affecting 1.2 million ha of land).

Landsat Image at the time of the flood in 2000 is shown in Appendix 2.3.

(6) Hydrodynamic Simulation of Mekong River

1) Objective and Software

In order to evaluate the effect of constrictions on river and flood plain flow due to bridge piers and approach road, detailed hydrodynamic simulations of the Mekong River and its tributary in the floodplain between Phnom Penh and Neak Loeung and its downstream have been carried out. Danish Hydraulic Institute (DHI)'s unsteady non-uniform river flow software MIKE 11 has been used for hydrodynamic simulations. MIKE 11 applies implicit finite difference numerical scheme to solve St.Venant's fully dynamic wave equations.

2) Simulation Cases

Case I

The hydrodynamic model based on the September 2000 flood has been calibrated as Case I. The model network has been set up using existing river and flood plain conditions and hydraulic structures and the runoff and boundary conditions for 2000 flood have been applied.

Case II

This case simulates flow condition when the National Road 1 (NR1) running in parallel with the Mekong river from Phnom Penh to Neak Loeung will be improved. This case is an update to Case I where planned or improved hydraulic structures or openings along NR1 have been used.

Case III

This case simulates flow condition with an assumption that alternative Route A of the 2nd Mekong Bridge will be constructed. This case uses set up of Case II plus cross-sections at Route A and approach road on flood plain of the left bank of Mekong river.

Table 2.3.9 presents a list of the model cases and their characteristic features.

Table 2.3.9 Hydrodynamic Simulation Cases

<table>
<tr><th rowspan="2">Simulation Case</th><th colspan="2">Model network and Boundary Condition</th><th colspan="2">Change in Cross section Due to</th></tr>
<tr><th>Base Model Set Up</th><th>Opening Along NR1</th><th>Bridge</th><th>Approach Road</th></tr>
<tr><td>Case I</td><td rowspan="3">Existing river and flood plain cross sections, existing hydraulic structures, runoff and boundary conditions corresponding to September 2000 flood.</td><td>Same as Year 2000</td><td rowspan="2">None</td><td rowspan="2">None</td></tr>
<tr><td>Case II</td><td rowspan="2">Planned or improved hydraulic structures or openings along N.R.1</td></tr>
<tr><td>Case III</td><td>Route A</td><td>Route A</td></tr>
</table>

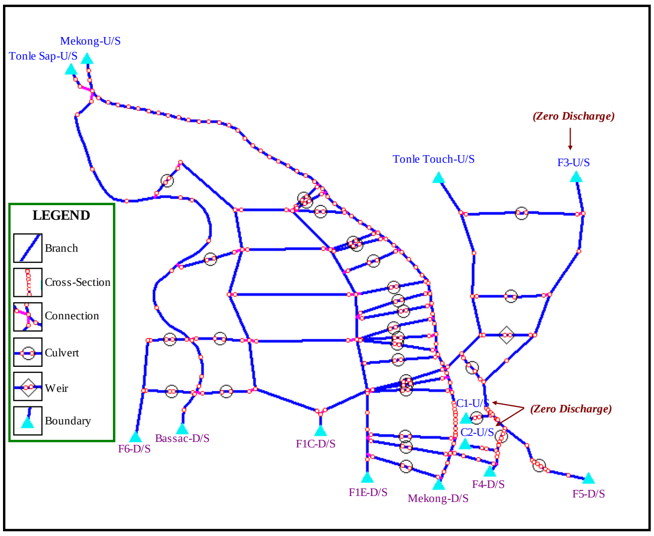
Source: Prepared by JICA Study Team

3) Model Development

a. Simulation Network

Simulation network varies slightly from case to case. Figure 2.3.8 shows simulation networks for Cases III, the difference among the simulation cases are the openings along NR1, cross-sections of alternative route alignment including approach roads. Simulation model developed during this study is similar to the hydrodynamic model developed by the March 2003 JICA Study entitled: “The Feasibility Study on the Improvement of National Road No.1 (Phnom Penh – Neak Loeung Section) in the Kingdom of Cambodia”. The previous JICA model has been extended or updated as follows:

- The previous JICA model has been extended to more downstream of Neak Loeung as well to include the approach roads along flood plains. Additional cross-sections have been input at bridge locations.
- Cross-sections of flood plains around Neak Loeung have been updated based on topographic survey carried out during this study.
- Boundary conditions have updated based on rating curves developed by the March 2004 JICA Study entitled: “Development of Hydro-Hydraulic Model for the Cambodian Floodplains”.
- Culverts or openings along NR1 have been updated based on the October 2004 JICA Draft Report entitled: “Basic Design Study Report on the Project for the Improvement of National Road No. 1”.



Source: JICA Study Team

Figure 2.3.8 Hydrodynamic Simulation Network for Case III

b. Basic Element for the Model Network

The basic elements used to establish the simulation model network are:

- For branches consisting of river and flood plains and their connectivity, their cross-sections were used for defining branches. The river cross-sections were extracted from Ministry of Public Works and Transport's (MPWT) Waterways Department's June 1999 bathymetric survey book entitled: "Hydrographic Atlas, Mekong River in Cambodia". The floodplain cross-sections are the same as the March 2004 JICA Study with some additional cross-sections derived from topographic map of the 1960s and updated around Neak Loeung by utilizing topographic survey result of the present study. In MIKE 11, hydraulic properties of cross-sections at bridge locations have been used which would produce equivalent effect as the real bridge cross-section with piers.
- Hydraulic structures consisted of closed and open culverts and overflow weirs. Data on locations and sizes of existing culverts and weirs are the same as the March 2003 JICA Study Locations and sizes of the existing culverts along right bank of Mekong River downstream of Neak Loeung have been obtained from field survey.

c. Boundary Conditions

The same boundary conditions have been applied for all the cases. To establish the boundary conditions, discharge distribution of September 2000 flood as estimated by the March 2003 JICA Study have been basically conserved. Two types of boundary conditions have been applied as follows:

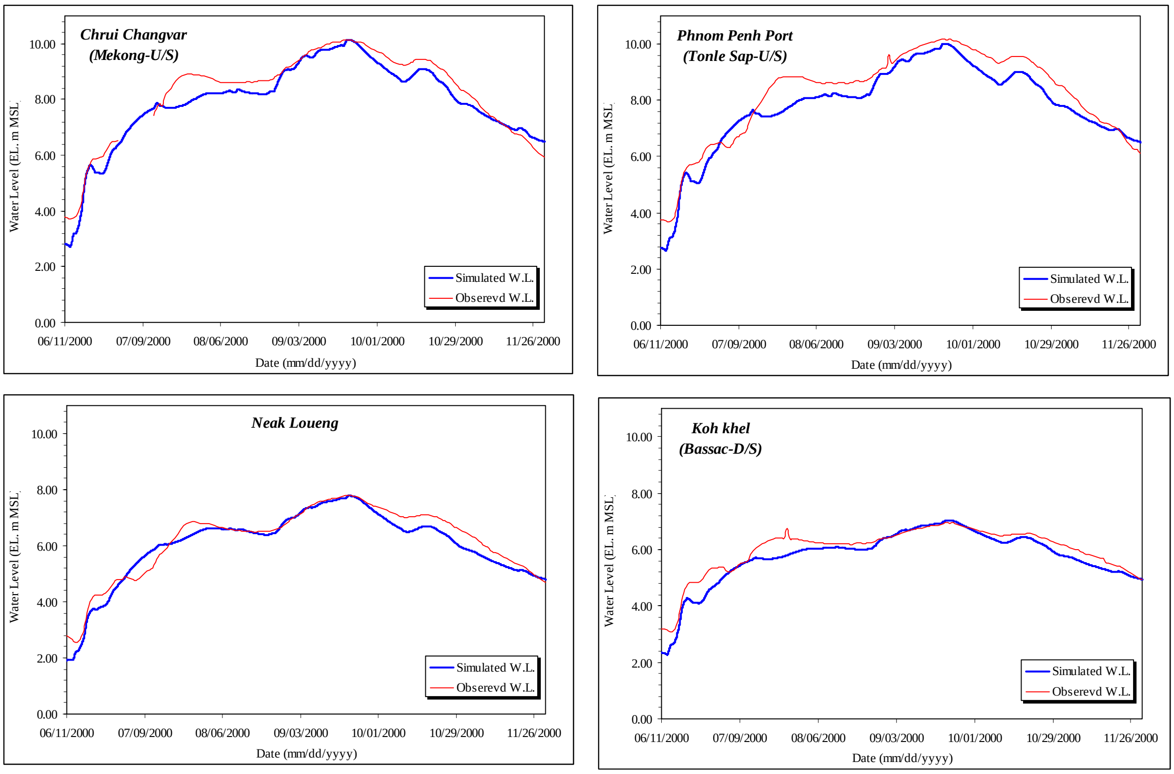
- Upstream (U/S) Boundary Condition: There are 6 upstream boundary conditions, three of which have zero discharge. The other three boundaries are: Mekong-U/S, Tonle Sap-U/S and Tonle Touch-U/S.
- Downstream (D/S) Boundary Condition: There are 7 downstream boundary conditions. which are: Mekong-D/S, Bassac-D/S, F6-D/S, F1C-D/S, F1E-D/S, F4-D/S and F5-D/S.

d. Hydraulic Parameters

- Manning's roughness coefficients of 0.03 for river and 0.10 for flood plain sections have been applied.
- Space step (dx) of 1000 m and time step (dt) of 20 minutes that produces stable results have been applied for all hydrodynamic simulations.

4) Model Calibration

The simulation model has been calibrated against September 2000 flood. Figure 2.3.9 shows the comparison between observed and simulated water levels at 4 selected locations: Chruoy Changvar, Phnom Penh Port, Neak Loeung and Koh Khel. It can be said that the developed simulation model has been calibrated to a satisfactory level.



Source: JICA Study Team

Figure 2.3.9 Simulated and Observed Water Levels at Selected Locations for 2000 Flood

5) Simulation Results

The findings for simulation case III are as follows:

1. Simulated maximum water levels at bridge locations is EL. 7.80 m.
2. Simulated maximum water levels along approach roads is EL. 8.23 m.
3. Simulated maximum velocity at bridge locations is 2.04 m/s.
4. Simulated maximum velocity along approach roads is 1.18 m/s.
5. In comparison with Case II, maximum rise in water levels due to construction of bridge at locations would be 7 cm upstream of bridge along Mekong River for Cases III.
6. In comparison with Case II, maximum rise in water levels due to construction of bridge at locations would be 4 cm along approach road for Cases III.

Table 2.3.10 presents the simulated maximum water levels and velocities at selected locations for different simulation cases.

Table 2.3.11 presents comparison among simulation cases for maximum changes in water levels.

Table 2.3.10 Simulated Maximum Water Levels and Velocities at Selected Locations

Model Output	Location	Distance from Chrui Changvar (m)	Simulation Case		
			Case I	Case II	Case III
Water Level (m MSL)	Chrui Changvar	0	10.13	10.10	10.13
	Bridge	54,650	7.85	7.79	7.80
	Neak Loeung	56,000	7.79	7.72	7.70
	Approach Road	-	8.21	8.19	8.23
Velocity (m/s)	Chrui Changvar	0	1.40	1.40	1.40
	Bridge	54,650	1.89	1.87	2.04
	Neak Loeung	56,000	1.80	1.78	1.77
	Approach Road	-	1.22	1.18	1.18
Discharge (m^3/s)	Neak Loeung	56,000	33,110	32,620	32,405

Source: JICA Study Team

Table 2.3.11 Comparison among Simulation cases for Maximum Change in water Level

Compared Cases		Maximum change in water level along Mekong River			Maximum Change in Water level along approach Road (cm)
Discussed Simulation Case	With reference to Simulation Case	Change (cm)	From Location	Up to Location	
Case II	Case I	-7.0	3 km u/s of Neak Loeung	16 km u/s of Neak Loeung	-2.0
Case III	Case II	7.0	0.40 km u/s at bridge	1.65 km u/s at bridge	4.0

Source: Prepared by JICA Study Team

2.4 Initial Environmental Examination (IEE)

2.4.1 Scoping and TOR for IEE Study

(1) Scoping for IEE Study

Initial environmental examination (hereinafter referred to as IEE) study is carried out in accordance with Cambodian EIA Law, JICA's new guidelines for environmental and social considerations, and relevant international EIA standards/guidelines. The main purpose of IEE study is to identify the potential impacts of the proposed projects at three different phases (i.e., pre-construction, construction, and operation phases). Several competent environmental agencies or organizations such as the Ministry of Environment (MOE) were consulted on the TOR development for IEE study at the initial stage of this study.

The JICA guidelines refer to a wide range of natural and social impacts covering 13 natural environmental items, including impacts on human health and safety, as well as 12 social environmental items. Tables 2.4.1 and 2.4.2 compare three cases of scoping range i) the full-coverage by the requirement of the JICA guidelines, ii) the preliminary scoping at the time of S/W mission in December 2003, and iii) the proposed scoping agreed among stakeholders in May 2004. Although some impacts to be assessed are deleted from the list in December 2003, the full-coverage of the impacts to be assessed stipulated by the guideline was proposed, taking into account whatever possible impacts might be provoked by the construction of the alternative crossing methods at Neak Loeung.

Table 2.4.1 Scoping for IEE-level Study on Natural Environment*

No.	Impacts to be Assessed	JICA Guidelines Requirement	Scoping at S/W Mission (December 2003)	Agreed Scoping at Kick-off Stakeholder Meeting (May 2004)
1	Air Quality	X	X	X
2	Water Quality (Surface/Subsurface Water and Groundwater)	X	X	X
3	Soil and Sedimentation Quality	X		X
4	Waste Disposal	X	X	X
5	Noise and Vibration	X	X	X
6	Subsidence	X		X
7	Bad Smells	X	X	X
8	Topography and Geology	X		X
9	River Bed Materials	X	X	X
10	Fauna and Flora	X	X	X
11	Use of Water Resources	X		X
12	Accidents	X	X	X
13	Greenhouse Effect Gas	X	X	X

Note: X means "applicable". *: Natural environment includes such elements as item No. 1, 2, 5, 12 and 13 that affect human health and safety.

Table 2.4.2 Scoping for IEE-level Study on Social Environment

No.	Impacts to be Assessed	JICA Guideline Requirement	Scoping at S/W Mission (December 2003)	Agreed Scoping at Kick-off Stakeholder Meeting (May 2004)
1	Migration of Populations Involuntary Resettlement	X	X	X
2	Impact on Local Economy (Employment, Livelihood, etc.)	X	X	X
3	Utilization of Land and Local Resources	X	X	X
4	Social Institutions (Social Capital and Local Decision-making institution)	X	X	X
5	Existing Social Infrastructure and Services	X	X	X
6	Vulnerable Social Groups	X		X
7	Equality of Benefits and Losses and Equality in Development process	X		X
8	Local Conflicts of Interests	X	X	X
9	Gender	X		X
10	Children's Rights	X		X
11	Cultural Heritage	X	X	X
12	Infectious Diseases (HIV/AIDS)	X	X	X

Note: X means "applicable".

(2) TOR for IEE Study

The objectives of IEE Study are to collect fundamental environmental information around the study area, and estimate potential environmental and social impacts to be caused by the proposed project. TOR for IEE study on natural and social environment was determined in accordance with the JICA guidelines and in consultation with stakeholders through a series of stakeholder meetings, and the impacts on the following 16 villages in 6 communes in the project affected area were assessed.

Table 2.4.3 Villages to be Assessed in IEE Studies

Province	District	Commune	Number of Villages
Kandal	Leuk Daek	Kampong Phnum	2
Kandal	Leuk Daek	Preak Tonloab	2
Prey Veaeng	Peam Ro	Preak Khsay Ka	2
Prey Veaeng	Peam Ro	Preak Khsay Kha	6
Prey Veaeng	Peam Ro	Neak Loeung	2
Prey Veaeng	Peam Ro	Banlich Prasat	2

Also, several remarks, suggestions or comments obtained through a series of discussion/or consultation processes with MOE, MRC, MAFF, MOWRM and other relevant agencies/or organizations were incorporated within this TOR development.

Based on the comprehensive literature reviews, which is explored in Chapter 6 of Interim Report of the Study, the collection of the up-to-date natural environmental information was carried out in order to describe the current existing natural environmental conditions around the study area and to qualitatively identify potential impacts to be caused by the proposed project. In the same manner, social environmental conditions around the study area of Neak Loeung were also profiled, and potential impacts on the social impacts were qualitatively and quantitatively identified. In addition, field surveys were conducted on demand.

Local fishery survey was conducted within this baseline environmental collection study in order to collect information of the current condition of the local fishery and the type of fishes caught around Neak Loeung, in particular, information about both Mekong Giant Catfish and Mekong Dolphin.

In addition, local flood damage survey was conducted in order to study loss/or damages caused by past major flood events around Neak Loeung, in particular, information about the property loss/or damages, evacuation places, evacuation periods, and difficulties people had to hold during past flood events.

2.4.2 Alternative Routes and Options Subject to IEE Study

Basically, there are three alternative routes for the bridge option, two for the ferry option, and three for ferry-bridge option. The optimum crossing plan was selected among those alternatives, reflecting several evaluation factors such as structural characteristics, social and environmental impacts, land acquisition and compensations, conformity with existing facilities, and so on. Here, based on the information of the current natural and social environment, the features for each plan are evaluated.

<u>I. Bridge Option</u>

The following three bridge route options were initially under consideration:

- Route A : About 1.6 km upstream side of the existing ferry line.
- Route B : About 1 km upstream side of the existing ferry line
- Route C : About 1 km downstream side of the existing ferry line.

In addition, following two more engineering options (i.e., ferry option, and ferry-bridge option, mentioned above) were also considered:

<u>II. Ferry Option</u>

1) Existing ferry with proper maintenance.
2) Improvement of the ferry transportation capacity/or service.

<u>III. Ferry - Bridge Option</u>

It should be noted that same computed regional traffic volumes of the future transport demand were used for each scenario (see the future transport demand forecast study section for more detailed descriptions).

Basically, Option I-1) is regarded as "Do Nothing" or "Zero" option. In Option I-2), new ferry is to be operated, and new pier, port facilities such as the parking lot and approach road are to be constructed. The approach road of Option I-2) is close to that of the Bridge Option C.

Under ferry-bridge scenarios, an additional ferry is to be temporally introduced to meet the increased traffic demands until the bridge construction is completed. In this scenario, neither new piers nor new port facilities are to be constructed, and the bridge operation schedule is the same as that of the bridge option, mentioned above. Basically, the same three bridge route options (i.e., Routes A, B and C) are considered within this ferry - bridge option.

Also, it should be noted that several floodplain areas, bounded by existing national roads 1, 11, 101 and the approach roads to be constructed within this proposed project, were treated as "flood-free zones" within this study, and relevant studies such as regional run-off study or the design of the drainage system were carried out within the feasibility study to be followed by other relevant separate studies in the future (see the engineering study section of this main report for more detailed descriptions).

2.4.3 Summary of Impacts on Natural Environment

IEE results of each engineering option for the construction and the operation phases are summarized in Tables 2.4.4-2.4.7. First of all, IEE study was carried out for three bridge options with different routes (see Tables 2.4.4 and 2.4.5). Then the second IEE study was carried out for entire engineering options including both ferry and ferry-bridge options, too (Tables 2.4.6 and 2.4.7).

The set of 13 key environmental evaluation factors such as the air quality and the water quality listed in these tables is based on the New JICA guideline for the environmental and social consideration (JICA, 2004) for the clarification.

As a result of the first IEE study (see Tables 2.4.4 and 2.4.5), IEE results of all three bridge route options seem to be same although several minor variations in the impact evaluation of those three exist. In other words, the significance of environmental impacts to be caused for each scenario is judged to be almost identical, but there are still slight variations in the evaluation results, mainly due to the difference of spatial scales such as the bridge span/or the total distance of the approach roads on both sides of the Mekong River. These minor variations of impacts for each bridge route option are expressed using additional symbol "+" in both Tables 2.4.6 and 2.4.7.

In the second IEE study that covers both ferry and ferry-bridge options, generic IEE results of all three bridge route options (i.e., the results of the first IEE study without the evaluation of minor variation, "+") are used for the simplification.

Based on the knowledge of the current natural environment of the study area, it was found that the following environmental factors would be important and critical in order to proceed the proposed bridge construction project.

During the construction period, it is expected to have several disturbances to the riverbed condition including benthos due to the bridge pier construction activities to be carried out inside the Mekong River. So, environmental impacts on the water quality of the Mekong River, local aquatic fauna and fishery around both Neak Loeung deep pool and riffle areas would be critical discussion points throughout the bio-physical environmental information-based IEE process (Note: According to current Cambodian fishery law, the project owner of any development project that would contain construction activities adjacent to/or inside of the major tributaries, navigational channel and floodplain area that are important for spawning/or breeding for migrating fishes must obtain the permission from the MAFF).

Also, inundation and subsidence issues related with the approach road construction would become the critical discussion points. Well-planned regional drainage program during the rain season shall be established before the construction will start. It is expected that large amounts of construction waste will be generated, so that it would be quite essential to prepare enough waste disposal sites with proper treatment methods. The roadside air quality and noise may be somewhat deteriorated due to the temporally increase of the local traffic volume (mainly, construction-related heavy vehicles).

After the bridge operation will start, most of critical environmental issues to arise during the construction period will be subdued/or disappear, but the following environmental impacts such as the subsidence around the approach roads on both sides and inundation issues would still be critical discussion points. Also, the erosion of the road bank to be caused by the wind-induced waves would not be negligible during the flood period. It is essential to prepare an appropriate road bank protection measures such as the implementation of proper roadside vegetation.

Similar environmental impacts identified within the IEE evaluation of the bridge option (except impacts to be caused by inside-river-related construction activities) would be caused at both construction/operation phases of the improved ferry option. Besides, impacts on the water quality in the operation phase of both ferry options would become critical discussion points to some extent.

More detailed descriptions of IEE evaluation process (Natural Environment) are attached in Appendix 2.4.

Table 2.4.4 IEE Study (Natural Environment: Bridge Option - Construction Phase)

	Bridge Option		
	A	B	C
1. Air quality			
Increased roadside air pollution.	C	C	C
2. Water Quality			
Risk of pollution to major tributaries.	A	A	A
3. Soil and sedimentation			
Potential for soil erosion (bridge).	B	B	B
Potential for soil erosion (approach road).	A++	A	A+
Disturbance to contaminated site.	U	U	U
Inland sedimentation change due to change of local flood flow pattern over floodplain.	B++	B	B+
4. Waste Disposal			
Generation of large amounts of construction wastes.	A	A	A
5. Noise/Vibration			
Increased roadside noise, dust and vibration	B	B	B
6. Subsidence			
Potential of large-scale consolidation and related topographical changes due to earthwork	A++	A	A+
7. Bad smell			
Potential of newly creation of bad smell due to long-term regional inundation & related biological decay of plants.	U	U	U
8. Topography and Geology			
Regional flood and inundation pattern change due to approach road construction.	B++	B	B+
Creation of new inundated area.	A++	A	A+
Potential of outbreak of water-borne disease (2^{nd} impact of inundation).	B	B	B
Potential of outbreak of mosquito-borne disease (2nd impact of inundation).	B	B	B
Enhanced river bank erosion/scouring .	C	C	C
Potential of seepage/erosion of approach road.	B	B	B
9. River bed (e.g., benthos)			
Disturbance to river bed condition (e.g., benthos).	A++	A+	A
10. Fauna/flora			
Destruction of riverside/floodplain vegetation.	B++	B	B+
Destruction of roadside vegetation.	C	C	C
Disturbance to bird habitats or floodplain habitats.	B++	B	B+
Disturbance to aquatic ecosystem/or habitats.	A++	A+	A
Reduced fish spawning and breeding area (bridge).	B++	B+	B
Reduced fish spawning and breeding area (approach roads).	B++	B	B+
11. Water Resources			
Water quality degradation.	B	B	B
Groundwater quality degradation.	C	C	C
Groundwater level drawdown.	D	D	D
Disturbance to regional groundwater flow.	D	D	D
12. Accidents			
Potential of increased traffic accidents.	B	B	B
Potential of increased vessel accidents(e.g., vessel collisions).	B	B	B
Potential of finding UXO.	U	U	U
13. Global warming (CO_2 emission)			
Increased CO_2 emission.	C	C	C

Note A: significant, B: major, C: minor, D: less significant, U: Unknown
"+" indicates slight difference in each scale of significance (i.e. A, B, C)

Table 2.4.5 IEE Study (Natural Environment: Bridge Option - Operation Phase)

	Bridge Option		
	A	B	C
1. Air quality			
Increased roadside air pollution.	C	C	C
2. Water Quality			
Risk of pollution to major tributaries.	D	D	D
3. Soil and sedimentation			
Potential for soil erosion (bridge).	B	B	B
Potential for soil erosion (approach road).	A++	A	A+
Disturbance to contaminated site.	D	D	D
Inland sedimentation change due to change of local flood flow pattern over floodplain.	B++	B	B+
4. Waste Disposal			
Generation of large amounts of construction wastes.	D	D	D
5. Noise/Vibration			
Increased roadside noise, dust and vibration	C	C	C
6. Subsidence			
Potential of large-scale consolidation and related topographical changes due to earthwork.	A++	A	A+
7. Bad smell			
Potential of newly creation of bad smell due to long-term regional inundation & related biological decay of plants.	U	U	U
8. Topography and Geology			
Regional flood and inundation pattern change due to approach road construction.	B++	B	B+
Creation of new inundated area.	A++	A	A+
Potential of outbreak of water-borne disease (2nd impact of inundation).	B	B	B
Potential of outbreak of mosquito-borne disease (2nd impact of inundation).	B	B	B
Enhanced river bank erosion/scouring.	C	C	C
Potential of seepage/erosion of approach road.	B	B	B
9. River bed (e.g., benthos)			
Disturbance to river bed condition (e.g., benthos).	D	D	D
10. Fauna/flora			
Destruction of riverside/floodplain vegetation.	D	D	D
Destruction of roadside vegetation.	D	D	D
Disturbance to bird habitats or floodplain habitats.	D	D	D
Disturbance to aquatic ecosystem/or habitats.	D	D	D
Reduced fish spawning and breeding area (bridge).	B++	B+	B
Reduced fish spawning and breeding area (approach roads).	B++	B	B+
11. Water Resources			
Water quality degradation.	D	D	D
Groundwater level drawdown.	D	D	D
Disturbance to regional groundwater flow.	D	D	D
12. Accidents			
Potential of increased traffic accidents.	B	B	B
Potential of increased vessel accidents (e.g., vessel collision).	B	B	B
Potential of finding UXO.	D	D	D
13. Global warming (CO_2 emission)			
Increased CO_2 emission.	C	C	C

Note A: significant, B: major, C: minor, D: less significant, U: Unknown
"+" indicates slight difference in each scale of significance (i.e. A, B, C)

Table 2.4.6 Natural Environment, ferry and ferry-bridge options included - Construction Phase

	I. Ferry		II. Bridge	III. Ferry& Bridge
	I-1	I-2		
1. Air quality				
Increased roadside air pollution	C	C	C	C
2. Water Quality				
Risk of pollution to major tributaries.	B	A	A	A
3. Soil and sedimentation				
Potential for soil erosion (bridge).	D	C	B	B
Potential for soil erosion (approach roads).	D	A	A	A
Disturbance to contaminated site.	D	U	U	U
Inland sedimentation change due to change of local flood flow pattern.	D	B	B	B
4. Waste Disposal				
Generation of large amounts of construction wastes.	D	B	A	A
5. Noise/Vibration				
Increased roadside noise, dust and vibration	C	B	B	B
6. Subsidence				
Potential of large-scale consolidation and related topographical changes due to earthwork.	D	C	A	A
7. Bad smell				
Potential of newly creation of bad smell due to long-term regional inundation & related biological decay of plants.	D	U	U	U
8. Topography and Geology				
Regional flood and inundation pattern change due to approach road construction.	D	C	B	B
Creation of new inundated area.	D	C	A	A
Potential of outbreak of water-borne disease (2nd impact of inundation).	D	C	B	B
Potential of outbreak of mosquito-borne disease (2nd impact of inundation).	D	C	B	B
Enhanced river bank erosion/ scouring.	D	D	C	C
Potential of seepage/erosion of approach road.	D	C	B	B
9. River bed (e.g., benthos)				
Disturbance to river bed condition (e.g., benthos).	D	C	A	A
10. Fauna/flora				
Destruction of riverside/floodplain vegetation.	D	C	B	B
Destruction of roadside vegetation.	D	C	C	C
Disturbance to bird habitats or floodplain habitats.	D	D	B	B
Disturbance to aquatic ecosystem/or habitats.	D	C	A	A
Reduced fish spawning and breeding area.	D	B	B	B
11. Water Resources				
Water quality degradation.	C	B	B	B
Groundwater quality degradation.	D	C	C	C
Groundwater level drawdown.	D	D	D	D
Disturbance to regional groundwater flow.	D	D	D	D
12. Accidents				
Potential of increased traffic accidents.	D	C	B	B
Potential of increased vessel accidents (e.g., vessel collision).	C	B	B	B
Potential of finding UXO.	D	U	U	U
13. Global warming (CO_2 emission)				
Increased CO_2 emission.	C	C	C	C

Note A: significant, B: major, C: minor, D: less significant, U: Unknown

Table 2.4.7 IEE Study (Natural Environment, ferry and ferry-bridge options included -Operation Phase)

	I. Ferry		II. Bridge	III. Ferry& Bridge
	I-1	I-2		
1. Air quality				
Increased roadside air pollution.	C	C	C	C
2. Water Quality				
Risk of pollution to major tributaries.	B	B	D	D
3. Soil and sedimentation				
Potential for soil erosion (bridge).	D	C	B	B
Potential for soil erosion (approach roads).	D	A	A	A
Disturbance to contaminated site.	D	D	D	D
Inland sedimentation change due to change of local flood flow pattern.	D	B	B	B
4. Waste Disposal				
Generation of large amounts of construction wastes.	D	D	D	D
5. Noise/Vibration				
Increased roadside noise, dust and vibration	C	B	C	C
6. Subsidence				
Potential of large-scale consolidation and related topographical changes due to earthwork.	D	C	A	A
7. Bad smell				
Potential of newly creation of bad smell due to long-term regional inundation & related biological decay of plants.	D	U	U	U
8. Topography and Geology				
Regional flood and inundation pattern change due to approach road construction.	D	C	B	B
Creation of new inundated area.	D	C	A	A
Potential of outbreak of water-borne disease (2nd impact of inundation).	D	C	B	B
Potential of outbreak of mosquito-borne disease (2nd impact of inundation).	D	C	B	B
Enhanced river bank erosion/ scouring.	D	D	C	C
Potential of seepage/erosion of approach road.	D	C	B	B
9. River bed (e.g., benthos)				
Disturbance to river bed condition (e.g., benthos).	D	D	D	D
10. Fauna/flora				
Destruction of riverside/floodplain vegetation.	D	D	D	D
Destruction of roadside vegetation.	D	D	D	D
Disturbance to bird habitats or floodplain habitats.	D	D	D	D
Disturbance to aquatic ecosystem/or habitats.	D	D	D	D
Reduced fish spawning and breeding area.	D	B	B	B
11. Water Resources				
Water quality degradation.	C	B	D	D
Groundwater quality degradation.	C	C	D	D
Groundwater level drawdown.	D	D	D	D
Disturbance to regional groundwater flow.	D	D	D	D
12. Accidents				
Potential of increased traffic accidents.	D	C	B	B
Potential of increased vessel accidents (e.g., vessel collision).	C	B	B	B
Potential of finding UXO.	D	D	D	D
13. Global warming (CO_2 emission)				
Increased CO_2 emission.	C	C	C	C

Note A: significant, B: major, C: minor, D: less significant, U: Unknown

2.4.4 Summary of Impacts on Social Environment

The IEE results of each engineering option for the construction and the operation phases are summarized in Tables 2.4.8-2.4.11. First of all, IEE study was carried out for three bridge route options (see Tables 2.4.8 and 2.4.9). Then the second IEE study was carried out for all engineering options including both ferry and ferry-bridge options, too (Tables 2.4.10 and 2.4.11).

The set of 12 key environmental evaluation factors listed in these tables is based on the New JICA guideline for the environmental and social consideration (JICA, 2004) for the clarification.

As a result of the first IEE study (see Tables 2.4.8 and 2.4.9), it can be seen that IEE results of all three bridge route options seem to be same although several minor variations in the impact evaluation of those three exist. In other words, the significance of environmental impacts to be caused for each scenario is judged to be almost identical, but there are still slight variations in the evaluation results, mainly due to the difference of spatial scales such as the bridge span/or the total distance of the approach roads on both sides of the Mekong River. These minor variations of impacts for each bridge route option are expressed using additional symbol "+" in both Tables 2.4.10 and 2.4.11.

In the second IEE study that covers both ferry and ferry-bridge options, generic IEE results of all three bridge route options (i.e., the results of the first IEE study without the evaluation of minor variation, "+") are used for simplification.

As a result of the IEE study on the social environment, it was revealed that there might have potential impacts on a wide range of the social environment during the construction phase as well as the operation phase of the bridge option (including the combined option) or the ferry improvement option with an additional pier.

The most significant social impact would be a considerable level of resettlements required for the construction of a bridge or an additional pier. The estimated number of PAHs (Project Affected Household) at the time of the IEE-level study ranges from 51 to 70, while that of PAPs (Project Affected Persons) ranges from 263 to 364. Another significant impacts would be loss of income and job opportunities of vendors, retailers and restaurants at the ferry terminals due to abolishment of ferry services.

In addition to these major impacts, other significant impacts are:

- That the prevalence rate of HIV/AIDS might increase due to the massive inflow of construction workers during the construction phase and the improved mobility of the epidemic through various mobile groups of people, being closely related to serious social threats to women and children.
- That the flood-free land will be created by spaces surrounded by National Road No.1, National Road No.11, and an approach road associated with the construction of a bridge or an additional pier and the flood-free land might bring about the economic disparity as well as land disputes in the project affected area.

It was strongly recommended that the full-scale EIA study be implemented for the agreed alternative option and route, taking the results of IEE study into account. It was also required to prepare the terms of reference for the full-scale EIA study for the smooth implementation of the feasibility study.

More detailed descriptions of IEE evaluation process (Social Environment) are attached in Appendix 2.4.

Table 2.4.8 IEE Study (Social Environment: Bridge Option - Construction Phase)

Potential Impacts	Bridge Option		
	A	B	C
1. Involuntary Resettlement			
Involuntary resettlement due to acquisition of land*	A	A++	A+
2. Impacts on Local Economy			
Decrease in sales of market, retailers and restaurants	D	D	D
Decrease in sales of vendors	D	D	D
Decrease in consumption and procurement by abolishment of Neak Loeung Ferry	D	D	D
Increase in sales by inflow of massive construction workers	P	P	P
3. Utilization of land and local resources			
Increase in land value by creation of flood-free land	B	C	C
Decrease in agricultural production by creation of flood-free land	C	C	C
Decrease in fishery production by creation of flood-free land	C	C	C
4. Social Infrastructure			
Improvement of accessibility to medial and educational services in urban areas	D	D	D
Aggravation of accessibility to medical and educational services in local areas	D	D	D
Improvement of accessibility to other social services in urban areas	D	D	D
Aggravation of accessibility to other social services in local areas	D	D	D
5. Existing Social Institution			
Division of communities and restriction of access inside communes and villages	D	D	D
Division of communities and restriction of access among communes and villages	D	D	D
6. Vulnerable Social Group			
Involuntary resettlement and loss of income of landless farmers	B	B	B
Involuntary resettlement and loss of income of female-headed households	B	B	B
Involuntary resettlement and loss of income of minority group	B	B	A
7. Equity of Benefits and losses			
Enlargement of disparity in income	D	D	D
Enlargement of disparity in assets	B	C	C
Enlargement of disparity in convenience to cross the river	D	D	D
Enlargement of disparity in accessibility	D	D	D
8. Conflicts of Interest			
Conflicts of interests stemming from land disputes	C	C	C
Conflicts of interests stemming from other economic reasons	C	C	C
Conflicts of interests stemming from other social reasons	C	C	C
9. Gender			
Aggravation of serious social problems such as human trafficking	C	C	C
Decrease in income and aggravation of livelihood of women	D	D	D
10. Children			
Aggravation of serious social problems such as human trafficking	C	C	C
Decrease in income and aggravation of livelihood of children	D	D	D
Children's detour in schooling	D	D	D
11. Cultural/Archaeological Heritage			
Resettlement of pagodas	D	D	D
Resettlement of other cultural/archaeological heritage	D	D	D
12. Infectious Diseases			
Increase in prevalence of HIV/AIDS stemming from massive inflow of construction workers	B	B	B
Increase in prevalence of HIV/AIDS stemming from improved mobility	D	D	D
Increase in prevalence of other infectious diseases	U	U	U

Note A: significant, B: major, C: minor, D: less significant, U: Unknown, P: Positive Impact, *: Impacts during Planning Phase, "+" indicates slight difference in each scale of significance (i.e. A, B, C)

Table 2.4.9 IEE Study (Social Environment: Bridge Option - Operation Phase)

Potential Impacts	Bridge Option		
	A	B	C
1. Involuntary Resettlement			
Involuntary resettlement due to acquisition of land*	D	D	D
2. Impacts on Local Economy			
Decrease in sales of market, retailers and restaurants	B	B	B
Decrease in sales of vendors	A	A	A
Decrease in consumption and procurement by abolishment of Neak Loeung Ferry	B	B	B
Increase in sales by inflow of massive construction workers	P	P	P
3. Utilization of land and local resources			
Increase in land value by creation of flood-free land	P	P	P
Decrease in agricultural production by creation of flood-free land	C	C	C
Decrease in fishery production by creation of flood-free land	C	C	C
4. Social Infrastructure			
Improvement of accessibility to medial and educational services in urban areas	P	P	P
Aggravation of accessibility to medical and educational services in local areas	D	D	D
Improvement of accessibility to other social services in urban areas	P	P	P
Aggravation of accessibility to other social services in local areas	D	D	D
5. Existing Social Institution			
Division of communities and restriction of access inside communes and villages	U	U	U
Division of communities and restriction of access among communes and villages	U	U	U
6. Vulnerable Social Group			
Involuntary resettlement and loss of income of landless farmers	D	D	D
Involuntary resettlement and loss of income of female-headed households	D	D	D
Involuntary resettlement and loss of income of minority group	D	D	D
7. Equity of Benefits and losses			
Enlargement of disparity in income	B++	B	B+
Enlargement of disparity in assets	B++	B	B+
Enlargement of disparity in convenience to cross the river	B	B	B
Enlargement of disparity in accessibility	C	C	C
8. Conflicts of Interest			
Conflicts of interests stemming from land disputes	B++	B	B+
Conflicts of interests stemming from other economic reasons	C	C	C
Conflicts of interests stemming from other social reasons	C	C	C
9. Gender			
Aggravation of serious social problems such as human trafficking	C	C	C
Decrease in income and aggravation of livelihood of women	B	B	B
10. Children			
Aggravation of serious social problems such as human trafficking	C	C	C
Decrease in income and aggravation of livelihood of children	B	B	B
Children's detour in schooling	U	U	U
11. Cultural/Archaeological Heritage			
Resettlement of pagodas	D	D	D
Resettlement of other cultural/archaeological heritage	D	D	D
12. Infectious Diseases			
Increase in prevalence of HIV/AIDS stemming from massive inflow of construction workers	B	B	B
Increase in prevalence of HIV/AIDS stemming from improved mobility	B	B	B
Increase in prevalence of other infectious diseases	U	U	U

Note A: significant, B: major, C: minor, D: less significant, U: Unknown, P: Positive Impact, *: Impacts during Planning Phase, "+" indicates slight difference in each scale of significance (i.e. A, B, C)

Table 2.4.10 Social Environment, ferry and ferry-bridge options included - Construction Phase

Potential Impacts	I. Ferry		II. Bridge	III. Ferry& Bridge
	I-1	I-2		
1. Involuntary Resettlement				
Involuntary resettlement due to acquisition of land*	D	A	A	A
2. Impacts on Local Economy				
Decrease in sales of market, retailers and restaurants	D	D	D	D
Decrease in sales of vendors	D	D	D	D
Decrease in consumption and procurement by abolishment of Neak Loeung Ferry	D	D	D	D
Increase in sales by inflow of massive construction workers	D	P	P	P
3. Utilization of land and local resources				
Increase in land value by creation of flood-free land	D	C	B	B
Decrease in agricultural production by creation of flood-free land	D	C	C	C
Decrease in fishery production by creation of flood-free land	D	C	C	C
4. Social Infrastructure				
Improvement of accessibility to medial and educational services	D	D	D	D
Aggravation of accessibility to medical and educational services	D	D	D	D
Improvement of accessibility to other social services	D	D	D	D
Aggravation of accessibility to other social services	D	D	D	D
5. Existing Social Institution				
Division of communities and restriction of access inside communes	D	D	D	D
Division of communities and restriction of access among communes	D	D	D	D
6. Vulnerable Social Group				
Involuntary resettlement and loss of income of landless farmers	D	B	B	B
Involuntary resettlement and loss of female-headed households	D	B	B	B
Involuntary resettlement and loss of minority group	D	B	B	B
7. Equity of Benefits and losses				
Enlargement of disparity in income	D	D	D	D
Enlargement of disparity in assets	D	C	B	B
Enlargement of disparity in convenience to cross the river	D	D	D	D
Enlargement of disparity in accessibility	D	D	D	D
8. Conflicts of Interest				
Conflicts of interests stemming from land disputes	D	D	C	C
Conflicts of interests stemming from other economic reasons	D	D	C	C
Conflicts of interests stemming from other social reasons	D	D	C	C
9. Gender				
Aggravation of serious social problems such as human trafficking	D	C	C	C
Decrease in income and aggravation of livelihood of women	D	D	D	D
10. Children				
Aggravation of serious social problems such as human trafficking	D	C	C	C
Decrease in income and aggravation of livelihood of children	D	D	D	D
Children's detour in schooling	D	D	D	D
11. Cultural/Archaeological Heritage				
Resettlement of pagodas	D	D	D	D
Resettlement of other cultural/archaeological heritage	D	D	D	D
12. Infectious Diseases				
Increase in prevalence of HIV/AIDS stemming from massive inflow of construction workers	D	B	B	B
Increase in prevalence of HIV/AIDS stemming from improved mobility	D	D	D	D
Increase in prevalence of other infectious diseases	D	U	U	U

Note A: significant, B: major, C: minor, D: less significant, U: Unknown, P: Positive Impact, *: Impacts during Planning Phase

Table 2.4.11 Social Environment, ferry and ferry-bridge options included - Operation Phase

Potential Impacts	I. Ferry		II. Bridge	III. Ferry& Bridge
	I-1	I-2		
1. Involuntary Resettlement				
Involuntary resettlement due to acquisition of land*	D	D	D	D
2. Impacts on Local Economy				
Decrease in sales of market, retailers and restaurants	D	D	B	B
Decrease in sales of vendors	D	D	B	B
Decrease in consumption and procurement by abolishment of Neak Loeung Ferry	D	D	B	B
Increase in sales by inflow of massive construction workers	D	D	D	D
3. Utilization of land and local resources				
Increase in land value by creation of flood-free land	D	C	B	B
Decrease in agricultural production by creation of flood-free land	D	C	C	C
Decrease in fishery production by creation of flood-free land	D	C	C	C
4. Social Infrastructure				
Improvement of accessibility to medial and educational services	D	P	P	P
Aggravation of accessibility to medical and educational services	D	D	D	D
Improvement of accessibility to other social services	D	P	P	P
Aggravation of accessibility to other social services	D	D	D	D
5. Existing Social Institution				
Division of communities and restriction of access inside communes	D	U	U	U
Division of communities and restriction of access among communes	D	U	U	U
6. Vulnerable Social Group				
Involuntary resettlement and loss of income of landless farmers	D	D	D	D
Involuntary resettlement and loss of female-headed households	D	D	D	D
Involuntary resettlement and loss of minority group	D	D	D	D
7. Equity of Benefits and losses				
Enlargement of disparity in income	D	C	C	C
Enlargement of disparity in assets	D	C	B	B
Enlargement of disparity in convenience to cross the river	D	D	C	C
Enlargement of disparity in accessibility	D	D	C	C
8. Conflicts of Interest				
Conflicts of interests stemming from land disputes	D	C	B	B
Conflicts of interests stemming from other economic reasons	D	C	C	C
Conflicts of interests stemming from other social reasons	D	C	C	C
9. Gender				
Aggravation of serious social problems such as human trafficking	D	C	C	C
Decrease in income and aggravation of livelihood of women	D	C	B	B
10. Children				
Aggravation of serious social problems such as human trafficking	D	D	C	C
Decrease in income and aggravation of livelihood of children	D	D	C	B
Children's detour in schooling	D	U	U	U
11. Cultural/Archaeological Heritage				
Resettlement of pagodas	D	D	D	D
Resettlement of other cultural/archaeological heritage	D	D	D	D
12. Infectious Diseases				
Increase in prevalence of HIV/AIDS stemming from massive inflow of construction workers	D	C	C	C
Increase in prevalence of HIV/AIDS stemming from improved mobility	D	C	B	B
Increase in prevalence of other infectious diseases	D	U	U	U

Note A: significant, B: major, C: minor, D: less significant, U: Unknown, P: Positive Impact, *: Impacts during Planning Phase

CHAPTER 3

TRAFFIC DEMAND ANALYSIS

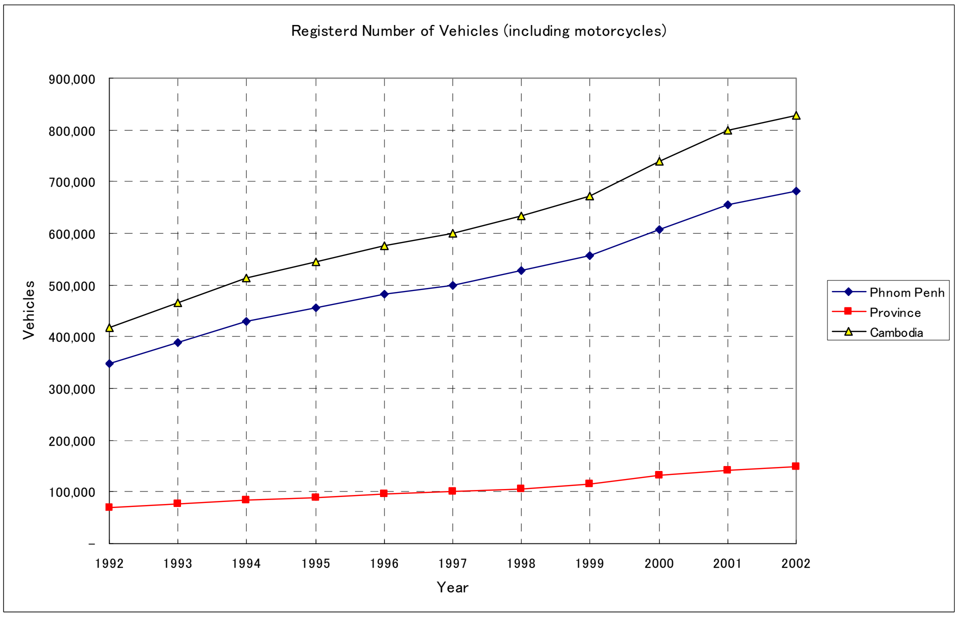
3. TRAFFIC DEMAND ANAYSIS

3.1 Current Road Network and Traffic Conditions

3.1.1 Road Network and Traffic in Cambodia

(1) Vehicle Registration

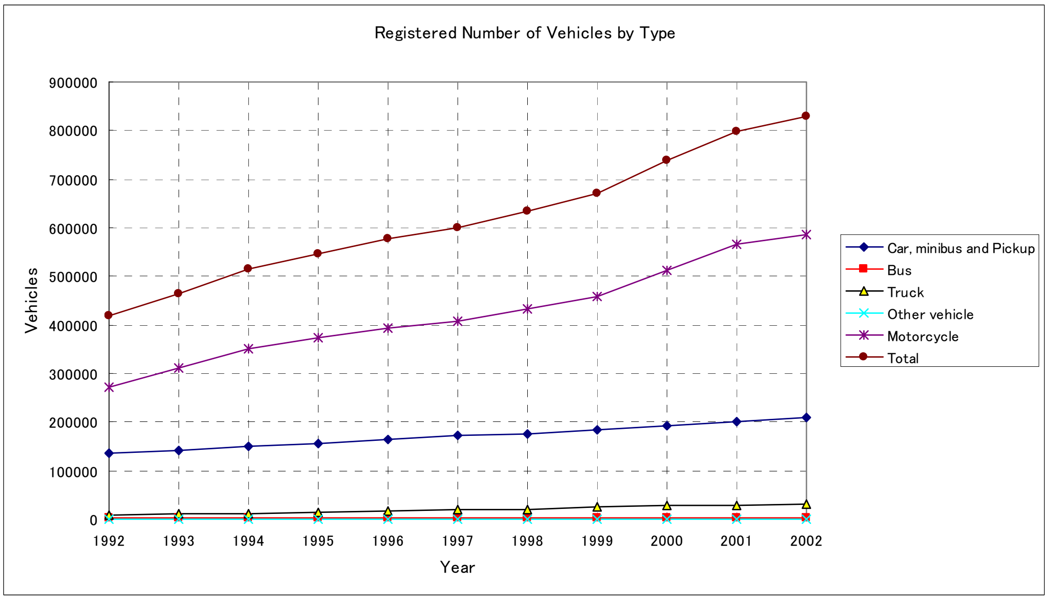
In Cambodia, the number of registered vehicles, including motorcycles, has increased by 7% per annum in the last 10 years (see Figure 3.1.1). Registered vehicles in Phnom Penh especially have contributed to this rapid increase and account for more than 80% of the total.



Source: Statistical Yearbook 2003,

Figure 3.1.1 1992 – 2002 Registered Number of Vehicles

Looking at the number of registered vehicles by type (see Figure 3.1.2), motorcycles increased by 8% per annum in the last 10 years and account for more than 70% of all the vehicles in 2002. Following motorcycles, light vehicles, including mini-buses and pick-ups, increased by 4% per annum in the same period. The number of registered vehicles are brokendown by provinces (see Table 3.1.1). About 680,000 vehicles, which account for 82% of the total vehicles, are registered in Phnom Penh where only 8.7% of the population resides. The number of vehicles around Neak Loeung (2,936 vehicles in Prey Veaeng and 1,718 vehicles in Svay Rieng provinces), are relatively few.



Source: Statistical Yearbook 2003

Figure 3.1.2 1992 – 2002 Registered Number of Vehicles by Type

Table 3.1.1 Estimated Registered Number of Vehicles by Province in 2002

No	Province	1+2+3 C+M+P	4 Bus	5 Truck/Trailer	6 Motorcycle	Total
1	Banteay Mean Chey	2,145	12	81	1,192	3,430
2	Bat Dambang	5,286	0	308	5,972	11,566
3	Kampong Cham	6,985	203	417	36,451	44,056
4	Kampong Chhnang	1,520	5	52	1,024	2,601
5	Kampong Spueu	3,201	7	202	1,972	5,383
6	Kampong Thum	1,292	0	96	5,163	6,551
7	Kampot	1,577	1	71	488	2,137
8	Kandal	9,938	125	205	40,047	50,315
9	Kaoh Kong	942	0	22	0	964
10	Kracheh	410	0	52	1,206	1,667
11	Mondol Kiri	142	0	27	0	169
12	Phnom Penh	162,997	2,736	28,251	487,217	681,201
13	Preah Vihear	97	1	11	634	744
14	Prey Veaeng	1,763	0	120	1,052	2,936
15	Pousat	1,037	7	88	627	1,759
16	Rotanak Kiri	53	1	16	0	70
17	Siem Reab	1,651	76	101	293	2,120
18	Krong Preah Sihanouk	4,059	1	73	167	4,300
19	Stueng Traeng	69	0	11	1,080	1,160
20	Svay Rieng	1,409	11	75	223	1,718
21	Takaev	2,495	9	109	1,463	4,076
22	Otdar Mean Chey	N/A	N/A	N/A	N/A	N/A
23	Krong Kaeb	22	0	1	7	30
24	Krong Pailin	38	1	0	0	39
Total		209,127	3,196	30,389	586,278	828,990

Note: “C+M+P” is car, minibus and pick-up
Source: Estimated by JICA Study Team based on MPWT statistical information

(2) Road Network

Roads in Cambodia are classified into national roads, provincial roads, district roads, village roads and others. The national road is further divided into two categories, primary national roads and secondary national roads. Primary national roads have single-digit numbers and secondary national roads have two-digit numbers. According to a road inventory survey undertaken by MPWT, the total length of national and provincial roads reaches about 7,700 km as summarized in Table 3.1.2.

Table 3.1.2 Total Length of Roads by Type

Class	Length (km)
Primary National Roads	1,988
Secondary National Roads	2,178
Provincial Roads	3,559
Total	7,725

Source: MPWT

3.1.2 Road Network and Traffic in Neak Loeung Area

(1) Road Network

The road network around Neak Loeung looks very simple. National Road No.1 (NR-1), connecting Phnom Penh and Bavet, the border city of Vietnam, is the only arterial road in the area. National Road No.11 (NR-11) runs from Neak Loeung to Kampong Cham Province and connects with National Road No.7. The NR-1 section between Neak Loeung and Bavet has been improved as 2-lane all-weather road by ADB funding. The NR-1 section between Phnom Penh and Neak Loeung is being improved under the Japanese grant aid. NR-11 was already improved by ADB funding. All major arterial roads in this area, accordingly, are improved or are to be improved; they contribute to the increase in transport of goods and services within and between regions. The complex provincial road network exists along NR-1 between Neak Loeung and Bavet (see Figure 3.1.3) and most parts of the provincial roads remain earth or gravel surfaced and are utilized for local transport.

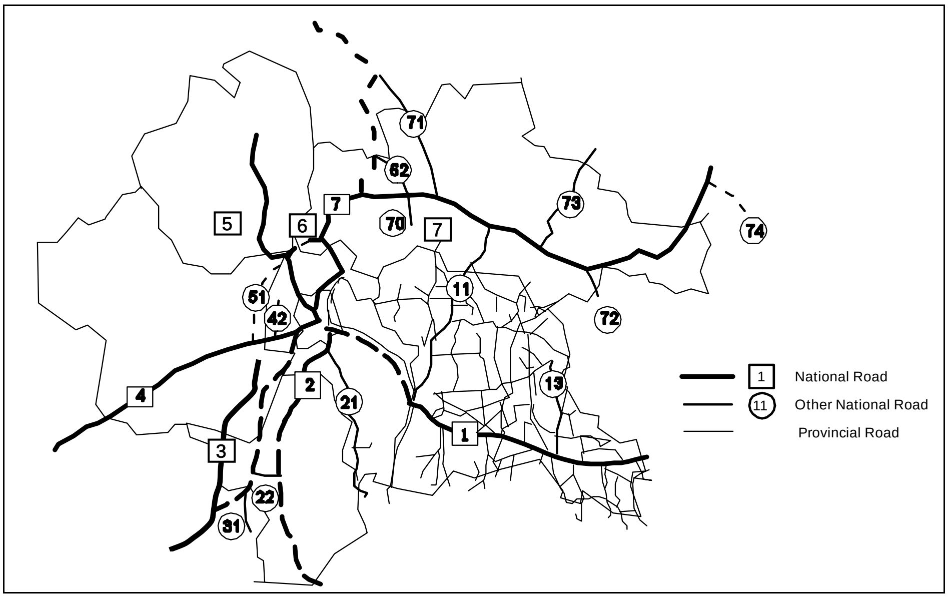
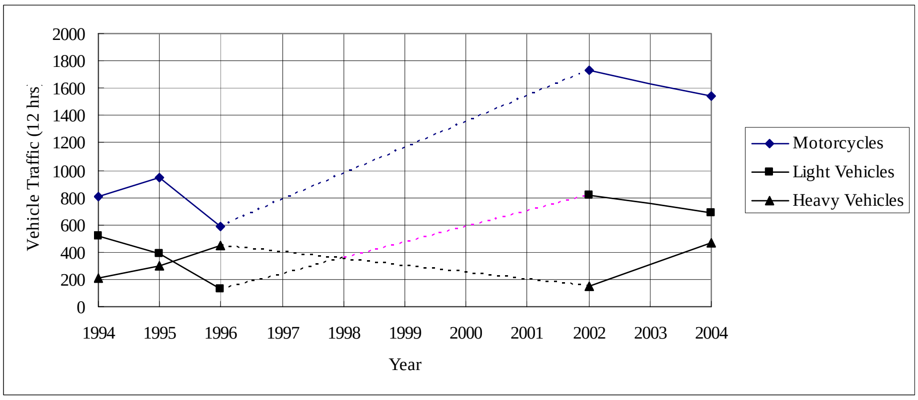


Figure 3.1.3 Road Network in Neak Loeung

(2) Traffic Trend

Figure 3.1.4 shows the past traffic trend from 1994 to 2004 at road sections in Neak Loeung. This trend indicates an increase of the traffic volume at Neak Loeung, especially that of motorcycles.



Source: JICA Study Team based on the results of past traffic count surveys.

Figure 3.1.4 Traffic Trend at Neak Loeung

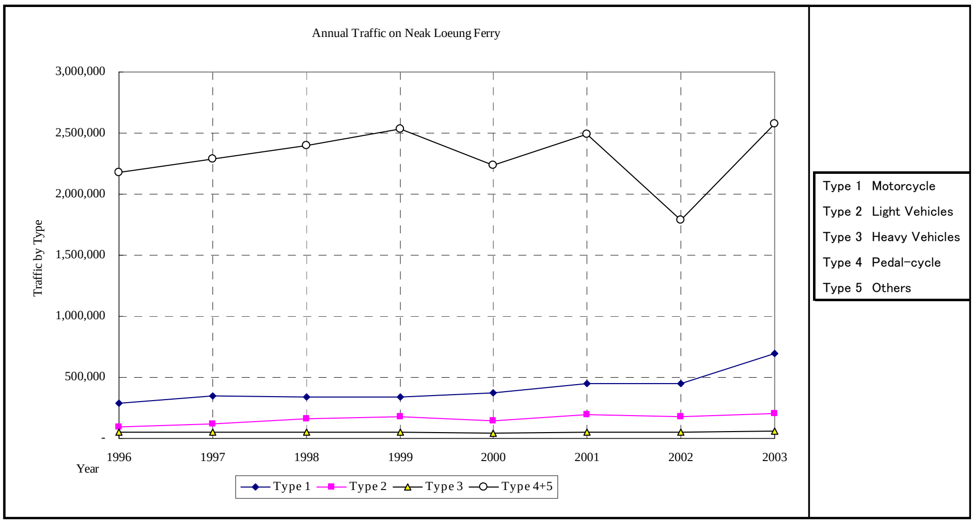
3.1.3 Traffic Characteristics of Neak Loeung Ferry

(1) Traffic on Neak Loeung Ferry

1) Annual Traffic Trend

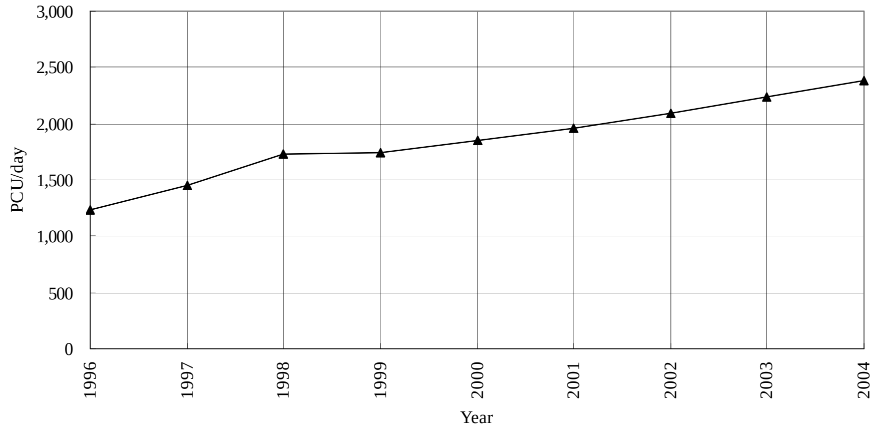
Two ferry ships normally and three during the high season are in service at Neak Loeung. According to the annual traffic trend (see Figures 3.1.5 and 3.1.6), traffic features are summarized as follows:

- Type 4 plus type 5 (pedal cycles and pedestrians) shows a steady trend in traffic and occupies a large portion of the total traffic, and that of 2000 and 2002 shows a sharp drop due to the serious floods of the Mekong River.
- Type 1 (motorcycles) shows a rapid growth from 2002 to 2003.
- Average annual growth rate is at 8.5% per annum.



Source: MPWT

Figure 3.1.5 Annual Traffic Trend on Neak Loeung Ferry



Source: MPWT

Figure 3.1.6 Annual Growth of Daily Average Traffic

Table 3.1.3 Traffic Classification on Neak Loeung Ferry

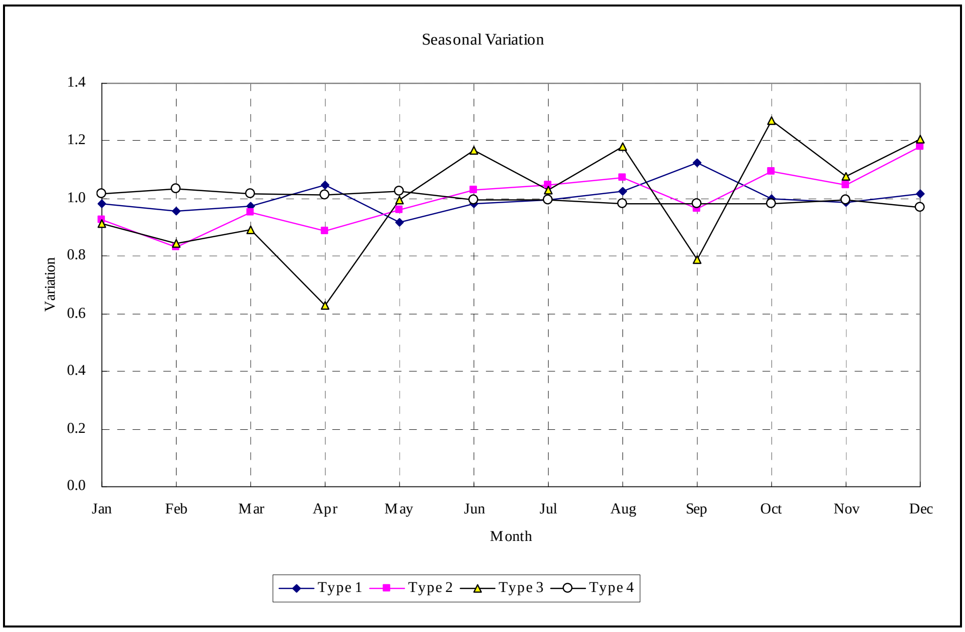
Code	Classification	Tariff (Riel)	Unified Type*
1	Pedestrian	100	Type 5
2	Bicycle, passenger carry goods and cattle cart	200	Type 4
3	Motorbike	500	Type 1
4	Trailer (horse, pushing, bicycle)	1,000	Type 5
5	Motorbike trailer and vehicle under 5 seats	5,800	Type 1
6	Vehicle 6 seats and up to 12 seats	8,500	Type 2
7	Passenger car from 13 seats to 20 seats and all types of vehicles loaded under 5 tons	12,600	Type 3
8	Passenger car from 21 seats or over and all types of vehicles loaded from 6 tons up to 8 tons	23,600	Type 3
9	All types of heavy vehicles loaded from 9 tons up to 15 tons	39,600	Type 3
10	All types of trailer vehicles loaded from 16 tons up to 18 tons	45,500	Type 3
11	Logging truck loaded from 18 tons up to 20 tons	52,800	Type 3

Note*: 11 classifications of vehicles are unified into 5 types of vehicles
Source: MPWT

2) Seasonal Variation

abased on seasonal variation in traffic on the Neak Loeung Ferry (see Figure 3.1.7), main features are summarized below:

- A larger traffic volume of Type 1 (motorcycles) is observed in September.
- The trend of Type 2 (light vehicles) shows an increase in the traffic volume from January to December.
- The trend of Type 3 (heavy vehicles) sharply fluctuates through the year. A small amount of truck traffic is observed in April and September, and a large number is observed in June, August, October and December.
- No fluctuation in Type 4 (pedal-cycles) is observed through the year.



Source: MPWT

Figure 3.1.7 2003 Seasonal Variation on Neak Loeung Ferry

(2) Annual Average Daily Traffic

1) Weekly Variation

The result of the traffic survey in May 2004 at Neak Loeung shows that ratio of the average weekday traffic to the average non-weekday traffic is 1.03 as tabulated in Table 3.1.4.

Table 3.1.4 Average Weekday and Non-Weekday Traffic

Category	PCU	Ratio
Average Weekday Traffic	2,447	1.03
Average Non-Weekday Traffic	2,376	1.00

Source: Traffic survey by JICA Study Team

2) Monthly Variation

The statistics on the ferry users by MPWT show that the monthly traffic variation of May and June, when the Study Team conducted the traffic survey, was 1.049 in comparison with the annual average monthly traffic.

3) Number of Holidays

The weekdays are 235 days and non-weekdays are 130 days including 26 national holidays[1] through the year in Cambodia. Since the weekday traffic and non-weekday traffic differ little, the fluctuations between weekdays and non-weekdays are minor.

4) Annual Average Daily Traffic

The above-mentioned leads to the following AADT formula:

[1] When the holidays overlap with Saturday or Sunday, the following Monday becomes a holiday

AADT = 0.97 x average weekday traffic volume (from traffic survey)

where,

0.97 = (1 x 235 + 1.03 x 130) / 365 / 1.049

Accordingly, the results of traffic survey on the weekday conducted by the Study Team are practically equivalent to AADT due to small differences between the two.

5) Annual Total Traffic Volume

Annual total traffic volume is calculated as follows:

Annual total traffic volume = average weekday traffic (from traffic survey) x 0.97 x 365

(3) Peak Hour Ratio

1) Peak Hour Ratio of Traffic on Ferry

a. Preconditions

Operating Hour

The ferry operated its service for 15.5 hours from 5:30 am to 9:00 pm during the traffic survey period.

PCU Conversion Rate on Ferry

The PCU rates were determined by the investigation of vehicles loaded on the ferry and by referring to those in JICA (2003) and JICA (2005)[2]. These rates are expressed as weighted average by 11 types of vehicles, which are categorized in the traffic survey. The results are presented in Table 3.1.5.

Table 3.1.5 PCU Conversion Rate on Ferry

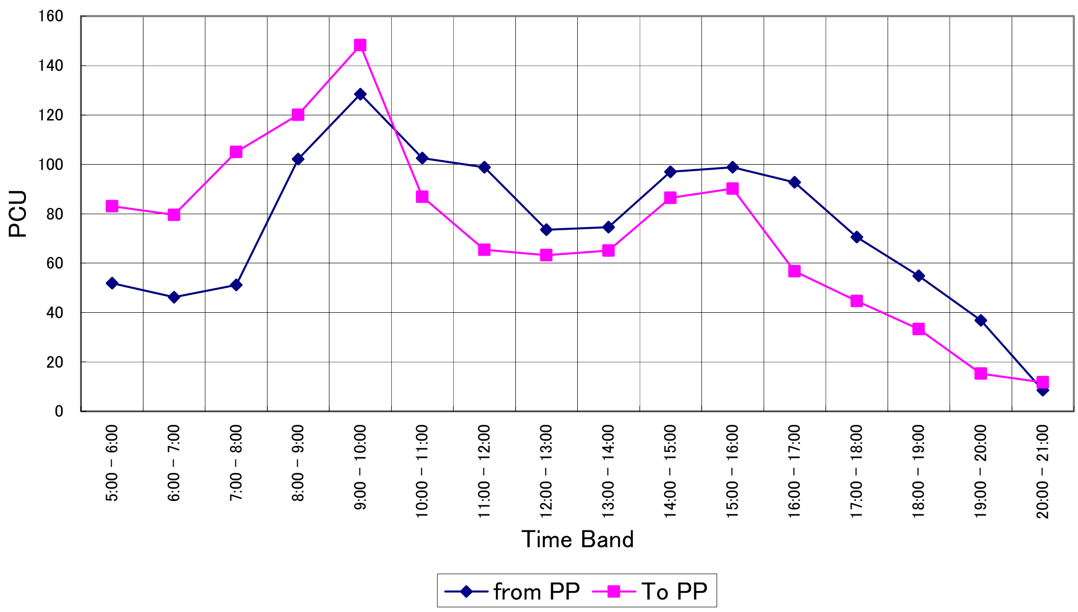
Unified Classification	MC	LV	HV
PCU Rate	0.128	1.165	2.241

Source: JICA Study Team
Note: MC: Motorbike, Motor Tricycle / Motorbike Trailer, LV: Sedan, Wagon, Light Van / Pickup, Jeep Light Truck, HV: Short & Long Body Bus / Short & Long Body Truck / Semi and Full Trailer Truck

Accordingly, 16-hour traffic in PCU, which the ferry carried during the traffic survey, is estimated as shown in Table 3.1.6.

Figure 3.1.8 shows hourly traffic variation.

2 JICA (2005) Basic Design Study Report on the Project for the Improvement of National Road No.1 (Phnom Penh – Neal Loueng Section) in the Kindom of Cambodia



Source: Traffic Survey by JICA Study Team

Figure 3.1.8 Hourly Traffic (Average Weekday)

Table 3.1.6 16-hour Traffic Volume on Ferry

(Unit: Number/16 hours)

Direction	Classification	MC	LV	HV	Total	Total	Pedal Cycle	Pede-strian
		(Vehicles)				(PCU)	(Veh.)	(Persons)
	PCU Conv. Rate	0.128	1.165	2.241	-	-	-	-
From Phnom Penh	Weekday	841	399	280	1520	1,201	295	3,749
To Phnom Penh		822	405	267	1494	1,175	285	2,234
From Phnom Penh	Non weekday	927	380	278	1585	1,184	290	4,136
To Phnom Penh		879	481	263	1623	1,263	303	2,225
Both Directions	Weekday	1,663	804	547	3,014	2,376	580	5,983
	Non weekday	1,806	861	541	3,208	2,447	593	6,361

Source: Traffic survey by JICA Study Team in 2004
Note: MC: Motorbike, Motor Tricycle / Motorbike Trailer, LV: Sedan, Wagon, Light Van / Pickup, Jeep Light Truck, HV: Short & Long Body Bus / Short & Long Body Truck / Semi and Full Trailer Truck

2) PCU Conversion Rate after Completion of Bridge

Conventional PCU conversion rates for the motorcycle are applied after the completion of the bridge. The conversion rate of 0.128 for the motorcycle category on ferry is modified to 0.254 after the completion of bridge.

Table 3.1.7 PCU Conversion Rates on Road and Bridge

Unified Classification	MC	LV	HV
Average Weekday	0.254	1.165	2.241

Source: JICA Study Team
Note: MC: Motorbike, Motor Tricycle / Motorbike Trailer, LV: Sedan, Wagon, Light Van / Pickup, Jeep Light Truck, HV: Short & Long Body Bus / Short & Long Body Truck / Semi and Full Trailer Truck

3) Peak Ratio after Completion of Bridge

The peak hour ratio is observed as high as 0.120 from the hourly traffic volumes, which were surveyed by JICA (2005).

Table 3.1.8 Peak Hour Ratio (Station 54.4 km on NR 1)

Item	MC	LV	HV	Total (PCU)	Peak Hour Ratio
	0.254	1.165	2.241		
12 hours	1,087	2,078	444	3,609	0.120 (B/A)
24hours	1,304	2,494	576	4,374 (A)	
Peak hour	155	318	54	527 (B)	

Source: Traffic survey in 2004 by JICA (2005)
Note: MC: Motorbike, Motor Tricycle / Motorbike Trailer, LV: Sedan, Wagon, Light Van / Pickup, Jeep Light Truck, HV: Short & Long Body Bus / Short & Long Body Truck / Semi and Full Trailer Truck,PC (pedal-cycle) is not converted to PCU due to non-motorized

(4) Heavy Direction Ratio

The results of traffic counts by JICA (2005) is used to derive the heavy direction ratio for the Study.

Table 3.1.9 Heavy Direction Ratio (Station 54.5 km on NR 1)

Direction	PCU	Heavy Direction Ratio
Both Direction	1,028	1.000
From Phnom Penh	448	0.435
To Phnom Penh	580	0.565

Source: Traffic survey in 2004 by JICA (2005)

3.1.4 Ferry Capacity

(1) Present Operation Conditions

1) Operation Hours

The Study employs operation hours of 15.5 hours from 5:30 am to 21:00 pm from the result of the traffic survey by the Study Team and observation survey at the ferry terminal.

2) Operation Time

Operation time has varied between a dry and a rainy season due to the height of water level and velocity of the river flow at the Mekong River. The observation survey at Neak Loeung Ferry Terminal revealed the average operation time shown in Table 3.1.10.

Table 3.1.10 Operation Time of Ferry to Cross the Mekong River

Unit: Minutes

Season	Operation Time	
	One way	Round Trip
Rainy	14	28
Dry	10	20
Annual Average	12	24

Source: Traffic survey by JICA Study Team
Note: Time includes embarkation and disembarkation time

3) Loading Capacity of Ferry

The loading capacity of the current ferry at Neak Loeung was observed as large as 24 PCUs.

(2) Capacity and Maximum Load of Ferry

Three ferries, with capacity of 24 PCUs each, are in service at Neak Loeung. Since the service interval is assumed to be 8 minutes[3], the total capacity of three ferries reaches 5,580 PCUs[4]. Considering a reasonable service level of the ferry, 36 minutes is employed as the average waiting time. Using the following equation of the queuing theory, the total daily maximum load of three ferries is estimated at 4,548 PCU.

$$Tw = \frac{V/C}{1-V/C} \times Ts$$

where,

Tw: Average waiting time (36 minutes)

Ts: Service interval (8 minutes)

C: Total capacity of three ferries (5,580 PCUs)

V: Maximum load of three ferries

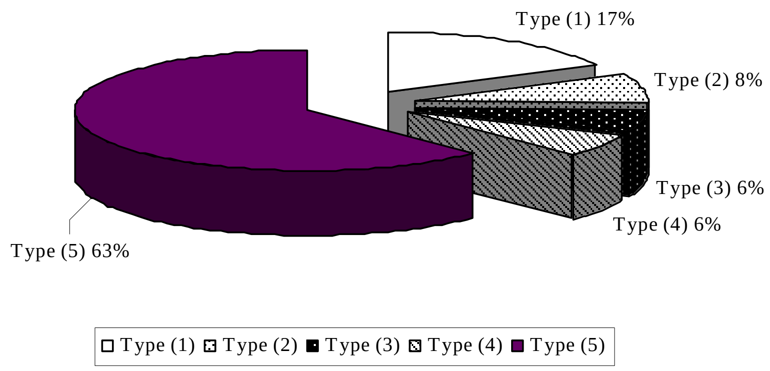
3.1.5 Results of Traffic Survey

(1) Traffic at Neak Loeung Ferry

1) Traffic Composition by Type

a. Weekday Traffic
Figure 3.1.9 shows the composition of weekday traffic observed on Neak Loeung Ferry; Type 5 (pedestrians) were observed to be 69% of the total weekday traffic. Type 1 (motorcycles) is next with 17% of the total. Shares of other types of vehicles are relatively small and range between 6-8% of the total weekday traffic.

[3] 24 minutes (operation time for round trip)/3 ferries
[4] 60minutes / 8 minutes x 24PCU x 15.5hours x 2 directions

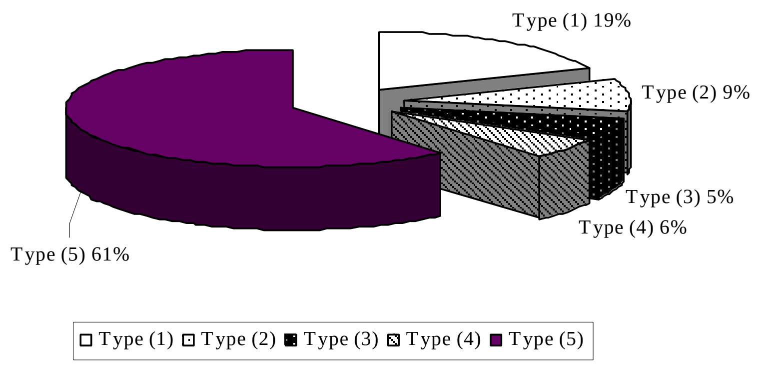


Source: JICA Study Team

Figure 3.1.9 Composition by Type (Weekday) on Neak Loeung Ferry

b. Non-weekday Traffic

Figure 3.1.10 shows the composition of non-weekday traffic observed on Neak Loeung Ferry. The weekday traffic and non-weekday traffic show almost the same compositional pattern and no significant differences between the two were observed.

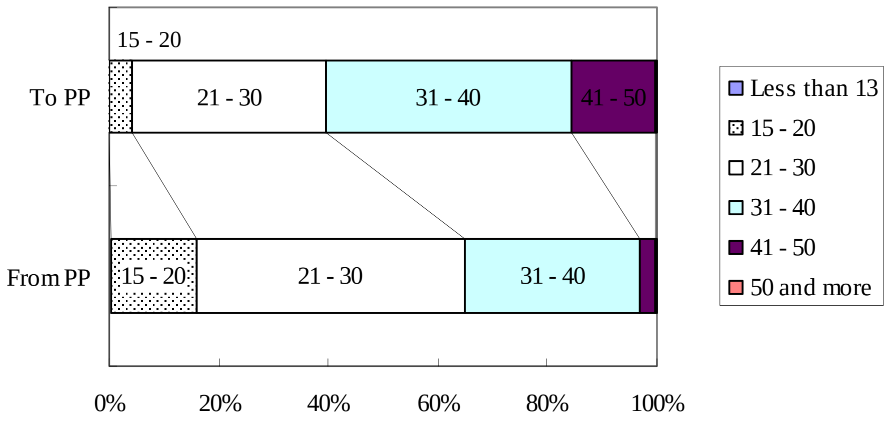


Source: JICA Study Team

Figure 3.1.10 Composition by Type (Non-weekday) on Neak Loeung Ferry

2) Age Composition

Figure 3.1.11 shows the traffic composition by vehicle age observed on weekdays at Neak Loeung Ferry with a different compositional pattern by direction. The vehicles of 21-30 years old from Phnom Penh to Prey Veaeng account for the largest share, whereas vehicles of 31-40 years old accounts for the largest share in the reverse direction. This implies that the traffic on Neak Loeung Ferry does not make regular round trips within a day.

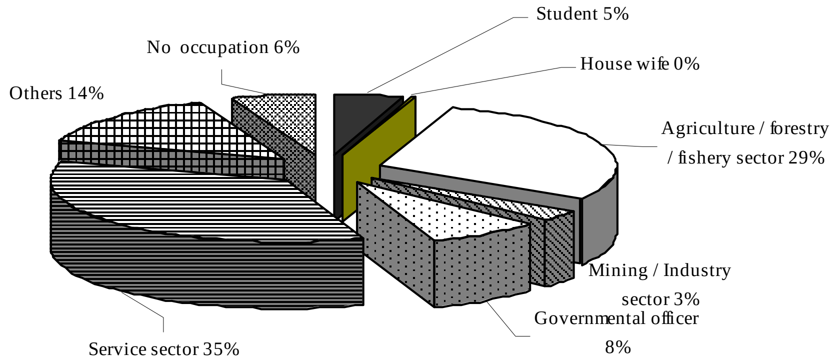


Source: Interview survey by JICA Study Team

Figure 3.1.11 Age Composition (Weekday to/from Phnom Penh) on Neak Loeung Ferry

3) Occupation

Figure 3.1.12 shows the occupational composition of the ferry users observed on weekdays. The service sector accounts for the largest portion followed by agriculture / forestry / fishery.



Source: Interview survey by JICA Study Team

Figure 3.1.12 Occupational Composition (Weekday to/from Phnom Penh) on Neak Loeung Ferry

4) Purpose of Trip

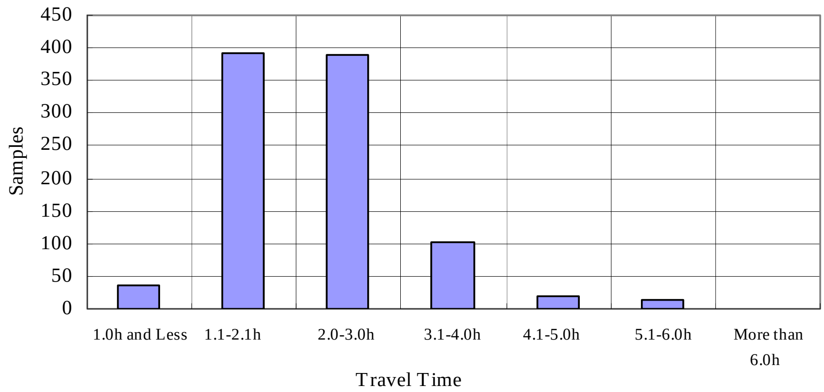
Figure 3.1.13 shows the composition of the trip purposes observed on weekday. As discussed in the age composition, the composition of the trip purposes differs by the trip direction. Business trips from Phnom Penh account for 36% of the total trips, whereas that to Phnom Penh accounts for 50%. The share of "to home" purpose was observed as 15% in both directions, which implies that less ferry users tend to commute for a short distance but most users travel a long distance.

Source: Interview survey by JICA Study Team

Figure 3.1.13 Purpose Composition (Weekday to/from Phnom Penh) on Neak Loeung Ferry

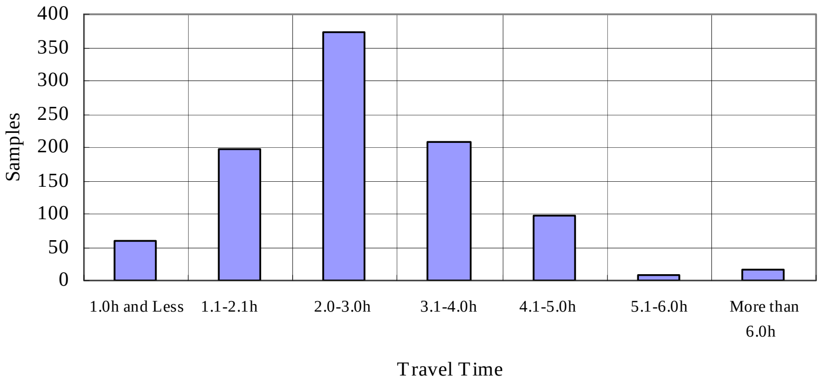
5) Travel Time

Figures 3.1.14 and 3.1.15 show the distribution of travel time observed on the ferry. The comparison between the two shows that ferry users to Phnom Penh tend to consume more time to travel than those from Phnom Penh.



Source: JICA Study Team

Figure 3.1.14 Travel Time Distribution (from Phnom Penh)



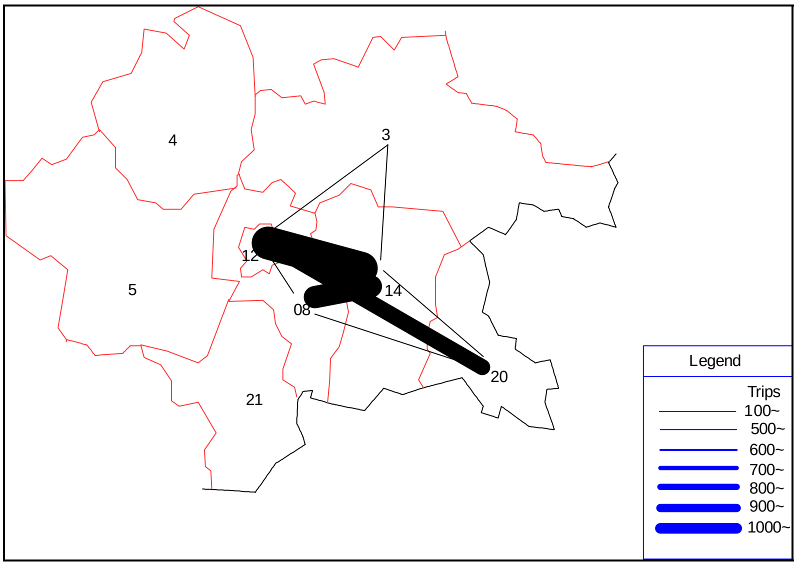
Source: JICA Study Team

Figure 3.1.15 Travel Time Distribution (to Phnom Penh)

6) OD Pattern

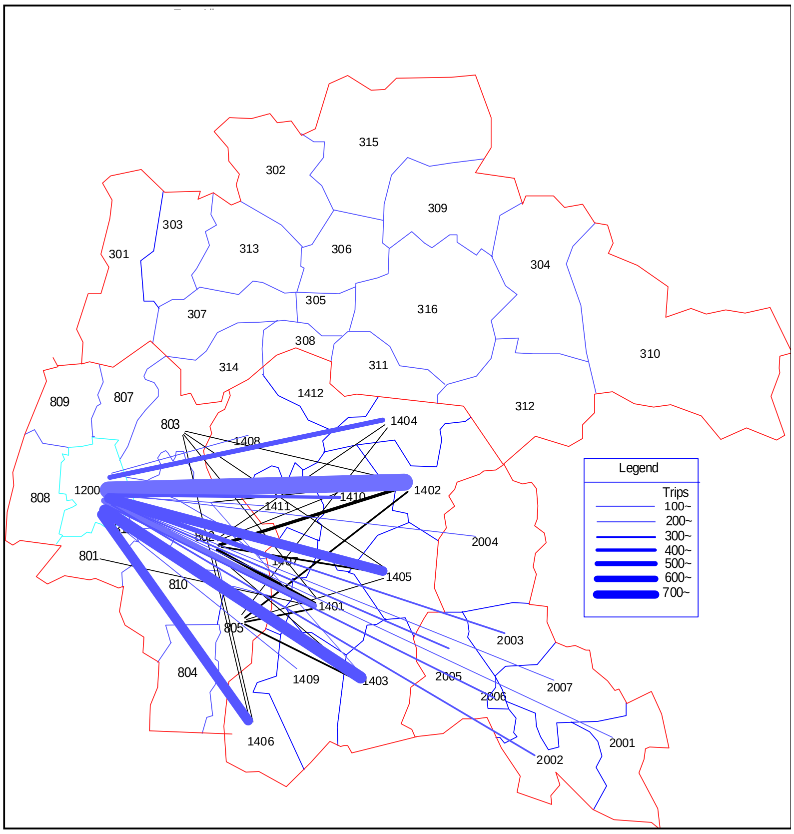
Most Trips to Phnom Penh

Figures 3.1.16 and 3.1.17 show the OD pattern observed on weekdays at Neak Loeung Ferry. Most of the weekday trips are generated and attracted within four regions: Phnom Penh City, Kandal, Prey Veaeng and Svay Rieng Provinces and, furthermore, trips to/from Phnom Penh City account for the majority of all trips.



Source: JICA Study Team

Figure 3.1.16 Trip Flow between Provinces (Weekday, All Trips) on Neak Loeung Ferry



Source: JICA Study Team

Figure 3.1.17 Trip Flow between Districts (Weekday, All Trips) on Neak Loeung Ferry

Fewer Trips between Both Sides along Mekong River

The results of OD survey also show that ferry users along both sides of the Mekong River account for only 1-2% of the total trips which is considered relatively few.

3.2 Methodology for Traffic Demand Forecast

The model commonly used for the traffic demand forecast is ‘four-step methods’. The four-step method is used to predict: (1) the number of trips made within the Study Area, (2) zonal origin-destination (OD) pair traffic, (3) the mode of travel used to make these OD trips, and (4) the routes and volumes of the travel from origin to destination. Based on the assumptions and results of the traffic demand studies by JICA (2003), which employs the said four-step method, this Study focuses on the traffic demand crossing the Mekong River at Neak Loeung. The future traffic demand estimated in the Study follows the workflow and improvement scenarios presented in Figure 3.2.1 and explained in the section below:

3.2.1 Base Case (without the Project)

Traffic demand is forecast under the assumption that there is no implementation of the Project and under the condition that the ferry operation would continue in the future at the same level of service and tariff as at present.

3.2.2 Improvement Scenarios (with the Project)

Future traffic demand is estimated to increase by a series of development programs and projects, including improvement of NR 1 and the implementation of cross border facilitation agreement. (Status of implementation of the GMS Cross Border Transport Agreement is presented in Appendix 3.2) In addition, the Second Mekong Bridge Project itself will contribute to an increase of traffic demand by generating transferred demand from pedestrians to vehicles and demand from the area development of the flood-free land. The selected series of development programs and projects are as follows:

(A) Base case under the same ferry operation.

(B) Traffic generated by improvement of NR 1 (to be completed in 2011).

(C) Cross-border truck traffic generated by implementation of cross border facilitation agreement at the border with Vietnam (to be executed in 2007).

(D) Traffic generated from modal change by the transfer from pedestrians and pedal-cycles currently using the ferry to mini-buses (when the bridge is completed).

(E) Cross-border passenger traffic between Cambodia and Vietnam after the implementation of cross border facilitation agreement (to be executed in 2005).

(F) Traffic generated by bridge construction.

(G) Traffic increase generated from the flood-free land development.

The process of the traffic demand forecast is shown in Figure 3.2.1.

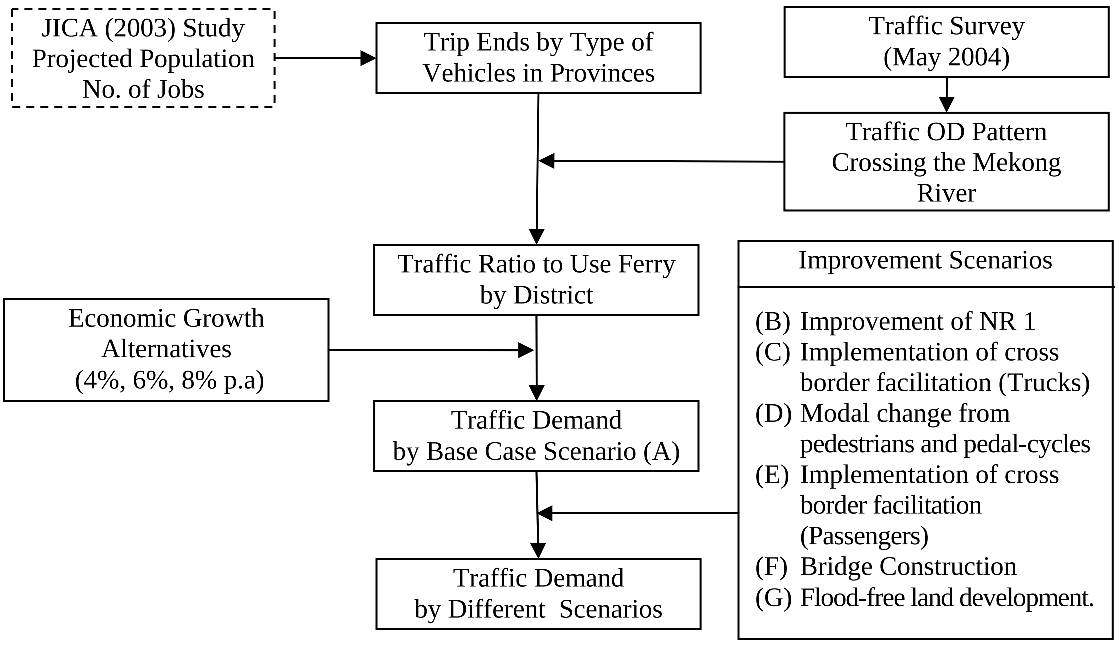


Figure 3.2.1 Workflow for Traffic Demand Forecast

3.3 Future Socio-economic Framework

3.3.1 Population

Future population is one of the main determinants of traffic demand forecast. According to NIS (2005) [5], the projected population in Neak Loeung and its neighboring area will increase by 30% in the next 15 years and reach 5.4 million in 2020 (Table 3.3.1). Based on population growth between 1998 and 2003, the projected provincial population is brokendown into districts as shown in Table 3.3.2.

Table 3.3.1 Projected Population by Province

(Unit: Persons)

Province	1998	2003	2005	2010	2015	2020
Phnom Penh	999,804	1,006,955	1,313,851	1,529,301	1,753,840	1,983,104
Kandal	1,075,125	1,161,443	1,242,506	1,343,407	1,459,431	1,582,712
Prey Veaeng	946,042	1,050,743	1,095,333	1,126,421	1,158,392	1,223,193
Svay Rieng	478,252	526,904	538,180	571,141	610,340	651,073
Total	3,499,223	3,746,045	4,189,870	4,570,270	4,982,003	5,440,082

Source: 1998 population by NIS (1998)[6], 2003 population by SEILA (2003)[7], 2005 - 2020 projected population by NIS (2005)

[5] NIS (2005) First Revision Populations for Cambodia 1998-2020, National Institute of Statistics, Ministry of Planning, http://www.nis.gov.kh/projcam/Index_Proj.htm

[6] NIS (1998) General Population Census of Cambodia 1998, National Institute of Statistics, Ministry of Planning

[7] SEILA (2003) Seila Program, http://www.seila.gov.kh/indexs.asp?language=kh&pgid=1

Table 3.3.2 Projected Population by District

(Unit: Persons)

Province	District	Year			
		2005	2010	2015	2020
Phnom Penh		1,313,851	1,529,301	1,753,840	1,983,104
Kandal		1,242,506	1,343,407	1,459,431	1,582,712
1	Kandal Stueng	100,548	118,778	140,636	165,813
2	Kien Svay	159,280	162,916	167,019	170,501
3	Khsach Kandal	131,145	149,099	169,902	192,788
4	Kaoh Thum	153,245	161,790	171,205	180,401
5	Leuk Daek	54,864	54,691	54,644	54,366
6	Lvea Aem	77,342	84,364	92,235	100,413
7	Mukh Kampul	84,715	87,805	91,217	94,361
8	Angk Snuol	113,576	131,512	152,633	176,395
9	Ponhea Lueu	107,866	114,754	122,362	129,924
10	S'ang	197,805	214,474	233,083	252,235
11	Ta Khmau	62,121	63,225	64,496	65,515
Prey Veaeng		1,095,333	1,126,421	1,158,392	1,223,193
1	Ba Phnum	90,541	96,625	103,061	113,408
2	Kamchay Mear	86,117	89,008	91,947	97,991
3	Kampong Trabaek	123,753	124,357	124,897	129,412
4	Kanhchriech	69,687	73,534	77,551	84,378
5	Me Sang	114,273	120,140	126,241	136,853
6	Peam Chor	62,895	64,163	65,457	66,776
7	Peam Ro	61,661	62,904	64,172	65,466
8	Pea Reang	126,954	128,715	130,429	136,353
9	Preah Sdach	121,899	121,259	120,557	123,655
10	Prey Veaeng	104,386	107,424	110,491	117,245
11	Kampong Leav (U)	59,048	62,077	65,261	68,608
12	Sithor Kandal	74,119	76,215	78,327	83,048
Svay Rieng		538,180	571,141	610,340	651,073
1	Chantrea	48,422	49,374	50,648	51,816
2	Kampong Rou	67,381	70,084	73,335	76,531
3	Rumduol	52,635	53,675	55,066	56,342
4	Romeas Haek	125,061	132,262	140,724	149,325
5	Svay Chrum	154,770	171,212	190,546	211,493
6	Svay Rieng (U)	22,724	23,264	23,960	24,611
7	Svay Teab	67,186	71,270	76,060	80,954
Total		4,189,870	4,570,270	4,982,003	5,440,082

Source: JICA Study Team.

3.3.2 Number of Jobs

The number of jobs in Neak Loeung and its neighboring area is estimated by sector under the following assumptions:

- The number of jobs in the primary sector is equal to that of the employees in the same sector of the district under the assumption that there is no commuting activities beyond districts.

- The number of jobs in the secondary sector is estimated based on the job statistics by the Ministry of Industry.
- The number of jobs in the tertiary sector is estimated under the assumption that commuting activities do not occur between Phnom Penh and Kandal province and there are no commuting activities beyond districts.

The estimated number of jobs in the relevant districts is shown in Table 3.3.3.

Table 3.3.3 Number of Jobs

(Unit: Persons)

Province	Sector	1998	2005	2010	2015	2020
Phnom Penh	Primary	37,029	45,820	50,973	61,400	59,976
	Secondary	109,490	181,543	242,625	346,000	395,830
	Tertiary	318,829	393,861	437,567	526,300	513,256
	Total	465,348	621,225	731,166	933,700	969,061
Kandal	Primary	351,795	406,564	439,580	477,545	482,450
	Secondary	20,533	56,767	86,891	122,114	151,371
	Tertiary	58,043	72,602	82,764	94,545	100,198
	Total	430,371	535,934	609,235	694,204	734,018
Prey Veaeng	Primary	404,324	445,559	441,626	437,110	431,908
	Secondary	5,725	21,059	32,256	44,073	56,524
	Tertiary	37,893	52,013	59,468	67,305	75,525
	Total	447,942	518,630	533,350	548,488	563,958
Svay Rieng	Primary	199,011	219,338	229,276	241,277	246,586
	Secondary	2,696	8,727	13,577	19,120	24,636
	Tertiary	18,394	23,608	27,259	31,487	35,132
	Total	220,101	251,673	270,112	291,884	306,354
Total	Primary	992,159	1,117,281	1,161,455	1,217,332	1,220,920
	Secondary	138,444	268,096	375,350	531,307	628,360
	Tertiary	433,159	542,084	607,058	719,637	724,112
	Total	1,563,762	1,927,461	2,143,863	2,468,276	2,573,391

Source: JICA Study Team

3.3.3 Gross Domestic Product (GDP)

There are several sources that discuss future GPD growth in Cambodia shown in Table 3.3.4. Based on these reference sources, the following three growth rates are set up from 2005 to 2020 for traffic demand forecast in the Study:

- High growth case: 8%
- Medium growth case: 6%
- Low growth case: 4%

Table 3.3.4 GDP Growth by Different Sources

Source	Issued	Case	GDP growth (Unit:% per annum)				
			2002	2005	2010	2015	2020
SEDP-II[8]	2001		6-6.5		-	-	-
NPRS[9]	2002		5-6	6.3-6.5[1)]	-	-	-
JICA (2003) [10] (Feasibility Study on NR 1)	2003	High	6-6.5	8	8	-	-
		Medium		6	6	-	-
		Low		4	4	-	-
CDP[11]			6	8	8		
ESCAP/UNDP (Maritime Policy Planning Mode)[12]	2001		6.5-7.5	6.5[2)]	-	-	-
JICA (Phnom Penh – Sihanoukville Growth Corridor)[13]	2003		6.7			-	-
IMF[14]	2004			1.9	4.5-6	6	6
JICA (Transport Master Plan)[15]	2001	Reform Scenario	7.7	8.4	6.8	5.5	-
		Non reform Scenario	2.8	1.2	2.3	2.6	-

Source: Prepared by JICA Study Team
Note: Actual growth rate is 5.2% in 2002 and 5.5% in 2003, [1)] Up to 2007, [2)] Up to 2011

3.4 Development Plans and Strategies

3.4.1 Metropolitan and Regional Development Strategies

Based on the existing development potentials and constraints discussed in Section 2.2, the urban and regional development strategy is studied taking into account the development hierarchies and linkages. The development strategy will be made in two stages (medium- and short-term stages) which reflect future development directions as shown in Figure 3.4.1.

(1) Strategy for Medium-term Development

<u>Dependence of Neak Loeung's Growth on Phnom Penh's Economy</u>

Currently, the Neak Loeung Area functions as a commercial center of Prey Veaeng and Svay Rieng Provinces and is strategically located at the critical crossing point of the Mekong River, which is potentially well connected to Phnom Penh, the growth center of Cambodia. The population of Phnom Penh, is estimated at one million at present, and it is the largest domestic market of consumer goods such as food, daily commodities and durable goods. Meanwhile, the Neak Loeung Area is a supply center of agricultural products collected from its rural areas to Phnom Penh and other urban areas.

8 RGC (2001) Second Socioeconomic Development Plan (SEDP-II, 2001-2005)
9 RGC (2002) The Cambodia National Poverty Reduction Strategy 2002-2005
10 JICA (2003) The Feasibility Study on the Improvement of National Road No. 1 (Phnom Penh – Neak Loeung Section) in the Kingdom of Cambodia
11 RGC (?) Cambodia. Development Plan 2020
12 ESCAP/UNDP (2001) Maritime Policy Planning Mode
13 JICA (2003) The Study on Regional Development of the Phnom Penh – Sihanoukville Growth Corridor in the Kingdom of Cambodia
14 IMF (2004) Staff Report
15 JICA (2001) The Study on the Transport Master Plan of the Phnom Penh Metropolitan Area in the Kingdom of Cambodia

Likewise, the future economic growth of the Neak Loeung Area in the medium-term perspective will largely depend on the sufficient growth of the Phnom Penh Metropolitan Area, due to the fact that the Phnom Penh is the largest market of consumer goods as well as the largest supplier of working opportunities for migrants from the rural area.

Developing Post-Garment Leading Industries

The country's current export-oriented industries, especially the garment industry, are located in the Phnom Penh Metropolitan Area. However, this leading industry alone cannot boost the economy of the capital, since the export share to Cambodia was lifted at the end of 2004 due to the phase-out of the Multi Fiber Agreement and Cambodia's accession to WTO. Diversification and development of new export industries are urgently required in order to reduce its dependence on exports of garments to the United States and EU countries whose markets are in severe competition with China and other garment exporters.

The post-garment industries should be mass production, labor-intensive and export-oriented manufacturing industries such as consumer goods to provide tens of thousands of people with job opportunities. Especially, employment opportunities of male workers should be increased since the present number of male workers in the manufacturing sector is less than half of female[16] workers. Such manufacturing industries would be food and beverage, rubber and plastic products, machinery and equipment, motorbike assembly, etc. These export-oriented industries have large potential, but at the same time, also have competitors such as Thailand, Viet Nam and China. Meanwhile, the service sector such as the tourism industry is another promising industry taking advantage of a large number of tourists to Angkor Watt.

Developing Import-Substituting Industries

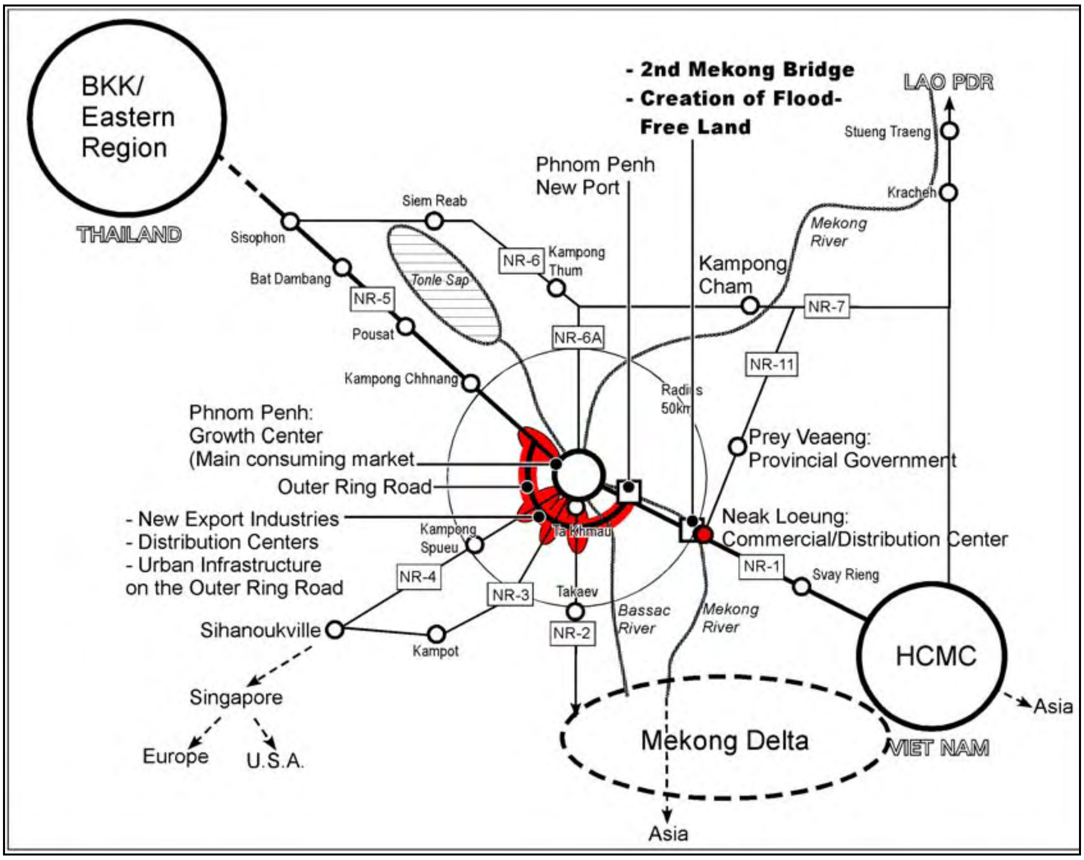
The second possibility is to develop import-substituting industries, which domestically produce a large quantity of consumer goods in the Phnom Penh Metropolitan Area to replace the huge amount of imported consumer goods from Thailand, Viet Nam, and China. Although the export-oriented industry is one of the major engines of the economic growth in Phnom Penh, the production of goods for selective import substitution to some extent by encouraging light manufacturing products is relatively competitive reflecting the market size in the Phnom Penh Metropolitan Area.

Increasing Demand of Urban Growth in the Neak Loeung Area as a Regional Center

In response to the growing demand of the urban growth in the Phnom Penh Metropolitan Area, the Neak Loeung Area should be prepared as a regional center to fulfill the following requirements:.

- Provision of flood-free land (year-round use) by the implementation of the Project.
- Preparation of urban and regional development plans for the neighboring area and Neak Loeung Area, and the plans should be consistent with National/Regional Development Plans and Phnom Penh Metropolitan Area Development Plan.

[16] 28% for male workers and 72% for female workers calculated from CAMBODIAN STATISTICAL YEAR BOOK 2003



Source: JICA Study Team

Figure 3.4.1 Medium-term Perspective for Future Regional Development

(2) Strategy for Short-term Development (Refer to Figure 3.4.2)

Encouragement of Regional Industrial Development and Shifting Administrative Function

Alongside integrated urbanization and growth of Phnom Penh Metropolitan Area, industrial development will be encouraged around the regional center areas within the radius of 50-70 km from the center of the capital, creating several industrial centers in these outer areas. Accordingly, Neak Loeung, Kampong Chhnang, Kampong Spueu, and Takaev would be candidates of industrial centers in these outer areas. Especially, Neak Loeung is endowed with the highest potential of all these candidates due to its strategic location on the 2nd West-East Corridor as well as at a critical crossing point thereon.

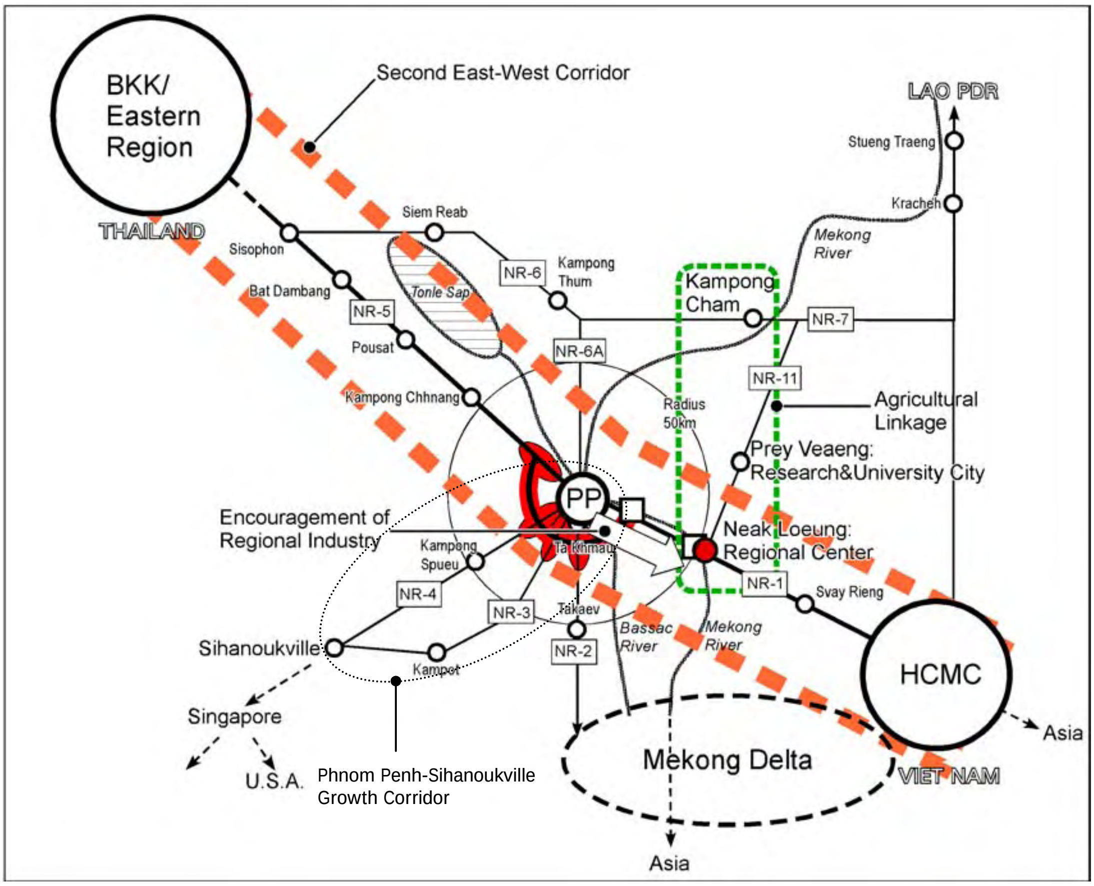
The development in the Metropolitan Area will encourage the development of agro-industry and livestock industry in the Neak Loeung Area, which will trigger remarkable improvements in agricultural productivities and diversification of agricultural production in such areas as Prey Veaeng, Svay Rieng, and Kampong Cham which will serve the Neak Loeung Area.

Need to Develop Flood-free Land for the Regional Center[17] (Provincial Town)

In response to the requirement of the regional industrial development 50-70 km area from Phnom Penh, the Neak Loeung Area should prepare flood-free land as extensively as possible to fulfill the function of commercial, industrial as well as government service

[17] City with sphere of influence equivalent to provincial area. Provincial capital is a typical one.

centers; this can be regarded as the multi-purpose ***"Neak Loeung Regional Center"***. On the other hand, the administrative function of Prey Veaeng capital should be shifted to Neak Loeung in anticipation of accumulated effects of the economy therein. Accordingly, Prey Veaeng could be redeveloped as a center of education and research in order to develop quality human resources in pursuit of agricultural and industrial development. In the long term, Neak Loeung might have possibility to be the provincial capital.



Source: JICA Study Team

Figure 3.4.2 Short-term Perspective for Future Regional Development

3.4.2 Regional Development through Creation of Flood-free Land

(1) General

In view of the medium- and short-term perspectives of the future regional development, closer linkage to Phnom Penh on the 2nd East-West Corridor and the strategic location of the Neak Loeung Area would lead to a conclusion that the Area is ultimately required to function as a multi-purpose "Neak Loeung Regional Center". Meanwhile, the Area is located in the flood-prone area, and one of the most serious weaknesses is that the Area is threatened to be frequently flooded in the rainy season. In fact, serious damage in NR-1 caused by the flood in 2000 could be found near Neak Loeung. Therefore, creation of the flood-free land is a key strategy to the development of "Neak Loeung Regional Center".

(2) Types of the Flood-free Land

In response to the future demand for the "Neak Loeung Regional Center", the construction of the 2nd Mekong Bridge will provide the Neak Loeung Area with opportunities to generate the flood-free land. Two types of flood-free land could be created by the construction of the Bridge. While the first type is a circle levee surrounded by NR-11, NR-1 and the approach road of the Bridge, the second type is the construction yards which will be constructed and utilized on both sides of the river during the construction of the Bridge. This means that in order to make maximum use of the favorable impacts on the regional development, circle levees and construction yards, which are unique to the construction of the Bridge, are envisaged as a key strategy of the "flood–free land".

1) Circle Levees

The approach roads could be used for embankment. Areas enclosed by NR-1, NR-11 (dyke roads of the Mekong River) and the approach roads of the bridge could produce "Circle Levee".

2) Construction Yards

For the bridge construction, two construction yards will be provided to stock construction materials, equipment yards, plant yards and/or field offices on both sides, Kandal and Prey Veaeng. It is sure that the construction yards will not be inundated with river water. The construction yards can be used for developments after the bridge construction. The flood-free lands are valuable assets for urbanizing the Neak Loeung Area.

(3) Development Direction

The area of the flood-free land, which will be newly created through the construction of the bridge, is around 100 ha in total, and the existing built-up area is around 70 ha. It will take a long time to materialize the full scale development of the flood-free land in reality. In this context, the following phasing will be taken:

1) First phase

The first development will take place by utilization of construction yards, which will be provided during the preparation and construction works of the project bridge. After the completion of the bridge, this land will be available as a tool of area development.

2) Second Phase

After strengthening the foundation of the development at the first phase, the development within the area of circle levees will be the next target. Necessary development steps will be taken to materialize the "Neak Loeung Regional Center" for the long term perspective.

(4) Local Development by Possible Utilization of Construction Yards

The idea of utilizing construction yards after the construction of the Bridge should not be treated as a simple countermeasure to mitigate the negative impacts or as a sort of by-product of the Bridge, but rather as a more positive concept, where the most attractive output is accrued from the maximum use of the benefits unique to the construction works of the 2nd Mekong Bridge. The following 4 positive concepts are proposed to maximize utilization of the construction yards.

<u>"Michi-no-eki" with One-Village One-Product Concept</u>

"Michi-no-eki" (Station on Road) basically provides places where long-distance buses stop for a break, including bus terminals, and places where truck drivers stop to take a break. The World Bank has been recently implementing several pilot projects in Kenya, China, etc. There are three types of "Michi-no-eki" concepts:

- Rest area type “Michi-no-eki” which serves for traffic safety by providing a suitable rest environment.
- Market type “Michi-no-eki” which serves for income generation by providing a function of business incubation to stimulate economic activities in a region.
- Terminal type “Michi-no-eki” which serves to facilitate the handling of long-distance transportation demand.

Taking into account the distance to Phnom Penh and Ho Chi Minh cities, the market type “Michi-no-eki” concept will be employed with the tentative proposal of the following facilities. The detailed contents of the “Michi-no-eki” in the construction yards are listed below.

- Parking area
- Water supply and Toilet Facilities
- Restaurant Facilities
- Market facilities for local products
- Rest facilities
- Information Center
- Memorial park of the 2nd Mekong Bridge to attract passers-by as a sight seeing spot.

Out of the above-mentioned facilities, market facilities for local products will be managed by using the concept of “One Village One Product” whose movement exists in Cambodia.

Evacuation Space from Flood

The construction yard might have function of evacuation. In fact, people and livestock have evacuated even to roads. Since it might be difficult to prepare sufficient evacuation space on roads, the construction yards will be utilized as evacuation space of people and livestock in case of flood.

Storage Facilities and Agro-Industry

The construction yards will also provide a space for stock facilities of agricultural products in rainy seasons, and this will contribute to raise farmer incomes. More value-added agro-processing industries by using agricultural products of remote areas such as Prey Veaeng, Svay Rieng, etc will be able to operate their factories constantly.

Administration Facilities

The construction yards will provide a space for operation/maintenance offices of the bridge and approach roads.

1) Support to Project Affected Persons

Many people have been making livelihood by ferry-related business. After the completion of the bridge, the ferry services at Neak Loeung will fall into disuse and the people, who have been working with ferry-related business, will lose their jobs as well. The “Michi-no-eki” may offer new business opportunities for such people. Such consideration will greatly contribute to the mitigation of adverse impacts toward the project affected persons and to the smooth implementation of the project.

2) Consideration to Returning Development Benefit

Cambodia is in its infancy for regional development procedures. Since the flood-free land development is expected to bring about development benefit to many people, it is necessary to create new scheme to return the benefit to the public for the sustainable development.

3.4.3 Flood-free Land Development Policy

(1) Development Concept

In terms of long-term development of the flood-free land, there are following two development policies:

Formation of Agro Corridor

- Development of Agro-industries
- Cooperation with agriculture oriented provinces

Integration of Urban Functions

- Shift of administrative functions
- Development of academic town

(2) Formation of Agro-corridor

a. Potential Development of Agro-industries

Prey Veaeng province borders on two agricultural provinces: Kampong Cham and Svay Rieng. Kampong Cham is an outstanding agricultural province for field crops and tree crops. Livestock farming is the main industry of Svay Rieng. Svay Rieng has little flood disturbance although their rice productivity is lower because they cannot benefit from the little fertility effect of floods. Agro-industries are favoring these three provinces in the future.

In the three provinces, the Neak Loeung Area is located at the strategic crossing point of the Mekong River, NR-1 and NR-11. The Neak Loeung Area could be developed as a regional center of agriculture, fisheries and agro-industry in more extensive area including the Mekong Delta and Ho Chi Minh city.

b. Cooperation with Agriculture Oriented Provinces

The function of NR-11 has been changed to an economic road (distribution road) from an administration road since NR-11 was improved as a flood-free road. The economic road means having a connection with Kampong Cham province, and the administration road means having a connection with the provincial capital, Prey Veaeng town.

With NR-1, this functional change of NR-11 has made three provinces easier to access each other than before. Consequently, the three agricultural provinces could also communicate and cooperate more.

(3) Integration of Urban Functions

a. Shift of Administrative Functions

There is no geographical advantage in Prey Veaeng town, since NR-1 and NR-11 were improved as flood-free roads. The divided urban functions, administration in Prey Veaeng town and commercial activities in the Neak Loeung Area, have limited development of both areas.

The integration of these two functions is necessary to develop the Neak Loeung Regional Center by shifting administrative functions from Prey Veaeng town to the Neak Loeung Area. Administrative functions include the government offices, provincial government offices and local offices of the central government. After the relocation, the Neak Loeung Regional Center would consist of:

- Government service center
- Regional commercial/trade center
- Agro-industry center.

b. Development of Academic Town

After the shift of administration to the Neak Loeung Area, redevelopment is required for the Prey Veaeng town. An academic town would contribute to the re-development of the town. The academic town would require developing higher education facilities and research institutions to diversify the local agricultural productions and support the agro-industries.

The following are suggested for development policies:

University and Institutions

- To built a university and institutions to contribute to development of agriculture, fisheries and livestock farming in the flood plain region, Kampong Cham, Prey Veaeng and Svay Rieng provinces (Making difference from the Tonle Sap is necessary to avoid a competition).
- To include education of forest conservation and management for the Northeast Region.

Human Resource Development

- To built local autonomy college to educate mid-level bureaucrats.
- To contribute to re-education for existing bureaucrats.

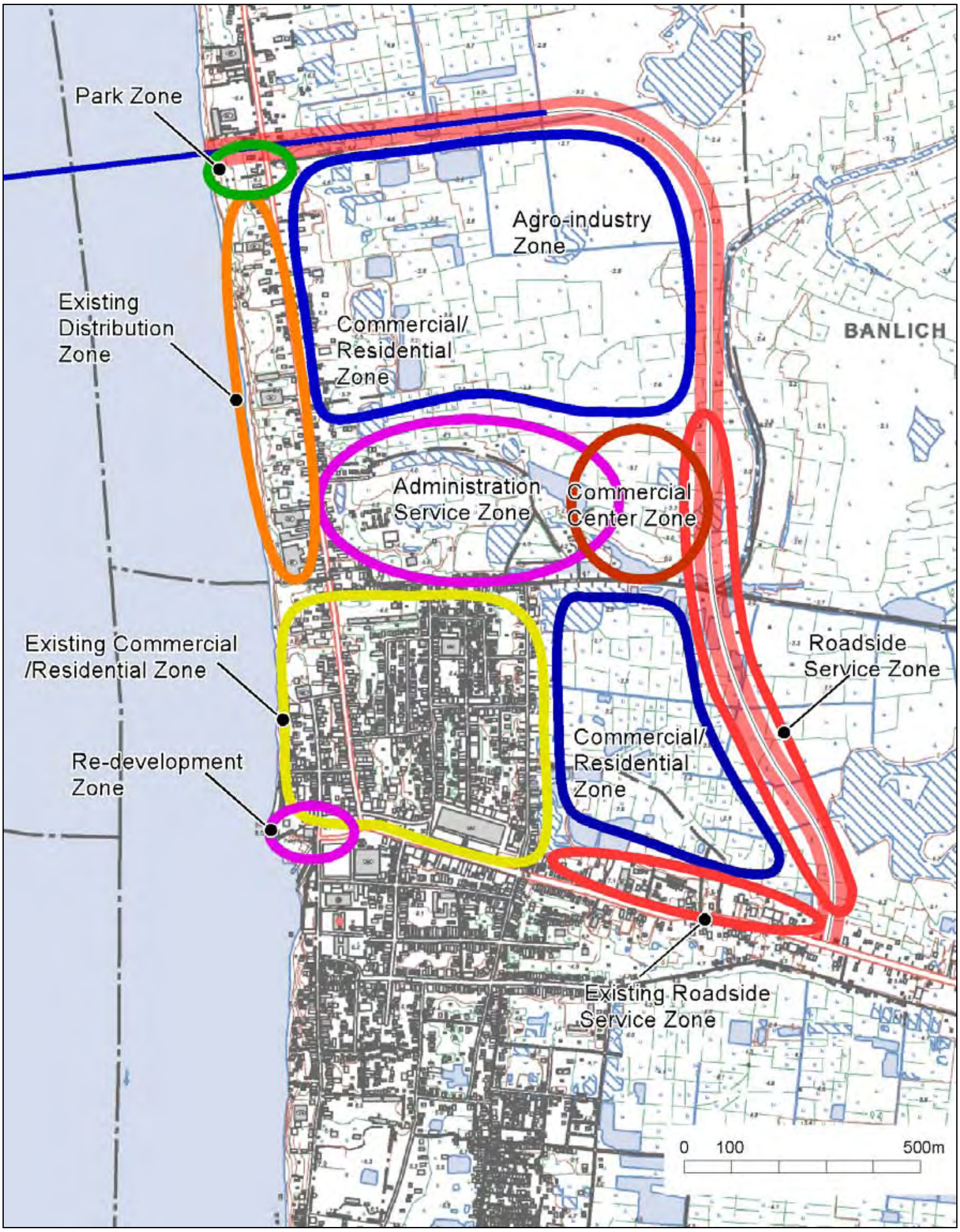
Cooperation with Neighboring Countries

- To collaborate with AIT (Asian Institute of Technology, Thailand) local autonomy college to educate mid-level bureaucrats (Development of Cambodia needs to educate people who can contribute to the future development with leadership).

(4) Preliminary Land Use Plan

1) Zoning

Schematic zoning for A-route(as an example) is prepared according to the above examination as follows:



Source: JICA Study Team

Figure 3.4.3 Preliminary Zoning Plan

2) Preliminary Land Use Pan

A preliminary land use plan is drawn up for as a future guideline although there are many uncertainties about the long term development.

Source: JICA Study Team

Figure 3.4.4 Preliminary Land Use Plan

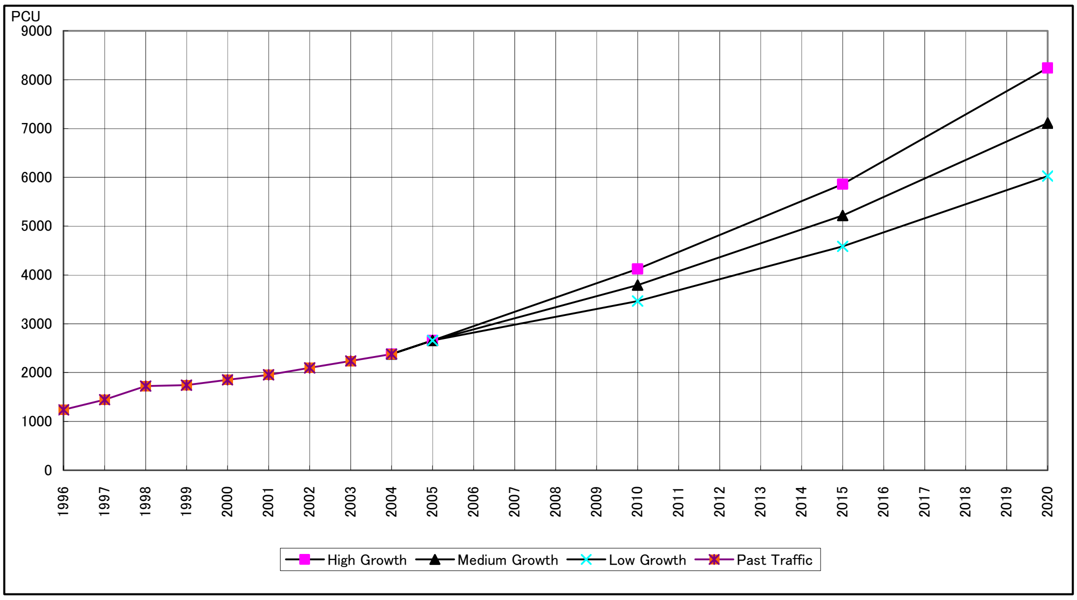
3.5 Traffic Demand Forecast

3.5.1 Review of the Related Studies

JICA (2003) studied the improvement of National Road No.1 in 2003. The study area of Neak Loeung and its neighboring area is covered by JICA (2003) study. In terms of traffic demand forecast, JICA (2003) employed the previously mentioned four-step method and estimates OD matrices of 2020 in the study area. According to the detailed comparison between JICA (2003) and this Study, it is found that no adjustment is required to the JICA (2003) OD matrices for the use of this Study. In this regard, this Study can also maintain consistency with the results of demand forecast made by JICA (2003).

3.5.2 Future Traffic Demand Forecasted by Economic Growth Case

As discussed previously, this Study employs three economic growth cases from 2005 to 2020: namely, a) high growth case of 8% per annum (p.a.), b) medium growth case of 6% p.a., and c) low growth case of 4% p.a. Based on the different economic growth cases, the future traffic demand on the project is forecast as shown in Figure 3.5.1.



Source: JICA Study Team
Note: Forecast traffic is plotted every five years.

Figure 3.5.1 Traffic Demand Forecast by Economic Growth Scenario

3.5.3 Traffic Generated by Improvement of NR 1

Traffic generated by improvement of NR 1 can be analyzed from the results of traffic assignment of JICA (2003). The difference between the traffic volumes with and without improvement of NR 1 is 0% - 5% as tabulated in Table 3.5.1. Accordingly, the traffic generated by the improvement of NR 1 at Neak Loeung, referring to the growth ratio at Section G, is considered to additionally grow by **5%** and this is adopted to the current Study.

Table 3.5.1 Traffic Generated by Improvement of NR 1

Section of NR 1	Station (km)	Ratio (Traffic Volume with Project/ without Project)		
		2005	2010	2015
A	0.0 - 3.5	1.00	1.00	1.01
B	3.5 - 7.0	1.00	1.01	1.01
C	7.0 - 14.1	1.00	1.02	1.02
D	14.1 - 25.2	1.00	1.04	1.04
E	25.2 - 36.3	1.00	1.05	1.05
F	36.3 - 46.8	1.00	1.05	1.05
G	46.8 - 55.4	1.00	1.05	1.05
Average		1.00	1.03	1.03

Source: JICA (2003) The Feasibility Study on the Improvement of National Road No. 1 (Phnom Penh – Neak Loeung Section) in the Kingdom of Cambodia
Note: Figures show the difference between the traffic volume with and without project

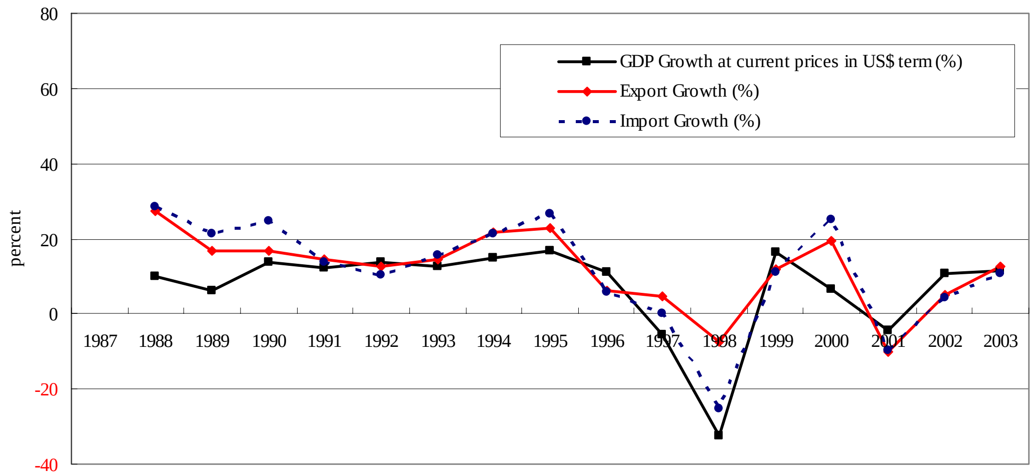
3.5.4 Cross-border Traffic (Truck)

(1) Trade between Cambodia and Vietnam

Large expansion of trade between Cambodia and Vietnam is expected if the following conditions are properly arranged:

- Promoting cross border facilitation including “one stop one document at the border”
- No transshipment between trucks at the border
- Regional integration within GMS
- Improvement of infrastructure including roads.

Figure 3.5.2 shows the relationship between GDP growth, and export and import growth during 1988 – 2003 in ASEAN. A good correlation can be observed among these factors, according to the diagram. Therefore, future import and export are assumed to follow the GDP growth either in ASEAN or Cambodia in the future.



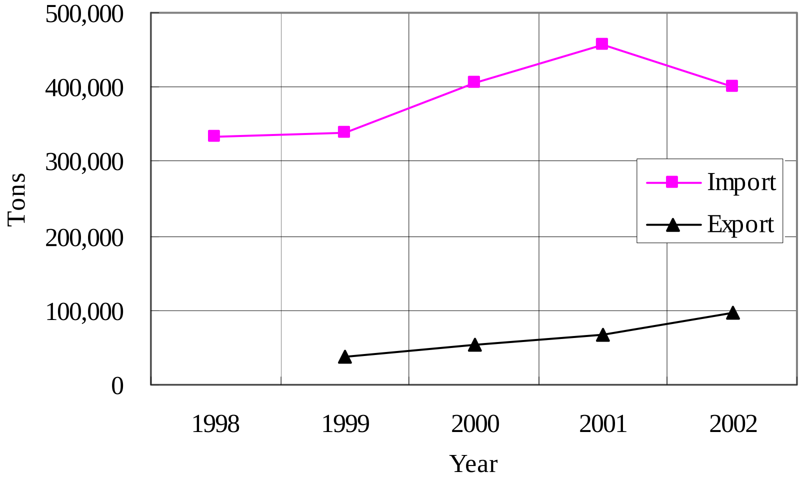
Source: ADB statistics prepared by JICA Study Team
Note: Brunei and Myanmar is excluded.

Figure 3.5.2 GDP and Export/Import Growth in ASEAN

Figure 3.5.3 shows the past trend of export and import in net weight between Cambodia and Vietnam. Under the assumption that the relation between import/export growth and GDP growth is linear, the annual growth in import and export is based on the following equations and resulted as indicated in Table 3.5.2.

Export growth (%) = 0.589 x GDP Growth Rate +7.639

Import growth (%) = 0.937 x GDP Growth Rate +4.796



Source: Ministry of Commerce in Cambodia

Figure 3.5.3 Cambodia's Border Trade with Vietnam

Table 3.5.2 Estimated Growth of Cambodia's Import and Export with Vietnam

GDP Growth Scenario	Item	Growth (% p.a.)
High	Import	12.3
	Export	12.4
Middle	Import	10.4
	Export	11.2
Low	Import	8.5
	Export	10.0

Source: JICA Study Team

Table 3.5.3 shows estimated border trade in net weight with Vietnam.

Table 3.5.3 Estimated Border Trade between Cambodia and Vietnam

Unit: Tons

Growth	Item	2002	2005	2010	2015	2020
High	Import	83,347	118,040	210,829	376,555	672,554
	Export	43,326	61,525	110,378	198,022	355,258
Middle	Import	83,347	112,150	183,926	301,640	494,692
	Export	43,326	59,575	101,295	172,232	292,844
Low	Import	83,347	106,459	160,077	240,701	361,932
	Export	43,326	57,667	92,874	149,574	240,890

Source: JICA Study Team

Looking at other trade among GMS countries, trade between Thailand and Vietnam for instance, the volume in both import and export is small. Major cargoes are heavy cargoes and suitable for ship transport. Accordingly, beside trade between Cambodia and Vietnam, through-traffic by trucks among other GMS countries are considered relatively small and negligible in this Study.

(2) Choice between Sihanoukville Port and Phnom Penh Port

Phnom Penh Port does not yet play an important role in container cargo transport. The statistics on Sihanoukville port indicates that the port handles container cargoes to USA, East Asia and Vietnam. Looking at container transport, there are several alternative transport routes, and the route choice depends on the transport cost by route. Current container transport cost between Phnom Penh and Ho Chi Minh (Saigon Port) is around $220/TEU. There is much possibility for the transport cost to drastically decrease under competitive conditions. The following assumptions may be realized, if the transport cost for the container cargoes decreases to the competitive level of via Sihanoukville Port:

- Half of the container cargoes to East Asia and USA will divert from Sihanoukville Port to Phnom Penh Port.
- All of the container cargoes to Vietnam will divert to Phnom Penh Port.

Table 3.5.4 shows possible container cargoes to be diverted from Sihanoukville Port to Phnom Penh Port.

Table 3.5.4 Assumption of Containers Diverted from Sihanoukville Port to Phnom Penh Port

Unit: TEU

Origin/Destination	Export	Import	Total
US	8,300	0	8,300
East Asia	4,000	29,300	33,300
Vietnam	16,500	24,500	41,000
Total	28,800	53,800	82,600

Source: Prepared by JICA Study Team
Note: 10.5 tons/TEU and 0.65 for full /empty ratio are employed.

Following the above assumption, the Sihanoukville Port Authority estimates around 220,000 TEU throughput at the port in 2015 after the diversion to Phnom Penh Port.

(3) Waterway and Truck Traffic between Cambodia and Vietnam

There are many uncertainties in modes of transport in import and export between Cambodia and Vietnam. Waterway navigation development including improvement of border customs procedures, installation of buoys for night passage, and maintenance of ship route by dredging is expected at the Mekong River, while improvement of NR 1 and other related roads has been in progress.

Modal share between inland waterway transport and land transport between Cambodia and Vietnam is analyzed based on the past trend and current improvement progress of road and waterway transport. The analytical results are shown in Table 3.5.5.

Table 3.5.5 Estimated Modal Share of Import/Export

Item	Mode	2001(Unit: tons)	Share by Mode (Unit: %)				
			2002	2005	2010	2015	2020
Import	Waterway	61,000 (70%)	70	75	78	82	85
	Truck	26,000 (30%)	30	25	22	18	15
Export	Waterway	Uncertain due to incompatible statistics		90	88	87	85
	Truck			10	12	13	15

Source: JICA Study Team

Accordingly, the transport volume by mode is estimated as follows:

Table 3.5.6 International Cargo Transport

(Unit: 1,000 tons)

Growth	Item	Mode	2005	2010	2015	2020
High	Import	Waterway	88.5	165.1	307.5	571.7
		Truck	29.5	45.7	69.0	100.9
		Total	118.0	210.8	376.6	672.6
	Export	Waterway	55.4	97.5	171.6	302.0
		Truck	6.2	12.9	26.4	53.3
		Total	61.5	110.4	198.0	355.3
	Waterway		143.9	262.6	479.1	873.6
	Truck		35.7	58.6	95.4	154.2
	Total		179.6	321.2	574.6	1,027.8
Middle	Import	Waterway	84.1	144.1	246.3	420.5
		Truck	28.0	39.9	55.3	74.2
		Total	112.1	183.9	301.6	494.7
	Export	Waterway	53.6	89.5	149.3	248.9
		Truck	6.0	11.8	23.0	43.9
		Total	59.6	101.3	172.2	292.8
	Waterway		137.7	233.6	395.6	669.4
	Truck		34.0	51.7	78.3	118.1
	Total		171.7	285.2	473.9	787.5
Low	Import	Waterway	79.8	125.4	196.6	307.6
		Truck	26.6	34.7	44.1	54.3
		Total	106.5	160.1	240.7	361.9
	Export	Waterway	51.9	82.0	129.6	204.8
		Truck	5.8	10.8	19.9	36.1
		Total	57.7	92.9	149.6	240.9
	Waterway		131.7	207.4	326.2	512.4
	Truck		32.4	45.5	64.1	90.4
	Total		164.1	253.0	390.3	602.8

Source: JICA Study Team

The estimated cargo tonnage of truck transport is converted to vehicular traffic by the average loading volume of 7.2 ton / truck, which was obtained by the traffic survey, and coefficients by empty truck are assumed as shown below.

Table 3.5.7 Assumption of Empty Cargo Coefficient

Year	Coefficient	Empty
2005	1.0	Around 50% empty
2010	0.8	Around 40% empty
2015	0.7	Around 30% empty
2020	0.6	Around 10% empty

Source: JICA Study Team

In addition, a route-choice ratio between NR 1 and NR 7 is set up considering the current destination of trucks. From the result of the traffic survey by the Study Team, around 50% of trucks comes through the Vietnam border on NR 7 to Phnom Penh. The traffic volume to Phnom Penh will drastically increase after the progress of cross border facilitation with Vietnam and full operation of new customs facilities at Bavet, the border city on NR 1. Considering these conditions, the following route choice ratio of NR-1 to all the trucks from Vietnam is assumed as shown in Table 3.5.8.

Table 3.5.8 Assumption of Route Choice between NR-1 and NR 7

Year	2005	2010	2015	2020
Ratio	0.5	0.9	0.9	0.9

Source: JICA Study Team
Note: Figures show a route-choice ratio of NR-1 via Bavet

Table 3.5.9 shows truck traffic crossing the Mekong River at Neak Loeung generated from the improved border trade with Vietnam.

Table 3.5.9 Estimated Truck Traffic Crossing the Mekong River to/from Vietnam

(Unit: Trucks)

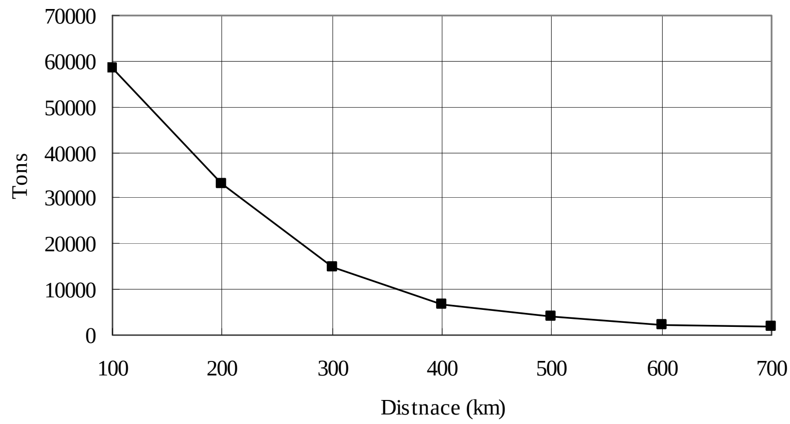
Growth	2005	2010	2015	2020
High	16	39	56	77
Middle		34	46	59
Low		30	37	45

Source: JICA Study Team
Note: Under the condition of no improvement of cross border facilitation.

(4) Impact by Bridge Construction and Improvement of Cross Border Procedures

Cambodia and its neighboring countries have been pursuing cross border facilitation to promote regional integration in GMS, which greatly contributes to acceleration of the border trade between Cambodia and Vietnam. A basic analytical tool derived from the Transport Study in Vietnam by JICA (2000)[18] is applied to estimate the impacts by the bridge construction and expected improvement of cross border facilitation on various procedures including abolition of transshipment of truck cargoes. These two factors are converted into travel time savings.

[18] JICA (2000) The Study on the National Transport Development Strategy in the Socialist Republic of Vietnam (VITRANSS)



Source: JICA (2000) VITRANSS prepared by JICA Study Team

Figure 3.5.4 Relationship between Transport Distance and Volume (by Truck)

The above diagram gives the following equation as the relationship between the transport distance and cargo volume, which is transported by truck.

$$Y=96300 \times 0.784^X$$

Where,

Y: Transport cargo volume (tons)

X: Transport distance (km)

Construction of bridge and abolition of transshipment of cargoes between trucks at the border bring about the following time savings of truck transport:

Table 3.5.10 Time Saving and Impact of Cross Border Facilitation

	Condition	Time	Impacts
Current average travel time between Phnom Penh and Ho Chi Minh	Including transshipment at the border	10.1 hours (average speed is 50 km/h)	
Construction of bridge	In place of ferry crossing	28 minutes[1)]	11% increase
Abolition of transshipment	Directly pass through the border without transshipment	5.0 hours saving (6.1 hours of travel time)	164% increase (2.64 times of initial volume)

Source: JICA Study Team
Note: [1)] Time saving of 26 minutes is estimated current average waiting time minus travel time by bridge.

Tables 3.5.11 - 3.5.13 shows projected truck traffic under the condition of current trend, without transshipment at the border and construction of bridge at Neak Loeung.

Table 3.5.11 Truck Traffic Crossing the Mekong River (Based on Current Trend)

Unit: Vehicles

Growth	2005	2010	2015	2020
High	16	39	56	77
Middle	16	34	46	59
Low	16	30	37	45

Source: JICA Study Team

Table 3.5.12 Truck Traffic Crossing the Mekong River without Transshipment

Unit: Vehicles

Growth	(2005)	2010	2015	2020
High	(26)	64	91	126
Middle	(26)	56	75	97
Low	(26)	50	61	74

Source: JICA Study Team
Note: Increment to estimated traffic based on the current trend

Table 3.5.13 Truck Traffic Crossing the Mekong River after Completion of Bridge

Unit: Vehicles

Growth	(2005)	(2010)	2015	2020
High	(5)	(11)	16	22
Middle	(5)	(10)	13	17
Low	(5)	(9)	11	13

Source: JICA Study Team
Note: Increment to estimated traffic based on the current trend

3.5.5 Traffic Generated from Modal Change

Many pedal-cycles and pedestrians currently use ferry transport to cross the Mekong River. The traffic survey by the Study Team revealed that major destination of these users is Phnom Penh. Accordingly, there is much possibility that the ferry users by pedal-cycles and pedestrians will change their transport modes when the bridge is completed. Hance, it is assumed that users will grow as the district-population increases and will cross the bridge by mini-buses. Table 3.5.14 shows the mini-bus traffic crossing the Mekong River transferred from the pedal-cycles and pedestrians on ferry ships. All the traffic is converted into PCU by the conversion rate of 1.75.

Table 3.5.14 Traffic from Pedal-cycles and Pedestrians

Unit: PCU

Mode	(2010)	2015	2020
From pedal-cycles	(65)	70	76
From pedestrians	(693)	748	813
Total	(758)	818	890

Source: JICA Study Team

3.5.6 Cross-border Traffic (Passenger)

Cross border facilitation is also expected to generate passenger traffic. Passenger traffic is expected to increase according to the progress of unification of GMS. Table 3.5.15 shows the current passenger trend including traffic between Cambodia and Vietnam.

Table 3.5.15 International Visitors to Cambodia by Air

Unit: Passengers

Countries		1998	1999	2000	2001	2002
ASEAN		38,046	48,791	55,684	58,363	55,465
	Thailand	10,983	15,272	16,550	17,496	17,109
	Vietnam	3,044	5,217	8,333	7,828	7,671
	Others	24,019	28,302	30,801	33,039	30,685
Asia & Ocean		69,375	88,263	99,666	104,735	118,880
Europe		46,165	60,031	65,657	66,088	79,246
USA		21,773	36,233	42,156	43,905	64,415
Africa & others		551	1,064	1,486	1,598	2,181
Siem Reap Direct Flight		10,423	28,525	87,012	133,688	202,791
Total		186,333	262,907	351,661	408,377	522,978

Source: Statistical Year Book 2003

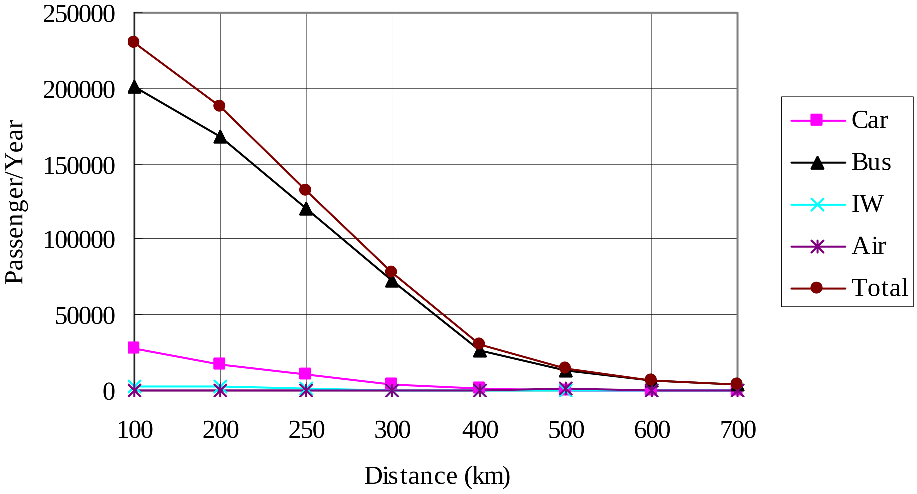
The number of visitors by different mode of transport modes to/from Thailand and Vietnam is shown in Table 3.5.16.

Table 3.5.16 Share of Visitors by Mode

Country	Air		Land & Boat		Total	
	No. of Passenger	Share	No. of Passenger	Share	No. of Passenger	Share
Thailand	26,099	0.44	33,476	0.56	59,575	1.00
Vietnam	8,507	0.27	23,101	0.73	31,608	1.00

Source: Statistical Year Book 2002

Potential passenger traffic between Cambodia and Vietnam is analyzed based on long passenger trip traffic surveyed in the Transport Study in Vietnam by JICA (2000). The relationship between the passenger traffic and trip distance is shown in Figure 3.5.5.



Source: JICA (2000) VITRANSS prepared by JICA Study Team

Figure 3.5.5 Passenger Traffic by Trip Distance

The number of visitors between Cambodia and Vietnam will greatly increase when the border is fully opened without any obstructions in customs procedures and transportation development. It is expected to grow to more than 16 times the current number according to potential analysis based on visitors to Thailand.

Potential Visitors from Vietnam to Cambodia = Potential (Thai/Vietnam) x Existing (Vietnam/Thai)

where,

Potential (Thai/Vietnam) = 31 (ratio of the estimated passengers traveled by 700 km divided by that by 250 km)

Existing (Vietnam/Thai) = 31,608/59,575

Table 3.5.17 shows the number of potential visitors between Cambodia and Vietnam and they are assumed to be fully realized in 2020.

Table 3.5.17 Estimated Visitors to/from Vietnam

Unit: Passengers

Year	Annual		Daily		Total	
	Car	Bus	Car	Bus	Ann.	Daily
2005	4,993	31,217	14	86	36,210	99
2010	11,120	69,524	30	190	80,644	221
2015	24,766	154,838	68	424	179,604	492
2020	55,156	344,844	151	945	400,000	1,096

Source: JICA Study Team
Note: 2005 passengers are estimated under the condition of 5% annual growth from 2002

The number of visitors is converted to that of cars / mini-buses by using occupancy rates of 2.5 and 16.63 respectively. Consequently, the PCU traffic is derived as shown in Table 3.5.18.

Table 3.5.18 PCU Traffic by Visitors to/from Vietnam

Unit: PCU/day

Year	Car	Bus	Total
2005	6	9	15
2010	14	20	34
2015	32	45	76
2020	70	99	170

Source: JICA Study Team

3.5.7 Traffic Generated by Bridge Construction

(1) Traffic Generated by Kizuna Bridge

In case of Kizuna Bridge which opens in December 2001, the traffic after completion of the bridge will greatly increase by around 75% according to the past traffic survey results (see Table 3.5.19 and Figure 3.5.6).

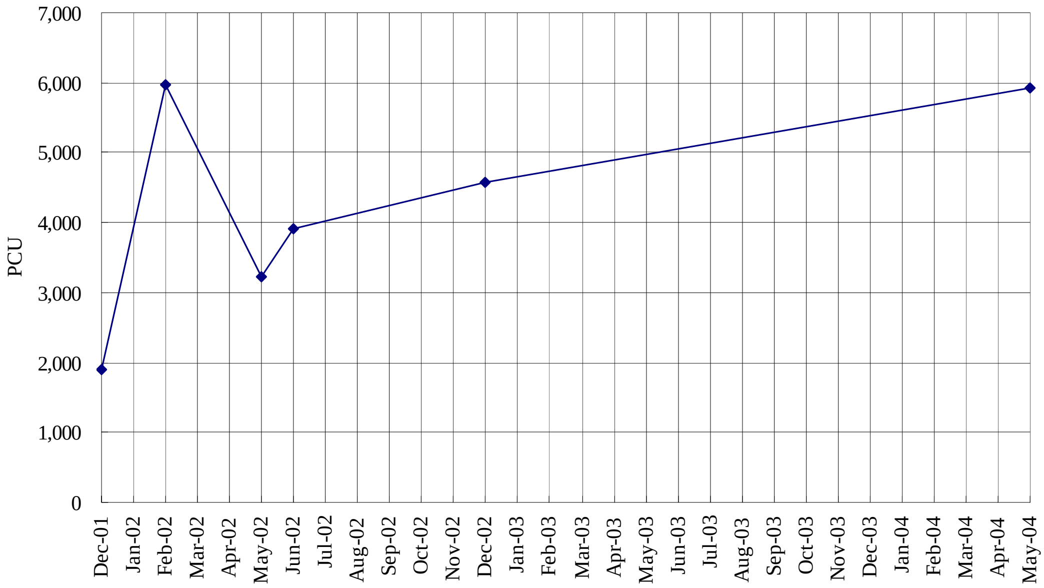
Table 3.5.19 Traffic at Kizuna Bridge

Unit: Vehicles/12h and PCU/12h

Type	Before	After	Growth (After/Before)
MC	1,889	2,915	1.54
LV	465	800	1.72
HV	183	375	2.05
PCU	1,432	2,513	1.75

Source: JICA Study Team prepared from several JICA studies

Note: "Before" is the count date on 01 Nov. 2001 and "After" is that on 02 May 2001. MC: Motorbike, Motor Tricycle / Motorbike Trailer, LV: Sedan, Wagon, Light Van / Pickup, Jeep Light Truck, HV: Short & Long Body Bus / Short & Long Body Truck / Semi and Full Trailer Truck



Source: JICA Study Team prepared from several JICA studies

Figure 3.5.6 Traffic Before and After Kizuna Bridge

It should be noted that Kampong Cham, where Kizuna Bridge is located, forms an important regional center in the region surrounding the suburban area where many people commute to the regional center for work, business activities, shopping and other purposes. Kizuna Bridge greatly contributed to expansion of the suburban area extending to the opposite side of the Mekong River, which was less populated before the completion of the bridge. This is one reason why great impacts by the construction of the bridge could be derived.

(2) Traffic Generated by the Project

According to the traffic survey, the average travel time observed at Neak Loeung is around 2.5 hours. After completion of the bridge, around 28 minutes will be saved by diversion from the ferry to the bridge. This travel time saving is estimated to bring about **6%** increase in traffic, excluding border trade traffic by the construction of bridge, based on the relationship between passenger traffic and trip distance obtained by the Transport Study in Vietnam by JICA (2000) (refer to Figure 3.5.4).

(3) Toll Free Bridge

5% increase is assumed as the toll free case. This is because the impacts on traffic by toll free is considered not to exceed those brought about by the construction of the bridge, estimated at **6 %** increase.

3.5.8 Traffic Generated from Area Development

Area development is planned in the Study to widely augment the benefit to Neak Loeung and its neighboring area. Considering the number of newly resided and newly employed people (jobs), traffic volume generated from the area development is estimated as shown in Table 3.5.21. Inter-zonal trips are estimated under the condition that the intra-zonal ratio is 90% of the total. The bridge traffic is estimated under the condition that 80% of the inter-zonal traffic, which is generated from newly resided employees from the area development, that is, 8% of the total traffic will use the new bridge. The results are summarized in Table 3.5.22:

Table 3.5.20 Population and Job Generated from Area Development

Unit: Persons

Item		2015	2020
Total	Population	1,200	5,000
	Jobs	600	2,500
New	Population	300	1,600
	Jobs	150	800
Move[1)]	Population	900	3,400
	Jobs	450	1,700

Source: JICA Study Team
Note: [1)] Come from within Neak Loeung

Table 3.5.21 Traffic Generated from Area Development

Unit: Vehicle or PCU Trips

Type	2015			2020 (additional to 2015)			All total		
	New	Exist-ing	Total	New	Exist-ing	Total	New	Exist-ing	Total
MC Generated	865	901	1,766	942	1,049	1,992	1,808	1,950	3,758
MC Attracted	975	1,014	1,989	1,059	1,175	2,234	2,034	2,188	4,223
LV Generated	197	205	401	214	239	453	411	443	854
LV Attracted	222	230	452	241	267	508	462	497	960
HV Generated	14	14	28	15	16	31	28	31	59
HV Attracted	14	15	29	15	17	32	29	31	61
Total (Vehicle)	2,287	2,379	4,665	2,486	2,763	5,250	4,772	5,140	9,915
Total (PCU)	1,017	1,058	2,074	1,105	1,228	2,334	2,122	2,286	1,017

Source: JICA Study Team
Note: MC: Motorbike, Motor Tricycle / Motorbike Trailer, LV: Sedan, Wagon, Light Van / Pickup, Jeep Light Truck, HV: Short & Long Body Bus / Short & Long Body Truck / Semi and Full Trailer Truck

Table 3.5.22 Traffic Crossing the Mekong Bridge from Area Development

Unit: Vehicle or PCU Trips

Type	2015	2020 (additional to 2015)	Total
	New	New	
MC G	69	75	307
MC A	78	85	
LV G	16	17	70
LV A	18	19	
HV G	1	1	5
HV A	1	1	
Total (Vehicle)	183	198	382
Total (PCU)	81	88	170

Source: JICA Study Team

Note: 8% of the traffic by the newly resided employees generated/attracted from area development. MC: Motorbike, Motor Tricycle / Motorbike Trailer, LV: Sedan, Wagon, Light Van / Pickup, Jeep Light Truck, HV: Short & Long Body Bus / Short & Long Body Truck / Semi and Full Trailer Truck

3.5.9 Future Traffic Demand Forecast by Scenario

(1) Timing of Facility Development

Prior to the traffic demand forecast, the following time schedule on facility development and institutional improvement is set up:

Year 2005: The border with Vietnam is fully opened for passengers

Year 2007: Transshipment at the border with Vietnam is abolished

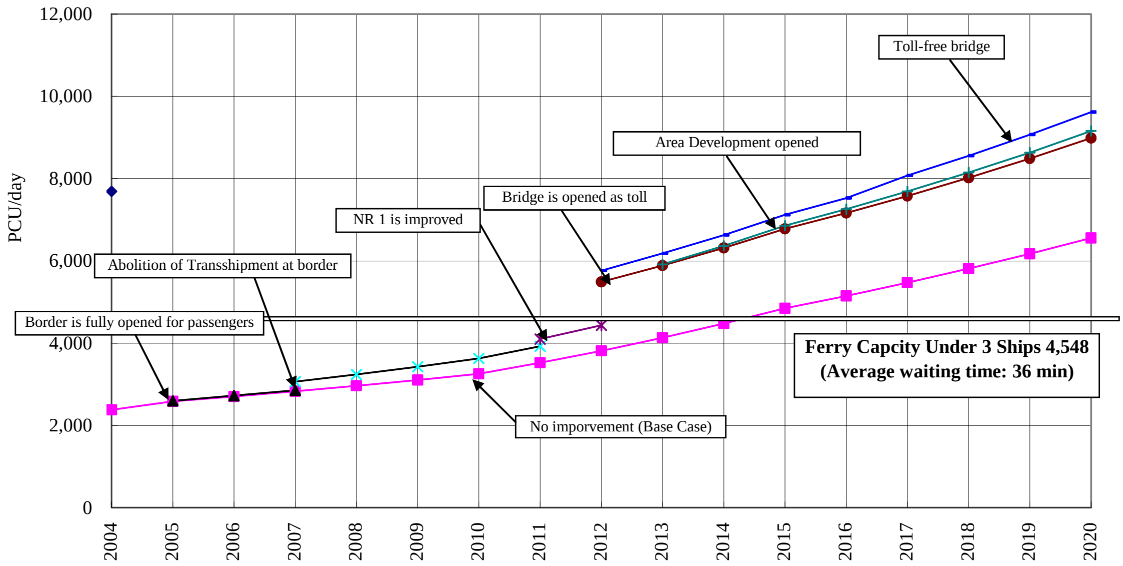
Year 2011: Road improvement on National Road No.1 is completed

(2) Appropriate Timing of the Bridge Opening

Allowing the average waiting time of 36 minutes, a total daily maximum load of three ferries is estimated at 4,548 PCUs as discussed in Section 3.1.4. Under the assumption that all facility development is completed as scheduled, the daily traffic volume to cross the river is estimated at 4,361 PCUs in 2012 and this exceeds the loading capacity of three ferries in 2013. Accordingly, it is desirable for the bridge to open to traffic in the Year 2012 before the existing ferry capacity is saturated. This timing will eventually be compatible with the completion of the NR1 improvement in 2011. Along with the bridge opening, area development is supposed to start at the flood-free land. The time schedule therefore is set up as follows:

- Year 2012: The project bridge is open to traffic in 2012[19] and the area development starts at the flood-free land.
- Year 2020: Area development at the flood-free land is completed.

[19] For economic and financial analysis, September 2012 is employed as the opening time of the bridge.



Source: JICA Study Team

Figure 3.5.7 Traffic Demand by Scenarios (Medium Case)

(3) Results of Traffic Forecast

All the results of traffic forecasts derived from various improvement scenarios are shown in Table 3.5.23 and the AADT by vehicle type is shown in Table 3.5.24.

Table 3.5.23 Summary of Estimated Future Traffic Volume by Improvement Scenario

Unit: Vehicles or PCU/day

Improvement Scenarios					Growth Case	2004	2005	2010	2015	2020	Remarks
A	Base Case (without Project) (PCU)				High		2,583	3,526	5,383	7,490	
					Medium	2,376	2,583	3,253	4,848	6,557	
					Low		2,583	2,983	4,313	5,625	
B	Traffic Generated by Improvement of NR1 (PCU)			Impact Coefficiency					0.05	0.05	NR1 will be improved in 2011
				Base Case	High				269	374	
					Medium				242	328	
					Low				216	281	
C1	Cross-border Traffic (Truck)	(Vehicle)		No Improvement	High			39	56	77	
					Medium		16	34	46	59	
					Low			30	37	45	
C2				Without Transshipment	High			64	91	126	Transshipment at the border will be abolished in 2007
					Medium			56	75	97	
					Low			50	61	74	
C3				Bridge Open After No Transshipment	High				16	22	
					Medium				13	17	
					Low				11	13	
C1		(PCU) (3+4.5)/2= 3.75		No Improvement	High			146	209	289	
					Medium		59	129	171	221	
					Low			114	140	170	
C2				Without Transshipment	High			240	342	474	Transshipment at the border will be abolished in 2007
					Medium			212	281	363	
					Low			187	230	278	
C3				Bridge Open After No Transshipment	High				61	84	
					Medium				50	64	
					Low				41	49	
D	Traffic Generated from Modal Change (PCU)				PCU				818	890	Pedal-cycles & pedestrians will change to mini-buses after the bridge opens in
E	Cross-border Traffic (Passenger) (PCU)				PCU		15	34	76	170	The border is fully opened for passengers in 2005
F	Traffic Generated by Bridge Construction (PCU)				High				323	449	The bridge will be open in 2012 (6% increment to Base Case)
					Medium				291	393	
					Low				259	338	
G	Traffic Generated from Area Development (PCU)								81	170	Area development will be completed in 2020
Ferry Only (excluding C3,D,F,G)				Without Transshipment	High			3,946	6,279	8,797	Under the Assumption of Ferry
					Medium	2,376	2,657	3,629	5,619	7,640	
					Low			3,318	4,975	6,524	
Toll Bridge (PCU)				Without Transshipment	High			3,946	7,562	10,390	Bridge (Toll)
					Medium	2,376	2,657	3,629	6,859	9,157	
					Low			3,318	6,174	7,971	
Toll-free Bridge (PCU)				Without Transshipment	High			3,946	7,941	10,910	Bridge(Toll-free)
					Medium	2,376	2,657	3,629	7,202	9,615	
					Low			3,318	6,483	8,369	

Source: JICA Study Team

Table 3.5.24 Estimated Future AADT by Year and Improvement Scenario

Unit: Vehicles or PCU/day

Category of Traffic	Remarks	Type	2005	2006	2007	2008	2009	2010	2011	**2012**	2013	2014	2015	2016	2017	2018	2019	2020
Base Case (without Project)	Medium Base Case (6% p.a.)	MC	1,816	1,920	2,023	2,126	2,230	2,333	2,476	**2,619**	2,761	2,904	3,047	3,235	3,423	3,611	3,799	3,986
		LV	870	919	968	1,016	1,065	1,114	1,222	**1,331**	1,439	1,548	1,657	1,793	1,929	2,065	2,201	2,338
		HV Combined	596	625	654	682	711	740	783	**826**	870	913	957	1,017	1,078	1,138	1,199	1,259
		Total	3,283	3,464	3,644	3,825	4,006	4,186	4,481	**4,776**	5,071	5,366	5,660	6,045	6,429	6,814	7,198	7,583
Traffic Generated by Improvement of NR1	NR1 will be improved in 2011 (5% increment to Base Case)	MC							124	**131**	138	145	152	162	171	181	190	199
		LV							61	**67**	72	77	83	90	96	103	110	117
		HV Combined							39	**41**	43	46	48	51	54	57	60	63
		Total					200	209	224	**239**	254	268	283	302	321	341	360	379
Cross-border Traffic (Truck)	No improvement	HV Truck	16	19	23	27	31	34	37	**39**	41	43	46	48	51	54	56	59
	Transshipment will be abolished in 2007	HV Truck			38	44	50	56	60	**64**	68	71	75	79	84	88	92	97
	Bridge opens in 2012	HV Truck								**11**	12	13	13	14	15	16	16	17
Traffic Generated from Modal Change	Pedal-cycles & pedestrians will change to mini-buses after the bridge opens	HV MB from Pedal-cycles								**38**	39	40	40	41	42	42	43	44
		HV MB from Passengers								**408**	415	421	427	435	442	450	457	465
		Total HV MB								**447**	454	461	468	476	484	492	500	508
Cross-border Traffic (Passenger)	The border is fully opened for passengers in 2005	LV	5	7	8	10	11	12	15	**18**	21	24	27	34	40	47	54	60
		HV MB	5	6	8	9	10	11	14	**17**	20	23	26	32	38	44	51	57
		Total	11	13	16	18	21	24	29	**35**	41	47	53	66	78	91	104	117
Traffic Generated by Bridge Construction	The bridge will be open in 2012 (6% increment to Base Case)	MC								**157**	166	174	183	194	205	217	228	239
		LV								**80**	86	93	99	108	116	124	132	140
		HV Combined								**50**	52	55	57	61	65	68	72	76
		Total								**287**	304	322	340	363	386	409	432	455
Traffic Generated from Area Development	Area development will be completed in 2020	MC								**0**	37	74	147	179	211	243	275	307
		LV								**0**	8	17	33	41	48	55	63	70
		HV Combined								**0**	1	1	2	3	3	4	4	5
		Total								**0**	46	91	183	223	262	302	342	382
Total Traffic (Vehicle Base)		MC	1,816	1,920	2,023	2,126	2,230	2,333	2,600	**2,907**	3,102	3,297	3,529	3,770	4,011	4,251	4,492	4,732
		LV	876	926	976	1,026	1,076	1,126	1,298	**1,495**	1,627	1,759	1,899	2,065	2,230	2,395	2,560	2,725
		HV MB	5	6	8	9	10	11	14	**464**	474	483	493	508	522	536	551	565
		HV Combined	596	625	654	682	711	740	822	**917**	966	1,015	1,064	1,132	1,199	1,267	1,335	1,402
		HV Truck	16	19	61	71	81	91	97	**114**	121	127	134	142	150	157	165	173
		Total	3,309	3,496	3,721	3,915	4,108	4,301	4,832	**5,898**	6,290	6,682	7,120	7,616	8,111	8,607	9,102	9,598
Total Traffic (PCU Base)		PCU by MC	232	246	259	272	285	299	333	**738**	788	838	896	958	1,019	1,080	1,141	1,202
		PCU by LV	1,020	1,079	1,137	1,195	1,253	1,312	1,513	**1,742**	1,896	2,049	2,213	2,405	2,598	2,790	2,982	3,175
		PCU by HV MB	9	11	13	16	18	20	25	**812**	829	846	863	888	913	939	964	989
		PCU by HV Combined	1,336	1,401	1,465	1,529	1,593	1,657	1,843	**2,056**	2,165	2,275	2,385	2,537	2,688	2,839	2,991	3,142
		PCU by HV Truck	59	73	230	267	304	341	363	**428**	452	477	502	531	561	590	620	649
		PCU Total	2,657	2,809	3,104	3,279	3,454	3,629	4,076	**5,776**	6,130	6,485	6,859	7,319	7,778	8,238	8,698	9,157

Source: JICA Study Team
Notes: MC: Motorbike, Motor Tricycle / Motorbike Trailer
LV: Sedan, Wagon, Light Van / Pickup, Jeep Light Truck
HV Combined: Short & Long Body Bus / Short & Long Body Truck / Semi and Full Trailer Truck
HV Truck: Large Body Truck / Semi & Full Trailer Truck (from Vietnam)
HV MB: Short & Long Body Bus