5.6 Trip Assignment Process

The purpose of the trip assignment process is to replicate the amount of traffic on the road system. Thus, the content of trip matrixes (daily pcu trips) is "loaded" onto the roadway network where trip origin-destination patterns are permitted to interact with embedded network parameters (distance, time, speed, capacity and other user-specified criteria).

Two separate assignment methodologies were applied to ensure that Highway 18 evaluations are conducted in a through manner.

1) An equilibrium assignment process, which consists of an iterative series of all-or-nothing traffic assignments with an adjustment of link capacity/speed reflecting congestion encountered in the associated iteration. The load from each assignment after the first iteration is combined with the previous load in such a way as to minimize the impedance of each trip and thus reducing the number of iterations to find the equilibrium loads. Equilibrium assignment is multipath because the final loads are a linear combination of the all-or-nothing loads of each iteration. These loads may be assigned to different paths because of the time adjustments after each iteration.

2) A single-iteration assignment, during which trips between all zone, follow a single (all-or-nothing) minimum time path based on free-flow speeds embedded in each link.

The equilibrium avalogy is generally considered a more robust approach to trip assignment. However, distortions in trip allocation will occur if part or parts less complex network reach satuation (V/C approaches unity). This occurs in the study area by year 2005 (to a degree), and most certainly under year 2015 conditions. Specifically, Highway 5 between Ha Noi and Hai Phong, and the Highway 1 corridor northeast of Ha Noi are shown as experiencing severe congestion. As a result, the equilibrium process distributes trips from these corridor into more underutilized (relative to Highways 1 and 5) segments of Highway 18 (i.e. Highway 286).

5.7 Forecast Demand

Trip matrixes for future years (2005, 2015) were assigned to future networks which, as discussed in previous parts of this chapter, reflect both "with" and "without" JICA Highway 18 improvement scenarios. Findings were, for presentation purposes, grouped over 10 discrete modeling sections (Figure 5.11). The principal determinant of section selection is that the volume on all individual links comprising each of the ten sections be identical. Thus, section boundaries are formed by centroids or link junction. Forecast demand is therefore presented in Section 5.7.1 stratified by ten modeling sections.

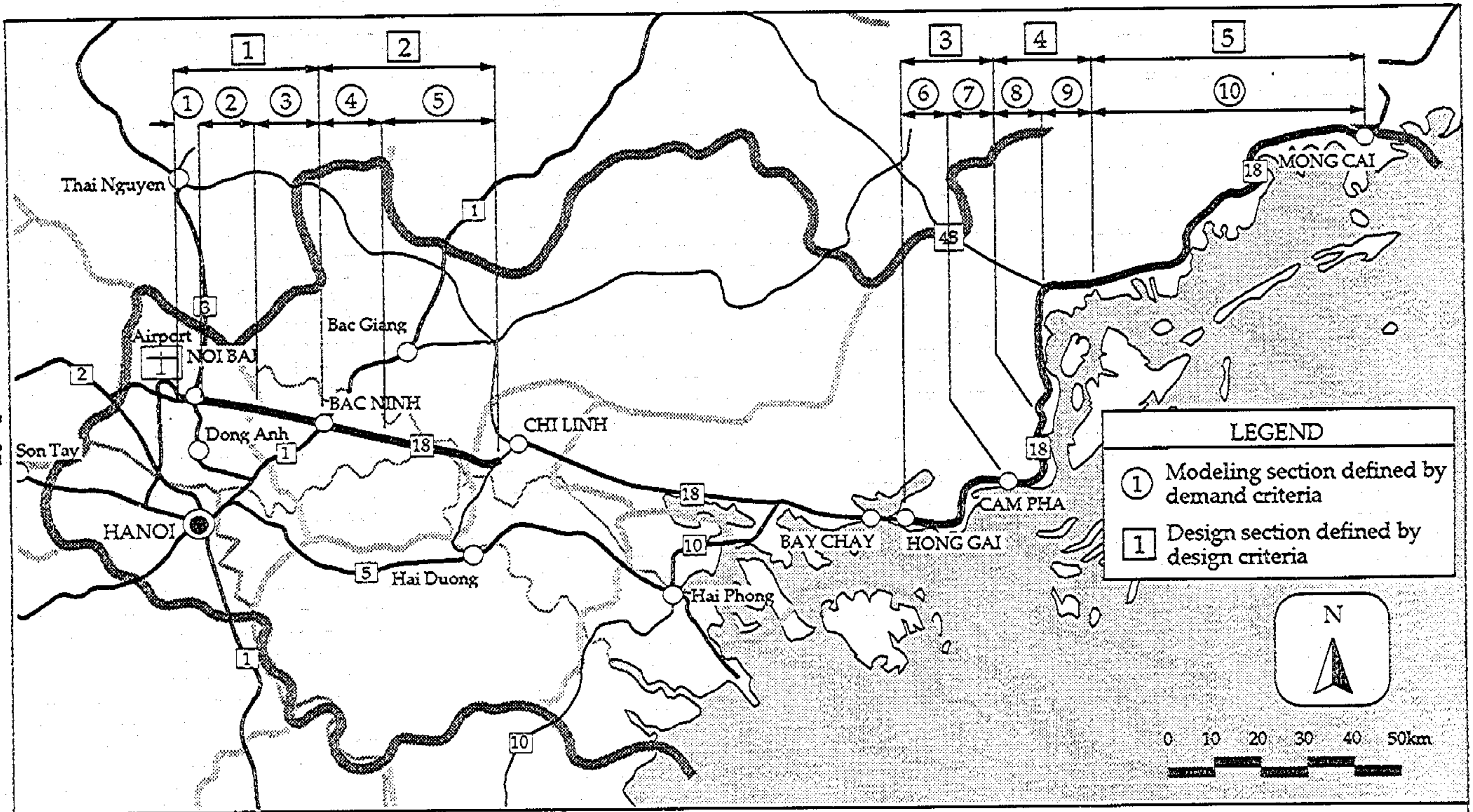


Figure 5.11 Analysis Section Definitions Highway 18 Corridor

The engineering design and economic analysis components of the Highway 18 study are, however, based on five design sections. The ten modeling sections readily conform to the five design section (refer Figure 5.11). Therefore, to maintain consistency with other elements of the study, roadway sufficiency is discussed in Section 5.7.2 in terms of five design sections.

5.7.1 Utilization Patterns

The strong growth in vehicle trip activity intimated by the trip matrixes is confirmed by results of the assignment process. Several conclusions may be drawn in terms of the total daily unconstrained pcu demand calculated on principal road links throughout the study area (Figure 5.12)

(1) Highest volume segments are encountered on Highway 5, with daily activity ranging between 66,000 and 83,000 pcu's, depending on status of Highway 18. These data suggest that, in the longer term future, the four-lane Highway 5 cross-section (currently under construction) may prove inadequate to meet demand along the Ha Noi - Hai Phong axis.

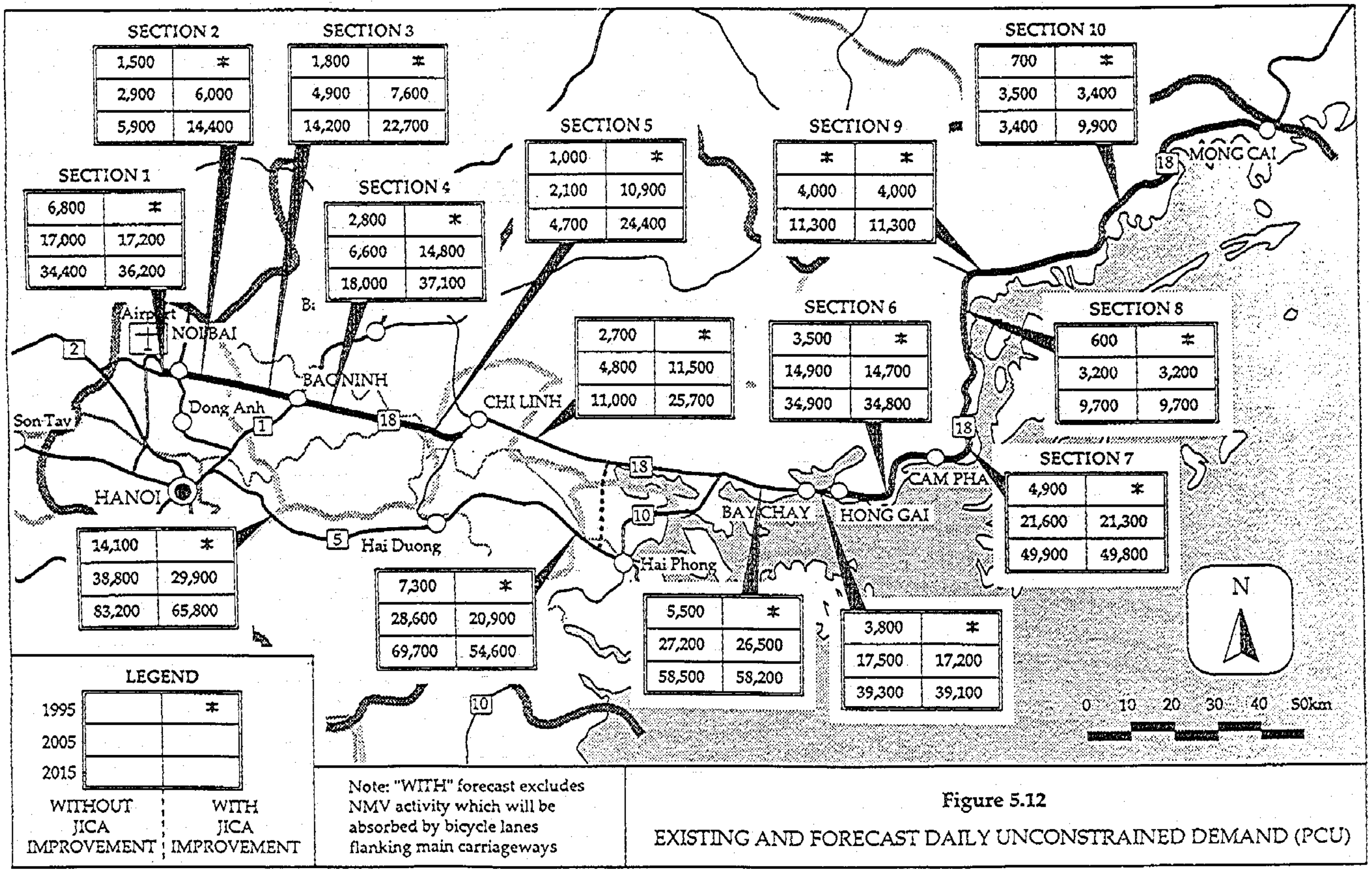
(2) The status of Highway 18 catalyzes a considerable "swing" in traffic demand between the Highway 5 and 18 axis. In 2005, for example, the volume on Highway 5 east of Ha Noi Province is shown as almost 40,000 pcu if Highway 18 is not improved, but only 30,000 pcu if Highway 18 is improved.

(3) Two sections of the Highway 18 corridor at present, experience considerable capacity constraints. These are Highway 286 between Highway 3 and Highway 1, as well as the Pha Lai ferry segment. These constraints are clearly mirrored in the forecasts, as is the urgent need for improving these segments if future demand potential is to be realized. At Pha Lai ferry (modeling section 5), for example, the assignment process suggests that less than 5,000 pcu's per day can be accommodated under the "without" improvement scenario under year 2015 condition. However, demand will increase dramatically to over 24,000 pcu per day if the ferry is replaced by a bridge and the section road upgraded to a reasonable standard.

(4) The Highway 286 segment (modeling sections 2 and 3) exhibits similar results. Along section 3, year 2015 demand is shown as ranging from 14,200 to 22,700 pcu per day for the "without" and "with" scenarios, respectively.

(5) Since the improvement of Highway 18 is very likely, it must be assumed that considerable growth will occur in this important corridor. East of Bac Ninh (section 4), for example, the current daily volume of under 3,000 pcu's will likely reach 15,000 pcu's and 37,000 pcu's over the next two decades. Likely, near Pha Lai ferry (section 5), daily demand is, over the next 20 years, shown as increasing by a factor of 24 relative to 1995 volumes.

Note: Conversion factor is used to attain the number of traffic volume as to the equivalent passenger car unit (pcu), i.e., truck = 2.5, bus = 2.25, car = 1.0, motorcycle = 0.33 and bicycle = 0.25.



Note: "WITH" forecast excludes NMV activity which will be absorbed by bicycle lanes flanking main carriageways

Figure 5.12

EXISTING AND FORECAST DAILY UNCONSTRAINED DEMAND (PCU)

(6) Demand along several sections will, by year 2015, approach 40,000 daily pcu's. These include section 1 (Highway 2), section 4 (Highway 18 near Bac Ninh) and section 6 (Highway 18 between Hong Gai and Cam Pha). The considerable truck content of the Cam Pha - Cua Ong traffic stream (section 7) catalyzes a daily loading which is shown as approaching 50,000 pcu's by year 2015.[20]

(7) Demand forecasts along Highway 18 north of Cua Ong (section 8.9 and 10) are modest relative to other parts of the corridor totaling some 4,000 and 10,000 daily pcu's by year 2005 and year 2015, respectively. However, even the year 2015 total still represents a roughly 15-fold increase over current levels of traffic activity.

The motorcycle, which already at present outnumbers other motorized modes combine on all "flat terrain" sections, is forecast to increase in dominant role in future as motorcycle ownership patterns continue to rapidly increase. The mix among cars, buses and trucks varies depending on the proximity of urband concentrations or pockets of industrial activity. Near Bac Ninh (section 4) for example, year 2015 vehicle trip forecasts suggest that some 3,900 cars, 3,200 buses and 6,000 trucks will use Highway 18 (Table 5.14).

5.7.2 Sufficiency Analysis

The analysis of Highway 18 sufficiency, that is, the ability of the road to absorb forecast demand, is conducted for each of the five design sections (refer Figure 5.10). Demand and capacity data developed for the ten modeling sections was correspondingly combined to the five design sections on a distance-weighted basis.

Two points are particularly relevant in light of the sufficiency review:

(1) Road performance involves the interplay of two different capacities (existing road, improved road) with forecast "with improvement" demand. It must, however, be recognized that capacity, like demand, is dynamic over time. Only capacity for a motorway will, for example, remain unchanged since that facility enjoys absolute control of access and roadside activity will not occur within the motorway's right-of-way. In the case of arterials, however, flanking land uses will, over time, modify as existing urbanization patterns expand and intensify, or new land uses are introduced thus altering what at present are essentially rural environments.

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[20] As no routing choices exist east of Bai Chay ferry, demand forecasts under "with" and "without" forecasts are identical, albeit at differing levels of service. It is also noted that all "with" forecasts do not include non-motorized vehicle pcu's as this mode will be accommodated by bicycle lanes flanking the main carriageway, not the carriageway proper.

Table 5.14 Summary of Existing and Forecast Unconstrained Vehicle Demand Highway 18 Corridor

SECTION (1)		ANALYSIS	VEHICLES PER DAY (3)										
			WITHOUT JICA HWY 18 IMPROVEMENT (4)						WITH JICA HWY 18 IMPROVEMENT (4)(5)				
NUMBER	NAME	YEAR (2)	CAR	BUS	TRUCK	TOTAL	MC (6)	NMV	CAR	BUS	TRUCK	TOTAL	MC (6)
1	NOI BAI – HIGHWAY 3	1995	1,000	600	800	2,400	4,600	3,900	1,000	600	800	2,400	4,600
		2000	1,750	1,000	1,000	3,750	9,200	3,650	1,800	1,050	1,100	3,950	9,200
		2005	3,150	1,700	1,300	6,150	18,450	3,400	3,300	1,750	1,550	6,600	18,450
		2010	4,700	2,500	1,750	8,950	26,450	2,400	4,950	2,600	2,150	9,700	26,450
		2015	7,100	3,750	2,350	13,200	37,950	1,650	7,500	3,900	3,000	14,400	37,950
2	HWY 3 – HA BAC PROVINCE	1995	<50	100	150	250	1,300	2,000	<50	100	150	250	1,300
		2000	50	150	150	350	2,350	1,850	150	250	300	700	2,350
		2005	100	250	200	550	4,250	1,700	950	750	800	2,500	4,250
		2010	150	400	250	800	6,000	1,200	1,550	1,300	1,100	3,950	6,000
		2015	200	750	350	1,300	8,450	850	2,550	2,300	1,550	6,400	8,450
3	HA BAC PROVINCE – BAC NINH	1995	50	<50	100	150	1,600	3,850	50	<50	100	150	1,600
		2000	50	<50	150	200	3,950	3,600	150	100	300	550	3,950
		2005	100	50	250	400	9,850	3,350	1,000	550	850	2,400	9,850
		2010	250	100	300	650	18,800	2,350	1,700	1,000	1,200	3,900	18,800
		2015	500	150	400	1,050	35,850	1,650	2,800	1,750	1,650	6,200	35,850
4	BAC NINH – VIET HUNG	1995	150	150	300	600	1,800	3,800	150	150	300	600	1,800
		2000	250	250	350	850	4,200	3,600	500	450	850	1,800	4,400
		2005	450	400	500	1,350	9,700	3,250	1,650	1,250	2,750	5,650	10,600
		2010	800	750	700	2,250	17,550	2,300	2,500	2,000	4,050	8,550	19,050
		2015	1,450	1,450	950	3,850	31,800	1,600	3,850	3,150	5,950	12,950	34,100
5	VIET HUNG – CHI LINH	1995	100	50	150	300	450	650	100	50	150	300	450
		2000	200	50	250	500	800	600	400	200	700	1,300	1,050
		2005	300	50	400	750	1,450	500	1,450	900	2,650	5,000	2,350
		2010	500	100	550	1,150	2,250	350	2,200	1,400	3,900	7,500	3,750
		2015	850	250	800	1,900	3,550	250	3,300	2,050	5,800	11,150	5,850
6	HONG GAI – CAM PHA (7)	1995	400	600	450	1,450	1,400	850	400	600	450	1,450	1,400
		2000	650	950	1,150	2,750	3,700	800	650	950	1,150	2,750	3,700
		2005	1,100	1,500	2,750	5,350	10,000	750	1,100	1,500	2,750	5,350	10,000
		2010	1,650	2,300	4,400	8,350	14,450	500	1,650	2,300	4,400	8,350	14,450
		2015	2,600	3,450	7,000	13,050	20,950	350	2,600	3,450	7,000	13,050	20,950
7	CAM PHA – CUA ONG (7)	1995	450	750	750	1,950	1,850	1,200	450	750	750	1,950	1,850
		2000	750	1,200	1,850	3,800	4,950	1,100	750	1,200	1,850	3,800	4,950
		2005	1,250	1,950	4,550	7,750	13,300	1,000	1,250	1,950	4,550	7,750	13,300
		2010	1,800	2,850	7,200	11,850	19,200	700	1,800	2,850	7,200	11,850	19,200
		2015	2,650	4,200	11,400	18,250	27,750	500	2,650	4,200	11,400	18,250	27,750
8	CUA ONG – HIGHWAY 4B (7)	1995	100	100	100	300	100	<50	100	100	100	300	100
		2000	150	200	250	600	250	<50	150	200	250	600	250
		2005	250	350	800	1,400	700	<50	250	350	800	1,400	700
		2010	400	650	1,350	2,400	1,000	<50	400	650	1,350	2,400	1,000
		2015	700	1,200	2,350	4,250	1,400	<50	700	1,200	2,350	4,250	1,400
9	HIGHWAY 4B – TIEN YEN (7)	1995	100	150	100	350	150	100	100	150	100	350	150
		2000	150	300	300	750	400	100	150	300	300	750	400
		2005	300	500	850	1,650	1,100	100	300	500	850	1,650	1,100
		2010	500	900	1,500	2,900	1,600	100	500	900	1,500	2,900	1,600
		2015	850	1,550	2,500	4,900	2,300	50	850	1,550	2,500	4,900	2,300
10	TIEN YEN – MONG CAI (7)	1995	100	150	50	300	250	200	100	150	50	300	250
		2000	150	250	200	600	600	200	150	250	200	600	600
		2005	250	450	650	1,350	1,700	200	250	450	650	1,350	1,700
		2010	400	750	1,150	2,300	2,450	100	400	750	1,150	2,300	2,450
		2015	700	1,300	2,050	4,050	3,550	100	700	1,300	2,050	4,050	3,550

(1) Refer Figure 5.11 for section locations.
(2) Years 1995, 2005 and 2015 derived via assignment process. Years 2000 and 2010 derived via data interpolation.
(3) Rounded (to nearest 50) vehicles per day, total both directions of travel. Demand is unconstrained, i.e. not limited by capacity inherent to the road system.
(4) "With" and "wihout" JICA Hwy 18 improvement refers to upgrading of Noi Bai – Chi Linh and Hong Gai – Mong Cai segments.
(5) NMV (non-motorized vehicles) are accommodated by bicycle lanes flanking the main carriageway under the "with improvement" scenario.
(6) MC = motorcycle
(7) No alternative routing options exist east of Bai Chay ferry; "with" and "without" loadings are therefore identical.

The assignment capacity used in the modeling process, whose limits are calculated in accordance with ADB and IBRD-sponsored studies sensitive to Southeast Asian environments(21) (22), can be viewed as corresponding to "rural highway under uninterrupted flow" conditions. But, given the temporal impact of increasing urbanization and intensifying land use patterns, capacity will gradually moderate to lower levels which can be described as "semi-interrupted conditions". This plateau could, depending on statutory and developmental policies, further degrade to "interrupted conditions", particularly so in highly developed areas and certainly following the introduction of traffic control devices.

For purposes of the current study, it is adopted that the calculated 1995 capacity (uninterrupted conditions) will modify to semi-interrupted status by year 2005. Thus, the assignment capacity for an improved two-lane segment along Highway 18 will deteriorate from roughly 25,000 pcu per day to about 15,000 pcu per day. A similar rate (60 percent) is applied to unimproved capacities to maintain consistency of approach. This transition will be less pronounced for multi-lane arterials, and for two-lane arterials north of Cua Ong where rural environments are expected to remain largely unchanged in the foreseeable future.

(2) The sufficiency analysis seeks to ascertain how effective an enhanced two-lane section(23) is in meeting forecast levels of demand, and when additional capacity must be introduced into the corridor either as additional Highway 18 lanes or in terms of a new facility along a new alignment. The government has confirmed its stated intent to construct a motorway between Noi Bai and Hong Gai along an alignment which essentially parallels existing Highway 18. It is understood that preliminary feasibility studies regarding this facility have been completed by TEDI, and that final feasibility studies are expected to commence shortly. In light of this development, and pending completion of the motorway feasibility study, it must be concluded that justification for providing additional Highway 18 lanes between Noi Bai and Hong Gai is improbable, even in the longer-term future. This conclusion is reinforced by recent Government approaches to upgrading Highway 18 between Chi Linh and Hong Gai : improvements and right-of-way strategies support only an enhanced two-lane cross-section; a four lane profile is not being considered by the government.

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(21) "Road User Cost Model", op. cit.

(22) "Consulting Services for Highway Capacity Manual, Phase 2 - Interurban Highway", op. cit.

(23) Enhanced two-lane section implies a Class III road, per TEDI criteria. In flat terrain this entails a carriageway of seven meters width plus flanking two - meter NMV lanes. In hilly terrain, carriageway width is reduced to six meters.

A review of each design section yields:

(1) The existing capacity of design section 1 (Noi Bai - Bac Ninh) is very low (8,000 pcu per day) due to the poor state of Highway No. 286 and narrow width of existing bridges (3.5 - 4.0 m). Following implementation of an enhanced two-lane section, capacity will increase to over of 15,000 pcu per day. This should be sufficient for approximately ten years following completion of construction. The congestion degree is computed based on the traffic volume and road capacity. Table 5.15 indicates the congestion degree for "with project" and "without project" cases.

The traffic volume of passenger car units, shown in Figure 5.12 can be attained from the number of existing and forecast vehicle demand shown in Table 5.14, applying conversion factors (Truck = 2.5, Bus = 2.25, Car = 1.0, Motorcycle = 0.33, Bicycle = 0.25).

(2) The existing capacity of design section 2 (Bac Ninh - Chi Linh) is also very low (12,000 pcu/day). Constraints are posed by the actual road, which in places is unpaved or very rough, and also features a one-lane bridge. However, the Pha Lai ferry represents the limiting factor for the section: even with upgraded operation, it is unlikely that more than some 5,000 pcu per day can be accommodated. Thus, given forecast levels of demand, the upgrading to enhanced two-lane status, and the provision of an adequate bridge, emerge as priority objectives for this section.

The congestion degree is computed based on the traffic volume and road capacity. Table 5.15 indicates the congestion degree for "with project" and "without project" cases. The computation was made using the same conversion factors applied in design section 1 in the above.

(3) Design section 3 links Hong Gai, Cam Pha and Cua Ong. The forecast demand along this section is pronounced, and alternative facilities (such as the proposed motorway paralleling design sections 1 and 2) are not contemplated. Thus, any needed capacity enhancement must invariably focus on Highway No. 18 itself. The benefits gained by implementation of an enhanced two-lane section are marginal, and would prove beneficial for only some two years following construction. Clearly, along this section, the more intense capacity offered by four traffic lanes is required. Immediate upgrading to four lanes provides sufficient capacity over the entire planning horizon.

The congestion degree is computed based on the traffic volume and road capacity. Table 5.15 indicates the congestion degree for "with project" and "without project" cases. The computation was made using the conversion factors applied in design section 1 in the above.

(4) The required treatments of design section 4 (Cua Ong - Tien Yen) and design section 5 (Tien Yen - Mong Cai) are quite similar. Forecast levels of demand suggest that an enhanced two-lane cross-section will offer ample

capacity reserve for the foreseeable future. The priorities for improving these two sections are, from a road capacity point of view, clearly below those of design sections 1, 2 and 3.

The congestion degree is computed based on the traffic volume and road capacity. Table 5.15 indicates the congestion degree for "with project" and "without project" cases. The computation was made using the conversion factors mentioned in design section 1 in the above.

Table 5.15 Congestion Degree of Each Section

Section	Existing Highway Nos. 18 and 286			Improved Highway No. 18	
	Year	without project case		with project case	
	1995	2005	2015	2005	2015
1	0.23	0.62	1.78	0.51 (2 lane)	0.38 (4 lane)
2	0.23	0.55	1.5	0.99 (2 lane)	0.62 (4 lane)
3	0.41	1.8	4.2	0.39 (4 lane)	0.92 (4 lane)
4	0.08	0.4	1.2	0.21 (2 lane)	0.65 (2 lane)
5	0.09	0.44	1.2	0.23 (2 lane)	0.66 (2 lane)

Note: Congestion degree of 1.0 indicates the road is saturated and reaches its capacity.

5.8 Conclusions and Recommendations

The forecasting process and allied sufficiency analysis leads to several conclusions regarding treatments appropriate to Highway 18 improvement.

(1) Given the important role of the Noi Bai - Hong Gai vis-a-vis Highway No. 18, it is urged that the improvement of Noi Bai - Bac Ninh Section (i.e. constructions) should be completed at the earliest possible instance.

(2) Assuming realization of the alternate highway, it is reasonable to conclude that justification for upgrading the existing Highway 18 corridor between Bac Ninh and Chi Linh to beyond enhanced two-lane status is dubious from a view point of traffic. Indeed, recent actions by Government in the Chi Linh - Hong Gai segment of Highway 18 support and confirm this conclusion.

(3) The Hong Gai - Cam Pha - Cua Ong segment of Highway 18 requires capacity equivalent to four traffic lanes.

(4) Improvement of Highway 18 north of Cua Ong to Class III standard (mountainous terrain) seems appropriate in the light of modest levels of forecast traffic demand.

It is hoped that these conclusions and recommendations will prove beneficial to the Government of Vietnam in the on-going effort to improve transport infrastructure.

Chapter 6

PHYSICAL CONDITIONS OF STUDY AREA AND ENGINEERING SURVEY

CHAPTER 6 PHYSICAL CONDITIONS OF STUDY AREA AND ENGINEERING SURVEY

6.1 Physical Conditions of Study Area

6.1.1 Topography and River System

(1) Noi Bai - Chi Linh

The topography is favorable throughout the entire section. Flat land is spread out in the Red River Delta with an elevations at less than 10m. The area is mainly used for rice cultivation. The existing Highway No. 18 crosses Thai Binh river by Pha Lai ferry (200 - 250m) which is a major road transport bottleneck in this section.

(2) Hon Gai - Cua Ong

Highway No. 18 runs through flat or hilly coastal area but topography is generally favorable. Unfavorable road alignment due to rugged terrain is observed at Ha Tu. The terminus of this section is Cua Ong, a coal mining oriented town.

(3) Cua Ong - Mong Cai

Highway No. 18 mainly runs through the outer edges of mountainous area, however irrigated rice paddies exist in several river basins. The highway crosses a number of rivers, among these the major rivers (those exceeding 50 meters in width) are ; Ha Chant, Tien Yen, Dam Ha, Duong Hoa, Ha Coi, Nga Bat and Ka Long.

6.1.2 Climate

The seasons are influenced by the monsoons which blow from the southwest between May and October and from the northeast between November and April. The southwest monsoons bring heavy rainfalls, often storms and typhoons. During the northeast monsoon season (dry season) cold gusts and drizzles are common.

Annual average rainfall in Hanoi is about 1,700 mm of which 80 - 85% falls in the rainy season. The annual average number of rainy days is 140. Annual average temperature in Hanoi is 23.6^{o}C a its minimum of 4^{o}C and maximum 39.4^{o}C; mean humidity is 82%. In Quang Ninh province, the annual average rainfalls is 2,000 - 2,500 mm which is much higher than in Hanoi.

6.1.3 Geology

Geological sequence in the flat terrain is rather simple but complicated in the rolling/mountainous areas. A geological map of the study area is shown in Figure 6.1

(1) Noi Bai - Chi Linh

Geologically, the flat terrain in Red River Delta area is of alluvium or diluvium formation of Holocene or Pleistocene Ages, composed of alluvial or diluvial soils of gravel, sand, loam, silt and clay. According to the data obtained in the past studies, the bearing strata for the construction of pile foundation for bridge structures are situated at 20 - 30 meters depth from the existing ground level.

(2) Hon Gai - Cua Ong

The rolling terrain in Hon Gai - Cua Ong is mainly of limestone formation from the Carboniferous-Permian Age and of conglomerated sandstone or siltstone or coal formation of Triassic Age. The coastal plain in Cam Pha is of diluvial formation of Pleistocene Age and the soils are composed of silty clay.

(3) Cua Ong - Mong Cai

Geological sequence is a rather simple rolling terrain mainly composed of sandstone, siltstone or limestone formation from the Jurassic Age, and the coastal plain is of alluvial or dilluvial formation of Holocene or Pleistocene Ages and composed of variety of soils including gravel, sand, loam, silt and clay.

6.2 Soil and Material Investigation

6.2.1 Scope of Soil and Material Investigation

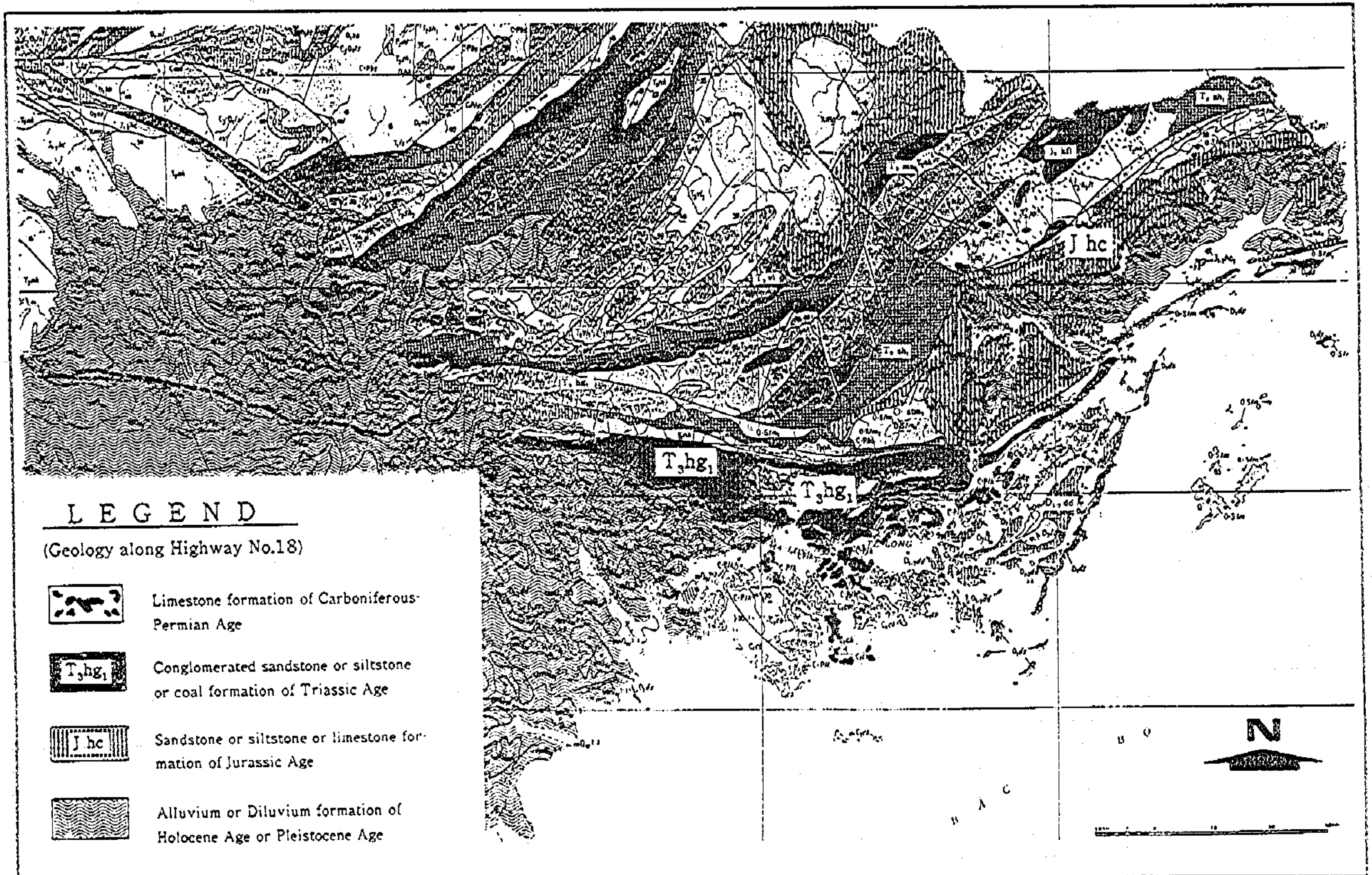
(1) Purpose of the Investigations

The purpose of the investigations is to obtain data for the preliminary design of embankment, pavement, bridges and other structures.

(2) Field Work and Laboratory Testing

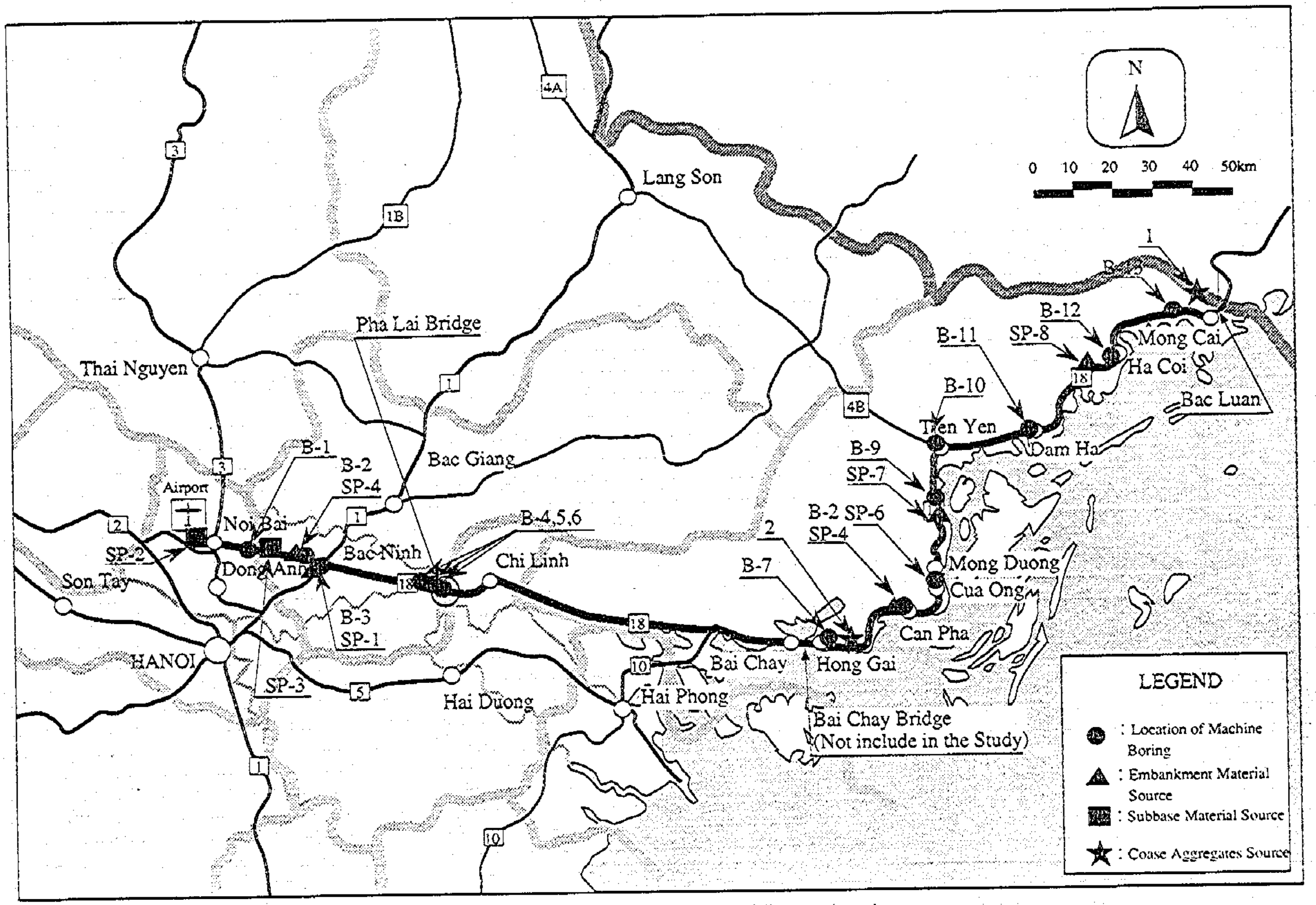
The field work and laboratory testing were conducted by a local consulting firm. The JICA Study Team planned and supervised investigations. Machine boring with standard penetration tests (2 in interval) was conducted at 13 locations. Thin-wall tube sampling were also carried out for soft soils. Test pit sampling were made at possible sources of embankment materials, pavement materials and concrete aggregates. (see Figure 6.2)

The laboratory testing for the following items were carried out for the collected samples.



HIGHWAY NO. 18 IMPROVEMENT

Figure 6.1 Geological Map of Study Area



Figre 6.2 Location Map for Soil Investigation

Item	Quantiry
- Specific gravity	72
- Natural water content	72
- Grain size analysis	72
- Liquid limit	72
- Plastic limit	72
- Absorption	72
- Triaxial compression (for thin-wall samples)	13
- Consolidation (for thin - wall samples)	13
- Compaction (for test - pit samples)	10
- CBR (for test - pit samples)	10

6.2.2 Special Descriptions of Results of Soils Investigation, Noi Bai - Pha Lai Stretch

(1) Borehole - B1 (Ca Lo Bridge)

Borehole - B1 is located at the right bank of the Ca Lo river. The exploration depth is 39.0 m and 20 standard penetration tests (SPT) and 2 thin-wall tube samplings were carried out. Laboratory testing was carried out on 8 different samples (6 disturbed and 2 undisturbed).

The thickness of Quaternary deposit strata (QIV) may range from 40 to 60 meters. The subsoil layers up to 3.5 m depth is comprised of clay (CH) followed by sandy clay (CL) up to 5.6 m depth. Layers of silty sand/gravel (SM) are then encountered up to 32.6 m depth and a layer of gravelly sand (GW) in the remaining 6.4 m depth. The ground water table was observed at 5.0 m depth below the top of borehole.

Piled foundation will be necessary for Ca Lo river bridge. Piles should be driven to reach gravel/sand layer which have "N" values of more than 40.

(2) Borehole B-2 (Ngu Nuyen Khe Bridge)

Borehole B-2 is located at the left bank of the Hgu Nuyen Khe river. Exploration was carried out as deep as 41.5 m together with 21 SPT and 2 thin-wall tube samplings.

Subsoil layers up to 10.2 m depth are comprised of clay or clayey sand (CH, CL) followed by fine sand or silty sand/gravel (SM) up to 37.5 m in depth. Weathered claystone strata existed in the remaining 4.0 m depth. The ground water table was observed 4.5 m below existing ground level. Supporting stratum of piled foundation will be the above-mentioned calystone.

(3) Borehole B-3 (NH No. 1 Flyover)

One boring was carried out near the toe of the existing embankment of National Highway No. 1. Exploration depth reached as deep as 50.0 m, since the bearing stratum of foundation pilling (NI ≤ 40) was not found up to 44 m below existing ground level.

A boring log indicates that the top 3.5 m layer is comprised of sandy clay (CL) followed by silty sand or silty gravel (SM, N = 6 - 24) up to 22.8 m in depth. The layers between 22.8 m and 40.5 m in depth consist of fine sand with gravel which consist of medium dense (N = 20) and dense (N = 30) layers.

The bearing stratum for foundation piling will be the hard to very hard gravely sand layers which are found in 44.0 m - 50.0 m depths. Ground water table was found at 3.0 m below existing ground level.

(4) Borehole B-4 (Pha Lai Low - Lying Area, Future Medium - Span Bridge)

A total of three (3) machine borings (B-4, B-5 and B-6) are carried out in connection with the planned Pha Lai Bridge. Borehole B-4 situates about 300 m west of right side dike of the Thai Binh river. As a result of the boring, the bearing stratum for foundation piling was found at relatively shallow depth of 10.0 m from the existing ground level. The boring location was situated in a swampy area and counted N-valves showed only 1-3 until a depth of about 8 m. A stiff 1 - 5 m thick weathered sandstone layer covers sandstone bed rock.

(5) Borehole B-5 (West End of the Thai Binh River Special Bridge)

Borehole B-5 situates the point near the west end of the Thai Binh river special bridge. Weathered sandstone stratum was found at a shallow depth of only 2.0 m, and weathered/sound sandstone strata follows up to 20.0 m in depth from the existing ground level.

(6) Borehole B-6 (East End of the Thai Binh River Special Bridge)

The borehole is located at the left bank of the Thai Binh river. The explored depth is 40.0 m. The subsoil up to 13.0 m in depth, comprised of cohesive soils and uncohesive soils (CL, SC and SM). Weathered or sound sandstone strata exists in the remaining 27.0 m of the exploration. No cavity was verified in the sandstone bedrock.

6.2.3 Summary of Field Investigation and Laboratory Test Pertaining to Machine Borings

(1) Work Items and Quantities Executed

The summary of actually executed items and quantities are shown in Table 6.1.

Table 6.1 Summary of Items and Quantities (Machine Boring and Laboratory Tests)

Borehole Number	Depth (m)	Thin-wall Sampling	Test (1)	SPT	Test (2)
B - 1	39.1	2	2	20	6
B - 2	41.5	2	2	21	6
B - 3	50.0	2	2	25	6
B - 4	20.0	3	3	9	3
B - 5	20.0	0	0	9	2
B - 6	40.0	1	0	19	5
B - 7	34.0	1	3	16	4
B - 8	30.0	1	2	14	3
B - 9	25.0	1	1	12	3
B - 10	25.0	0	0	12	3
B - 11	20.0	1	1	9	2
B - 12	25.8	1	1	12	2
B - 13	20.0	1	1	9	2
Total	390.4	16	15	187	47

Note: 1. Test (1) denotes laboratory test for thin-wall samples.
2. Test (2) denotes laboratory test for SPT samples.

(1) Summary of Bearing Strata

Summary of bearing strata for piled foundations are shown in Table 6.2.

Table 6.2 Summary of the Bearing Strata for Piled Foundations ($N \geq 50$)

Borehole No.	Description	Position of Bearing Strata (m)	Nomenclature
B - 1	Ca Lo Bridge	34.0	Gravelly sand
B - 2	Ngu Huyen Khe Bridge	37.5	Claystone
B - 3	NH No.1	48.0	Gravelly sand
B - 4	Pha Lai Bridge	10.0	Sandstone
B - 5	Pha Lai Bridge	3.5	Sandstone
B - 6	Pha Lai Bridge	13.5	Sandstone
B - 7	Hong Gai Bridge	15.0	Sandstone
B - 8	Cam Pha Bridge	19.0	Limestone
B - 9	Ba Che Bridge	10.2	Weathered claystone
B - 10	Tien Yen Bridge	6.3	Gravelly sand
B - 11	Dam Ha Bridge	11.2	Weathered siltstone
B - 12	Ha Coi Bridge	4.0	Gravelly sand
B - 13	Kinh Koong Bridge	7.0	Weathered claystone

6.2.4 Embankment Materials

(1) Locations of Material Source

Locations of embankment material sources are shown in Table 6.3.

Table 6.3 Locations of Embankment Material Source

Sampling Pit No.	Station (Km)	Place	Remarks
SP - 1	33.0	Bac Ninh	Along exist. road
SP - 4	28.8	Ton Loc	Along exist. road
SP - 5	143.2	Cam Pha	Near exist borrow pit
SP - 6	162.0	Dan Cu Cach	Along exist. road
SP - 7	185.0	Cai Tan	Along exist. road
SP - 8	253.3	Cha Lin Thin	Along exist. road

(2) Test Results of Embankment Materials

Sandy clay with gravel, or clay with gravel, with CBR of approximately 5 - 18 % was identified at several potential borrow pits and a number of possible borrow areas are found in the stretches of Bac Ninh - Chi Linh and Hong Gai - Mong Gai. However the embankment material source is scare in Noi Bai - Bac Ninh section. Table 6.4 shows the result of laboratory test of samples obtained at each sampling pit.

Table 6.4 Result of Laboratory Test of Embankment Materials

Sampling Pit No.	Moisture Content W (%)	Dry Density γd (t/m3)	CBR (%)	Remarks
SP - 1	15.37	2.02	9.0	Silt
SP - 4	8.75	2.00	10.0	Sandy clay w/gravel
SP - 5	16.50	1.74	5.0	Clay w/gravel
SP - 6	18.16	1.62	4.2	Clay w/gravel
SP - 7	16.38	1.80	5.0	Clay w/gravel
SP - 8	20.45	1.78	4.0	Clay w/gravel

6.2.5 Subbase and Coarse Aggregate Materials

(1) Subbase Material

Subbase materials of clay with gravel or fine sand, with CBR of approximately 15 were identified as shown in Table 6.5. Cement stabilization of these materials are recommended.

Table 6.5 Result of Laboratory Test, Subbase Materials

Sampling Pit No.	Station (Km)	Place	CBR (%)	Remarks
SP - 2	6.0	Son Dong	15.0	Clay w/gravel
SP - 3	24.0	Van Doan	15.0	Fine sand

(2) Coarse Aggregate Materials

Sampling and testing of currently available coarse aggregate materials were carried out, the quality of these materials were judged satisfactory. However, extensive quarry survey especially in Tien Yen - Mong Cai will be required including the utilization of river gravel. Table 6.6 shows the summary of laboratory test of presently available coarse aggregates. Yen Cu quarry has an estimated volume of deposit of more than 1,000,000 m3.

Table 6.6 Laboratory Test Result of Coarse Aggregates

Sample No.	Place	Specific Gravity (g/cm3)	Absorption (%)	Los Angeles Abration (%)	Type of Rock
1	Tai Van (Km 296)	2.72	4.2	18.0	Granite
2	Yen Cu (Km 128)	2.69	6.4	20.6	Limestone

6.3 Existing Conditions of Related Highway

6.3.1 Overview of the Environs of Existing Highways

Highway No. 18 is one of the important routes in northern Vietnam, which links Ha Noi and Mong Cai (Bac Luan) traversing the north delta with the major industrial area in northeast region and is also a side of the Ha Noi - Hai Phong - Ha Long triangle, which has priority for development in northern Vietnam.

Highway No. 18 runs across the territory of Ha Bac, Hai Hung and Quang Ninh provinces, through 19 towns, industrial areas of the above three provinces and many other important places such as Bac Ninh (km 0: starting from the beginning point of Highway No. 18), Pho Moi (km 10), Pha Lai (km 26), Chi Linh (km 37), Hong Gai - Ha Long (km 122), Cam Pha (km 150), Cua Ong (km 160), Mong Duong (km 165), Tien Yen (km 210), Dam Ha (km 236), Ha Coi (km 263), Mong Cai(km 300).

Highway No. 18 together with Highways Nos. 1, 5, 10, 183, 379, 279 and 4B from a road network in the northern delta and northeast region of Vietnam. According to Descision No. 1200/GT-DBVN dated 4/8/1994, the section of Highway No. 4B from Tien Yen to Bac Kuan bridge (Mong Cai) becomes the end part of the Highway No. 18.

Along Highway No. 18 there are 10 rivers and sea ports, especially the major ports such as Cai Lan (with estimated capacity of 14.3 millions tones per year by the 2010), Hon Gai and Cua Ong to which Highway No. 18 serves as a convenient artery link from the inland, and the north delta rich in resources.

Also, Highway No. 18 is an important trunk road, together with Highway No. 1, connectable with the road network in the southern and eastern regions of China so as to form a part of the Asian Highway System.

There are many industrial bases along Highway No. 18 and especially in Quang Ninh province where the coal mining industry is developing. Coal mines under operation now are mostly located alongside the Highway No. 18, namely Mao Khe, Uong Bi, Hon Gai, Coc 5, Coc 6, Ha Tu, Ha Lam, Mong Duong, etc. There are also many quarries in the region for construction materials such as sand, limestone, clay. There is great potential in forest and marine products.

Many factories and plants are located along the Highway No. 18 such as the thermopower plant at Pha Lai and Uong Bi, cement plant at Haong Thach, mechanical factories at Hong Gai and Cam Pha as well as brick factories, shipyards at Gieng Day, Tien Giao.

The area in which Highway Nos. 18, 5 and 10 are located has been established as an economic development triangle: Ha Noi - Hai Phong - Ha Long.

6.3.2 Existing Road Conditions

The study covers the area between Noi Bai and Bac Luan and its environs.

The area of projects divided into 5 sections:

- Section 1 : Noi Bai - Bac Ninh (30.9 km)
- Section 2 : Bac Ninh - Chi Linh (34.9 km)
- Section 3 : Hong Gai - Cam Pha - Cua Ong (39.5 km)
- Section 4 : Cua Ong - Bac Che - Tien Yen (45.5 km)
- Section 5 : Tien Yen - Mong Cai (Bac Luan) (93.5 km)

(1) Section 1: Noi Bai - Bac Ninh (30.9 km long)

The general direction of the selected route in this section is parallel to National highway No. 2 and Provincial Highway Nos. 286 and 401 which run eastward at a distance of 0 km to 5 km apart from the selected route.

The existing road conditions of the Highway Nos. 2, 286 and 401 are as follows:

The embankment width of the sub-sections:

- Highway No. 2 between Noi Bai and Highway No. 3 (km 5 + 500): 9 m
- Highway No. 286 between National Road No. 3 and Phu Lo (km 12 + 500): 9 m
- Highway Nos. 286 and 401 between Phu Lo - Do Lo - Yen Phong and Bac Ninh: 6 - 7 m

1) Embankment and Pavement Width

The width of embankment and pavement of each substation is shown in Table 6.7.

Table 6.7 Width of Section from Noi Bai to Bac Ninh

Subsection	Length	Location	Width	
			Embankment	Pavement
Highway No. 2	7.5 km	Noi Bai - Phu Lo	9.0 m	6.0 m - 7.0 m
Highway No. 286	7.0 km	Phu Lo - Kim Lu	6.0 m - 7.0 m	3.5 m - 4.0 m
Highway No. 286 and No. 401	16.4 km	Kim Lu - Bac Ninh	6.0 m - 7.0 m	4.0 m - 5.0 m
Total	30.9 km			

The pavement width of the sub-sections:

- Highway No. 2 from Noi Bai to Phu Lo 6.0 m - 7.0 m
- From (km 5 + 500) to (km 12 + 500) 3.5 m - 4.0 m

2) River Crossing

- Ca Lo river at km 12
- Ngu Huyen Khe river at km 27.

3) Profile of the Existing Route

- Between Noi Bai - Phu Lo : Length L = 7.5 km.
  Height H = 1.5 - 2.0 m
- Between Phu Lo - Bac Ninh : Length L = 23.4 km.
  Height H = 1.5 - 2.0 m.

4) Flood Situation:

Flooded conditions tend to remain in large areas for extended periods due to the fact that the water level in the river is higher than inside the dike. When in 1971 the dikes of Cau and Duong river broke, putting a stretch of 21 km of road in flooded condition at a depth of 1.5 m - 2 m for about one month.

(2) Section 2: Bac Ninh - Chi Linh (34.9 km long)

The existing Highway No. 18 in this section has a large of approximate 34.9 km. The beginning point (km 0) at Bac Ninh town is the point of intersection with Highway No. 1 A (km 140). The route lies within the delta area, both sides of the route are paddies and residential areas.

1) Embankment width

- From km 0 to km 24 + 400	6 m - 8 m
- From km 24 + 400 to km 29 + 400	10 m - 12 m
- From km 29 + 400 to km 34 + 800	8 m

2) Pavement width

- Between Bac Ninh - Pho Moi	4.5 m - 5.5 m
- Between Pho Moi - Pha Lai	4.5 m - 5.5 m
- Between Pha Lai - Chi Linh	7 m

3) Profile of the route

- From km 0 to km 24 + 400:
  Length L = 24.4 km. Height H = 0.5 - 1.5 m

- From km 24 + 400 to km 29 + 400:
  Length L = 5.0 km. Height H = 0.5 - 3.5 m

4) Flood Situation

The dike section from Dong Du (km 16) to ferry port (km 26 + 500) has average elevation of 8.5 m, and other section Dong Du (km 16) to Chau Cau (km 21 + 225) has average altitude of 6.8 m. In 1957 and 1971 during flooded periods, the surface of the road was under 2.5 ~ 3.0 m of water.

The section from Chau Cau (km 21 + 225) to Pha Lai (km 26 + 500) is usually flooded during the rainy season, causing traffic to be interrupted for a period of about 20 days.

(3) Section 3: Haong Gai - Cau Ong (39.5 km long)

This section of the existing Highway No. 18 has a length of approximately 39.5 km. This route lies inside of Ha Long city, Ha Tu and Cam Pha towns and is divided into 6 sun-sections.

1) Embankment width

- Sub-section 1: From km 122 + 00 to km 130	:	20 - 30 m
- Sub-section 2: From km 130 to km 136	:	8 - 10 m
- Sub-section 4: From km 144 + 600 to km 150	:	8 - 30
- Others	:	8 - 16 m

2) Pavement width

- Sub-section 1: From km 122 + 00 to km 130 : 14.0 - 14.5 m
- Sub-section 2: From km 130 to km 136 : 6.3 - 7.0 m
- Sub-section 3: From km 136 to km 144 + 600 : 6.0 - 7.0 m
- Sub-section 4: From km 144 + 600 to km 150 : 7.0 - 15.0 m
- Sub-section 5: From km 150 to km 155 : 6.0 - 7.0 m
- Sub-section 6: From km 155 to km 162 : 6.0 - 10.5 m

3) Profile of the Route

There are many small curves in this route. The entrance to the mining areas has many intersections which cause traffic congestion and reduce production efficiency in these areas. The existing terrain is higher than flood level. It is an inland route.

4) Drainage situation

This section is affected by coal mining activities. Following rainfall, surface water is blocked and erosion occurs.

(4) Section 4: Mong Duong - Tien Yen (45.5 km long)

This section includes Mong Duong and Ba Che.

1) Embankment width

- From km 161 + 500 to km 207 : 7 m - 9 m

2) Pavement width

- From km 161 + km 207 : 4 m - 7 m

3) There are 19 bridges along the route but most of bridges are small and narrow.

4) Flood situation

The existing terrain is inland area, surface water can quickly drain off via existing drainage system without flooding. The average diameter of the drainage sewers is smaller than 0.75 km.

(5) Section 5A: Tien Yen - Dam Ha (27 km long)

This section runs through Tien Yen and Ha Quang in Quang districts Ninh province. In the past, this section belonged to both Highway Nos. 18 (between km 193 - km 206) and 4B (between km 94 - km 122). The route is located about 3 km from the sea.

1) Embankment width

- Average width: 6.5 m - 7.0 m

2) Pavement width

- Average width: 3.5 m

3) Number of existing bridges

There are 11 bridges along the route with total length of 84.7 m.

4) Flood and drainage situation

The existing drainage system consists of sewers of diameters averaging 0.6 to 0.8 m. Rainwater is the major cause of traffic accidents. In 1993, 43 passengers and the driver of a passenger bus died in one such accident.

(6) Section 5B: Dam Ha - Ha Coi (40 km long)

This section runs through hills nearby the sea. The minimum distance from the route to the sea is about 1.5 km and the maximum distance from the route to the sea is about 5 km.

1) Embankment width

- Average width : 6.0 m

2) Pavement width

- Average width : 3.5 m - 4.0 m

3) Number of existing bridges

There are 5 bridges along the route with total length of 84.7 m.

4) Drainage situation:

The existing drainage system consists of sewers of diameters averaging 0.6 to 0.8 m.

(7) Section 5C: Ha Coi - Bac Luan (26.5 km long)

1) Embankment width

- Average width : 6.0 m

2) Pavement width

- Average width : 3.5 m - 4.0 m
- Inside Mong Cai town : 7.0 m - 10 m

3) Number of Existing bridges

There are 16 bridges along the route with total length of 362.2 m.

4) Drainage situation

The existing drainage system consists of sewers of varying diameters. Total length of the system is 759 m.

6.3.3 Existing Surface Conditions of Highway No. 18

The existing surface conditions of the pavement were surveyed and evaluated during the period from September 16 to September 18, 1995. The evaluation was conducted based on the criteria shown in Table 6.8.

Table 6.8 Criteria of National Road Surface Conditions

Code	Cracks	Rutting	Riding Condition	Other remarks
0	Not visible	None	very good	speed limited only by road geometry and safety factors.
1	Less than 5%	Less than 10 mm	Good	Speed mainly limited by geometry and safety factors with small influence of surface irregularities.
2	Less than 10%	Less than 20 mm	Fair	Speed partly restricted due to unevenness of riding surface (comfortable speed below 60km/h)
3	10% - 30%	20 to 30 mm	Poor	Speed restricted by surface conditions, comfortable speed below 40km/h.
4	above 30%	above 30 mm	Very poor	speed severely restricted, traveling speed below 20km/h.

Source : National Transportation Sector Review, UNDP, 1992

The pavement evaluation results of Highway No. 18 are shown in Table 6.9.

Table 6.9 Pavement Evaluation Results of Highway No. 18

Section	Location	Length	Evaluation of Pavement Surface			
			Good	Fair	Poor	Very poor
2	Bac Ninh to Chi Linh	34.9km	3.0 km	21.0km	5.0km	5.9km
3	Hong Gai to Cua Ong	39.5km	0	18.5km	10.0km	11.0km
4	Cua Ong to Tien Yen	45.5km	0	29.5km	7.5km	8.5km
5	Tien Yen to Bac Luan	93.5km	0	56.0km	23.0km	14.5km
		213.4km	3.0km	125.0km	45.5km	39.9km

Source: JICA Study Team

Chapter 7

DESIGN STANDARD

CHAPTER 7 DESIGN STANDARD

7.1 Introduction

This section discusses the design standards to be applied for the Highway No. 18 improvement project.

The design standards are divided into the following three sections :

- Geometric design standard ;
- Highway bridge design standard ; and
- Pavement design standard.

The government's standards are esteemed and reviewed refering the Japanese and American standards.

7.2 Geometric Design Standard

7.2.1 Overview

Although National Highway No. 18 is classified and considered as a major arterial route in its region, it lacks alternate routes between Bac Ninh and Chi Linh, and between Hong Gai and Cua Ong; therefore in some cases it merely is serving as a local highway. This situation is to be remedied and the actual status of the highway should be raised as a result of the improvement project.

A government standard exists which is related to the design of new construction, improvement and rehabilitation of public highways, namely "Vietnam Highway Design Standards, TCVN 4054 - 85". This standard will be followed for the maximum extent of the study where deemed appropriate.

7.2.2 Highway Classes in the Government Standard

Six classes of highway are specified in the government standard together with the design speed to be applied for each class (Table 7.1).

Table 7.1 Categories of Highway and Design Speed

Class of highway	Design Speed (km/hr)	
	Level terrain	Rolling/Mountainous
I	120	-
II	100	80
III	80	60
IV	60	40
V	40	25
VI	25	15

The understanding of the functional requirement of each class of highway is summarized for classes I - IV referring the government's standard.

(1) Class - I

Highest speed and highest capacity among national highways, holding special importance for the nation or for major economic area. From the functional point of view they may be called principal arteries for movement (4-lane divided highway).

(2) Class - Ib

Class - Ib is basically a Class - I highway in rolling or mountainous terrain. Since the published urban highway standard is not available, the study team adopted this highway class designation for 4-lane urban highways provided with center median.

(3) Class - II

Major differences from Class I are slightly lower design speed and provided lower highway capacity (2-lane 2-way highway). Adoption of 2-lane highway will not be realistic to keep the minimum design speed of 100 km/hr. The government standard also recommends such as main connectors of regional development centers (minor arterials/distributors).

(3) Class - III

The government standard has been widely used for :

- Main highways connecting social, economic and cultural centers;
- Highways connecting important industrial and agricultural areas and regional centers;
- Highways connecting with major maritime ports, railway stations and airports; and
- Highways leading to international borders.

7.2.3 Highway Classes

(1) Class of Highway for Noi Bai - Bac Ninh Section

Special consideration is necessary for the Noi Bai - Bac Ninh Section in the selection of highway class due to the following reasons :

- The districts where Highway No. 18 will pass are considered as future urbanized areas of Hanoi ;
- The improvement of existing highway is considered extremely difficult from its poor horizontal alignment conditions ; and
- Noi Bai international airport requires major land access from the east.

The study revealed the following results in future traffic demand projection (Table 7.2):

Table 7.2 Result of Future Traffic Demand Projection between Noi Bai and Bac Ninh

Unit : PCU ADT

Location	2005	2015
East of Noi Bai International Airport	6,000	14,400
West of Bac Ninh	7,600	22,700

Based on the above situations the adoption of Class - I is recommended. Since Highway No. 18 will pass through future urbanized areas the provision of sidewalks and spaces for future underground utilities should also be considered in the determination of long term right-of-way limit lines.

(2) Class of Highway for Bac Ninh - Chi Linh Section

1) Projected Traffic Demand

Projected traffic demand is shown in Table 7.3.

Table 7.3 Result of Future Traffic Demand Projection between Bac Ninh and Chi Linh

Unit : PCU ADT

Location	2005	2015
East of Bac Ninh	14,800	37,100
West of Chi Linh	10,900	24,400

2) Overview of Highway No. 18 Improvement

The following alternative solutions have been studied and compared :

Alternative - 1 : Widening of existing Highway No. 18 to four-lanes in existing subcorridor.

Alternative - 2 : Construction of alternate high-standard highway (hereinafter referred as "The Alternate Highway") separately in the Bac Ninh - Chi Linh corridor.

The above two alternatives were compared accroding to the following environmental, socio-economic, technical and transportation aspects (Table 7.4).

Table 7.4 Comparison of Highway Widening and Provision of the Alternate Highway

Item for Comparison	Alternative - 1 Improvement by Highway Widening		Alternative - 2 Reconstruction by the Provision of the Alternate Highway	
	Description	Rating	Description	Rating
1. Environmental Aspects * Residents displacement * Difficulty of land acquisition	*It is judged that the resettlement of affected inhabitants will entail great social problems. Difficult.	1	* Horizontal alignment can be selected avoiding towns and villages. Easy	2
2. Socio - Economic Aspects * Services to industrial areas * Services to Hanoi, Hai Phong and Ha Long cities	* Services to industrial areas and each cities are inferior since improved Highway No. 18 will serve mainly existing towns and villages .	1	* New highway locationing is possible to meet the regional development strategy. * Better accessibility can be provided for each cities	2
3. Technical Aspects * Design Speed * Construction and land acquisition/compensation * Ease of construction	60 - 80 km/hr * The cost will be lower compared with the alternate highway. Difficult	1	120 km/hr * The cost may be higher compared with the widening. Easy	1
4. Transportation Aspects * Traffic flow during the construction * Deterioration of the service level of the highway	* Economic loss due to traffic congestion during construction can not be avoidable * In near future the highway capacity of the improved Highway No.18 may drop considerably in urbanized areas, at the time traffic signals are required.	1	* Traffic congestion during construction can be avoided by the selection of construction timing and traffic management technique. * No deterioration of highway capacity is anticipated in the alternate highway if access control measures are provided.	2
Total of Rating		4		7
Recommended Priority	2		1	

- Environmental Aspects

  - Displacement of residents; and
  - Difficulty of land acquisition.

- Socio - Economic Aspects

  - Services for industrial areas; and
  - Services to the cities of Hanoi, Hai Phong and Ha Long.

- Technical Aspects

  - Design speed; and
  - Construction, land acquisition, and compensation cost.

- Transportation Aspects

  - Traffic flow during the construction; and
  - Deterioration of service level of Highway No. 18.

As a result of a comparison of the two alternatives, it was found that Alternative - 2 is superior to Alternative - 1.

The crucial disadvantage of Alternative-1 lies in its adverse environmental impact, i.e., the resettlement of inhabitants who will be affected by the widening of right-of-way along the existing Highway No. 18.

3) The Government's Basic Policy on the Expressway Development

Recently the government decided on the early realization of Hanoi - Bai Chay Expressway.

4) Class of Highway for Bac Ninh - Chi Linh Section

Based on the above discussions, the adoption of the Class-III, treated as level terrain, is recommended.

(3) Class of Highway for Hong Gai - Cua Ong Section

1) Projected Future Traffic Demand

Table 7.5 shows projected traffic demand.

Table 7.5 Results of Future Traffic Demand Projection between Hong Gai and Cua Ong

Unit : PCU ADT

Location	2005	2015
Hong Gai	14,700	34,800
East of Cam Pha	21,300	49,800

2) Overview of Highway No. 18 Improvement

In view of very large traffic volume, the adoption of a 4-lane highway is necessary in this section. Existing right-of-way width of Highway No. 18 is somewhat wider (more than 20 meters) therefore no serious problem associated with right-of-way widening is foreseen even if 4-lane highway was adopted for the improvement.

3) Class of Highway for Hong Gai - Cua Ong Section

Adoption of the government standard is difficult in this section, since the characteristics of Highway No. 18 cannot be considered as mere rural highway in this section. As the regional development will proceed in this area Highway No. 18 will easily become an urban highway over its entire section. The study team will establish the optimum geometric design standard referring the design policies of the Vietnamese government, Japan and AASHTO.

(4) Class of Highway for Cua Ong - Mong Cai Section

1) Projected Future Traffic Demand

Table 7.6 shows projected traffic demand.

Table 7.6 Result of Future Traffic Demand Projection between Cua Ong and Mong Cai

Unit : PCU ADT

Location	2005	2015
South of Tien Yen	3,200	9,700
East of Tien Yen	4,000	11,300
Southwest of Mong Cai	3,400	9,900

2) Overview of Highway No. 18 Improvement

Future traffic demand forecast in Cua Ong and Mong Cai section is rather conservative. The capacity of 2-lane 2-way highway will cover the traffic need for at least 20 years of design life.

3) Class of Highway for Cua Ong - Mong Cai Section

The study team recommends the adoption of Class-III for rolling/ mountainous terrain of the government standard except for the Cua Ong - Mong Duong section where the level terrain standard has been applied by the government.

7.2.4 Lane Width

In general, lane width is decided based on empirical data on vehicle speed, traffic volume, and ratio of heavy trucks. In this instance, however, in addition to the above should be added application of the government's road structure decrees, Japanese design standards and coefficients used in number of determined lanes based on traffic capacity and future traffic volume; in a practical manner. In this survey, study for lane width was conducted in consideration of the above design speed as well as the following data.

a. Traffic volume and heavy truck ratios are shown in Table 7.7. The heavy truck ratio is extremely high. Sections 1 - 3 have high volumes, therefore lane width under 3.0 m should be avoided.

Table 7.7 Heavy Truck Ratio of Each Section

Section	Traffic Volume (pcu/day)	Heavy Truck Ratio
1	22,700	33.5 % (54.3 %)
2	37,100	59.2 % (70.3 %)
3	49,800	76.2 % (85.5 %)
4	9,700	88.4 % (83.5 %)
5	9,900	81.3 % (82.7 %)

Note : Because of the high number of motorcycles, these are converted into automobile equivalents as part of the heavy truck ratio. Figure inside ( ) indicates this ratio when motorcycles are not figured.

b. According to Japanese design standards, lanes under 3 meters are apt to cause a high rate of accidents, and are to be avoided. In the case of a two-lane road with a design speed of 100 km/hr, lane width 3.5 - 3.75 m, 80 km/hr; 3.5 m is recommended.

c. Judging from the above, two types of lane width (3.5 m and 3.0 m) are applied as follows.

- Sections 1 - 3 : 3.5 m
- Sections 4 - 5 : 3.0 m

7.2.5 Recommended Geometric Design Standard for Noi Bai - Bac Ninh Section

(1) Geometric Standard for Throughway

1) Highway Class

It will be classified as the government's Class-I highway in its final stage of development.

2) Design Speed

The design speed is the maximum safe driving speed which can be maintained with comfort under favourable weather and traffic conditions. The design speed has a direct effect on the minimum standards of such features as sight distance, horizontal curvature, super-elevation, etc. The higher design speed of 120 km/hr was adopted for the entire section, although this speed will be too high in the future when surroundings are more fully developed. Adoption of higher design speed will not affect to the construction cost considerably since the terrain condition is very flat and landuse pattern is simple.

3) Lane Width

A lane width of 3.5 m is recommended in lieu of 3.75m which is specified by the government standard.

4) Shoulder Width

A 3.0 m outer shoulder and a 1.25 in inner shoulder are to be adopted considering design policies of the Vietnamese government, Japanese practice and AASHTO's policy.

5) Median Width

The median width is expressed as the dimension between the through-lane edges and includes inner shoulders. The principal functions of a median are :

- To provide freedom from undesirable interference of opposing traffic;
- To minimize headlight glare;
- To provide open green space; and
- To provide space for pier construction of grade separation structure.

Provision of a 5.0 m median including 1.25 m inner shoulders and with 2.5 m width raised is recommended in the final stage development. A 2.5 m width is generally sufficient for the construction of pier columns for grade separation structure. It would also include protection space with guardrail.

The geometric standards for other requirements are shown in Table 7.8. High-type highways require junctions (high-type new highway to high-type new highway interchange) and interchanges (high-type new highway to national highway or access road) in many cases. Table 7.9 indicates recommended design standard for throughway in the vicinity of junction or interchange ramp terminal.

Table 7.8 Geometric Design Standard for Throughway

Item	Unit	Throughway Geometric Design Standards			
Standard	-	Government Standard	Japanese Standard	AASHTO Standard	Recommended Standard
Terrain	-	Flat	Flat	Flat	Flat
Design Speed	km/h	120	120	112	120
Stopping Sight Distance	m	175	210	190	210
Lane Width	m	3.75	3.5	3.66	3.5
Median Width	m	-	4.5 (3)	4.3(1)	5.0(1)
Inner Shoulder Width	m	-	1.25	1.2(2)	1.25
Outer Shoulder Width	m	3.0	2.5(3)	3.0(3)	3.0
Minimum Radius	m	600	710	500	710
Minimum Radius not Requiring Transition Curve	m	-	4,000	-	4,000
Minimum Radius not Requiring Superelevation	m	-	7,500	-	7,500
Maximum Grade	%	4.0	2.0	3.0	3.0 - 4.0
Minimum Radius of Vertical Curve					
Crest	m	-	11,000	-	11,00
Sag	m	-	4,000	-	4,000
Crossfall or Carriageway	%	2.0	2.0	1.5 - 2.0	2.0
Crossfall of Outer Shoulder	%	3.0(4)	4.0(4)	4.0 - 6.0	2.0 (Paved)
Maximum Superelevation	%	-	6.0	4.0 - 6.0	6.0

Note :
(1) Total of raised median and inner shoulders
(2) Paved shoulder for 4-lane divided highway
(3) Usable shoulder
(4) Gravel or crushed rock shoulder

Table 7.9 Geometric Design Standard for Throughway in the Vicinity of Junction or Interchange Ramp Terminal

Item		Unit	Requirement
For Throughway			
Minimum Radius		m	2,000 (1,500)
Minimum Vertical Curve	(Crest)	m	45,000 (23,000)
	(Sag)	m	16,000 (12,000)
Maximum Gradient		%	2
For Ramp Adjacent to Nose			
Minimum Radius		m	250
Minimum Parameter of Clothold Curve		m	90(70)
Minimum Vertical Curve	(Crest)	m	2,000 (1,400)
	(Sag)	m	1,500 (1,000)
Minimum Vertical Curve Length		m	70 (50)
Deceleration Lane			
Length of Deceleration Lane		m	100
Length of Taper		m	100
Acceleration Lane			
Length of Acceleration Lane		m	200
Length of Taper		m	70

Note : () shows absolute minimum values.

(2) Geometric Design Standard for Junction or Interchange Ramps

The recommended geometric design standard for junction or interchange ramps of high-type highways is shown in Table 7.10.

Table 7.10 Geometric Design Standard for Interchange Ramps

Item	Unit	Junction or Interchange Ramps	
Design Speed	km/h	40	50
Sight Distance	m	40	55
Lane Width	m	3.5	3.5
Median Width, Raised	m	2.5	2.5
Inner Shoulder Width	m	0.75	0.75
Outer Shoulder Width	m	3.0	3.0
Minimum Radius	m	50	90
Minimum Radius for Curve not Requiring Transition Curve	m	140	220
Minimum Radius for Curve not Requiring Superelevation	m	800	1,300
Maximum Grade	%	6 (8)	5.5 (7.5)
Minimum Vertical Curve Length	m	40	50
Crossfall of Carriageway	%	2	2
Crossfall of Shoulder	%	4	4
Maximum Superelevation	%	10	10

Note : () shows absolute minimum values.

As for the design speed of junction or interchange ramps, AASHTO recommends the following (refer to "A Policy on Geometric Design of Highway and Streets, 1986"):

Ramp Design Speed

- Upper range : 85% of throughway design speed
- Middle range : 70% of throughway design speed
- Lower range : 50% of throughway design speed

Minimum Design Speed by type of ramp

- Loops : 40 km/hr (25 mph)
- Semi-direct connection : 48 km/hr (30 mph)
- Direct connection : 56 km/hr (35 mph)

While, the Japanese Standard specifies the speed as shown in Table 7.11:

Table 7.11 Design Speed of Throughways in Junction or Interchange Ramps

Category	Design Speed of Throughways (km/hr)	Design Speed of Junction or Interchange Ramps (km/hr)
Junctions	120/120	50 - 80
	120/100	50 - 80
	100/100	50 - 80
Interchanges	120/60	40 - 60
	120/80	40 - 50

With reference to the above, a 50 km/hr design speed for the junction ramps and a 40 km/hr design speed for the interchange ramps are recommended.

7.2.6 Recommended Geometric Design Standard for Bac Ninh - Chi Linh Section

(1) Highway Class

Government's Class - III highway in flat terrain.

(2) Design Speed

80 km/hr will be adopted in accordance with the government standard.

(3) Lane Width

A lane width of 3.5 m will be adopted (2 - lane 2 - way highway) in accordance with the government standard.

(4) Shoulder Width

The government standard calls for the provision of 2.5 m shoulder with 2.0 m paved bicycle lane on both sides of the highway. This policy will be followed in the study.

(5) Summary of Geometric Design Standard for Class-III highway.

Table 7.12 summarizes the recommended geometric design standard for Class-III highway in flat terrain together with the government and Japanese standards.

Table 7.12 Recommended Geometric Design Standard for Class - III Highway in Flat Terrain

Item	Unit	Government 's Standard	Japanese Standard	Recommended Standard
Class of Road	-	Class - III	-	Class - III
Terrain	-	Flat	Flat	Flat
Design Speed	km/h	80	80	80
Lane Width	m	3.5	3.5	3.5
Outer Shoulder Width	m	2.0	2.0	2.0
Bicycle Lane	m	2.0	2.0 (Separate Lane)	2.0
Crossfall of Carriageway	%	2.0	1.5	2.0
Crossfall of Shoulder	%	3.0 - 4.0	3.0 - 5.0	4.0 (2.0)
Maximum Superelevation	%	-	10	10
Minimum Radius	m	250	280 (230)	250
Minimum Length of Horizontal Curve	m	-	140	140
Maximum Grade	%	6.0	4.0	6.0
Minimum Radius of Vertical Curve				
* Crest	m	5,000	4,500	5,000
* Sag	m	2,000	3,000	2,000
Minimum Stopping Sight Distance	m	100	110	100
Minimum Passing Sight Distance	m	200	350	350
Vertical Clearance				
* Highway	m	4.75	4.5	4.75
* Railway (non-electric)	m	5.6	5.6	5.6
* High Voltage Power Line	m	7.0	-	7.0
* Telephone Line	m	5.5	-	5.5
Pavement Type	-	-	Hot Mix Asphalt Concrete	Hot Mix Asphalt Concrete

Note: Figure in ( ) show recommended crossfall of paved shoulder.

7.2.7 Recommended Geometric Design Standard for Hong Gai - Cua Ong Section

(1) Highway Class

Basically the government's Class - Ib highway in flat terrain will be followed. However, a 4-lane highway will be adopted to accommodate predicted future traffic demand.

(2) Design Speed

Basically 60 km/hr will be adopted in urbanized areas where the existing right-of-way should be fully utilized; however 80 km/hr will be adopted where no constraint is exist in the right-of-way acquisition and resettlement.

(3) Lane Width

A lane width of 3.50 m is adopted based on the government standard.

(4) Shoulder Width

Provision of a 2.5 m outer shoulder and a 0.5 m inner shoulder are recommended. Paved bicycle lane of 2.5 m width will be provided in the outer shoulders.

(5) Median Width

Provision of a 1.5 m median is recommended including 0.5 m inner shoulder, with 0.5 m raised.

(6) Summary of Geometric Design Standard in Hon Gai - Cua Ong Section

Geometric design standards in 80 km/hr sections are similar to those of Bac Ninh - Chi Linh sect except that 4-lane divided highway concept is provided. Table 7.13 summarizes the recommended geometric design standard for urbanized area in Hon Gai - Cua Ong Section.

7.2.8 Recommended Geometric Design Standard for Cua Ong - Mong Duong Section

Adopted standard is Class-III highway in rolling/mountainous terrain except that 3.5 m of lane widths and 2.0 m of hard shoulders are provided.

7.2.9 Recommended Geometric Design Standard for Mong Duong - Bac Luan

(1) Highway Class

Government's Class - III highway for rolling/mountainous terrain.

(2) Design Speed

60 km/hr as shown in the government standard.

(3) Lane and Shoulder Width

A lane width of 3.0 m and a shoulder width of 1.0 m will be adopted in accordance of the government standard.

(4) Summary of Geometric Design Standard for Mong Duong - Bac Luan Section

Table 7.13 Geometric Design Standard for Hon Gai - Cua Ong Section (Urbanized Area)

Item	Unit	Design Standard
Class of Road	-	Urban Road
Terrain	-	Flat
Design Speed	km/hr	60 (80)
Cross Section Elements		
Lane Width	m	3.5
Outer Shoulder Width	m	2.5
Bicycle Lane	m	2.5
Median Width (Raised)	m	0.50
Inner Shoulder Width	m	0.50
Crossfall of Carriageway	%	2
Crossfall of Shoulder	%	4(2) 1/
Vertical Clearance (to cross highway)	m	4.75
Min. Stopping Sight Distance	m	75
Horizontal Alignment		
Min, Radius		
Absolute Min.	m	150
Desirable	m	200
Min. Radius Without Superelevation	m	2,000
(*) Min. Curve Length	m	700/a or 100
Max. Superelevation	%	6
Min. Transition Curve Length	m	50
Min. Radius Without Transition Curve	m	600
Superelevation Runoff	-	1/175
Vertical Alignment		
Max. Grade	%	5
Min. Vertical Curve Radius		
Crest. Standard	m	1,400
Crest. Desirable	m	2,000
Sag. Standard	m	1,000
Sag. Desirable	m	1,500
Min. Vertical Curve Length	m	50
Max. Composition Grade	%	10.5

Note :

(*) 1) The value of "a" in minimum horizontal curve length shows an intersecting angle in degrees (min. 2 degrees), when the angle is less than 7 degrees.

1/ 2) Figure in ( ) shows crossfall of inner shoulder or paved outer shoulder.

2/ 3) Figure in ( ) show absolute minimum values

4) Refer to Table 7.12 for the design standard of minimum stopping sight distance, minimum horizontal curve radius and minimum vertical curve radius in case that 80 km/hr of design speed was applied.

Table 7.14 summarizes the recommended design standard for Class-III highway in rolling/mountainous terrain.

Table 7.14 Recommended Geometric Design Standard for Class - III Highway in Rolling and Mountainous Terrain

Item	Unit	Government Standard	Japanese Standard	Recommended Standard
Class of Road	-	Class - III	-	Class - III
Terrain	-	Rolling / Mountainous	Rolling / Mountainous	Rolling / Mountainous
Design Speed	km/h	60	60	60
Lane Width	m	3.0	3.0	3.0
Shoulder Width	m	1.0	1.25	1.0
Bicycle Lane	m	1.0	-	1.0
Crossfall of Carriageway	%	2.0	1.5	2.0
Crossfall of Shoulder	%	3.0 - 4.0	3.0 - 5.0	4.0 (2) 1/
Maximum Superelevation	%	-	10	10
Minimum Radius	m	130	150 (120)	150 (120) 2/
Minimum Length of Horizontal Curve	m	-	100	100
Maximum Grade	%	7.0	5 (8)	7.0
Minimum Radius of Vertical Curve				
* Crest	m	2,500	2,000	2,500
* Sag	m	1,500	1,500	1,500
Minimum Stopping Sight Distance	m	75	75	75
Minimum Passing Sight Distance	m	150	250	250
Vertical Clearance				
* Highway	m	4.75	4.5	4.75
* High Voltage Power Line	m	7.0	-	7.0
* Telephone Line	m	5.5	-	5.5
Pavement, Type	-	-	Hot Mix Asphalt Concrete	Hot Mix Asphalt Concrete

Note:
1/ Figure in ( ) shows crossfall of pave shoulder.
2/ Figure in ( ) shows absolute minimum values.

7.3 Bridge Design Standard

7.3.1 Introduction

Basically Vietnamese Bridge Design Code (Specifications 2057/QD-KT4-1979) follows AASHTO specifications. Due to the reasons explained below, a design load of 125 % of AASHTO HS20-44, is adopted. In light of the immense problems resulting from bridge failure and the high cost of replacement, it goes without saying that their structural design should be treated with great importance. With proper design, construction, and maintenance, a bridge can last for more than 50 years. Furthermore, once a bridge is built, due to the complicated nature of its structure, even relatively simple strengthening work can cause economic repercussions, not to mention the problems caused by traffic slowdown.

Therefore, when designing a bridge, it is necessary to consider not only the present conditions, but 30 to 50 years in the future as well. As a worldwide trend, vehicles are being made on a larger scale to accommodate greater loads. In Japan as well, design load has recently been raised from 20 t to 25 t.

Vietnam's design load at present subscribes to this reality as well. The bridge rehabilitation project on National Highway No. 1 has adopted a design load of 125 % of AASHTO HS20-44. This load is in response to Vietnam's standard H30. With the present and projected heavy truck ratio in mind, this is an appropriate design load for Highway No. 18 when considering its importance as a route: linking Cai Lan's port with Ha Noi, and carrying coal from Cua Ong, etc.

7.3.2 Loading Specifications

Vietnamese Bridge Design Code (Specifications 2057/QD-KT4-1979) will be followed together with AASHTO specifications.

(1) Loading Classification

Design load to be applied is 125% of HS 20 - 44 (Truck loading) or 125% of HS 20 - 44 (Lane Loading), whichever produces the maximum stress.

(2) Application of Live Loading

Application of live loading and reduction in loading intensity for multiple lanes shall conform to Article 3.11 and 3.12 of AASHTO standard, respectively.

(3) Impact

To provide for dynamic and vibration effects live loading to be applied are increased in accordance with Article 3.8 of AASHTO standard, as follows.

(4) Load Distribution

The load distribution is calculated based on Part C - Section 3 of AASHTO Standard.

(5) Wind Load

1) Transverse Direction

From Article 2.24 of Vietnamese Bridge Design Code, there are two cases of wind load to be applied to the vertical exposed area in the transverse direction :

a. The case with live load on the bridge : 50 kg/m^2
b. The case without live load on the bridge : 180 kg/m^2

Notes:

* Wind load on vehicles is neglected
* Reduction in wind load intensity is dependent on the type of structure with multiplication coefficient as follows :

- for two trusses : 0.4
- for three or more trusses : 0.5
- for solid structure : 1.0
- for railing 0.3 or 0.8

2) Longitudinal Direction

From article 2.25 of Vietnamese Bridge Design Code in longitudinal direction :

* Wind load intensity equal to 60% of intensity in transverse direction is applied to the superstructure and 100% of intensity in transverse direction will be applied to the part of pier or abutment above the ground or level water level.
* Wind load on vehicles and on solid superstructure in longitudinal direction is neglected.

(6) Brake and Traction

From Article 2.20 of the Vietnamese Bridge Design Code 2057-QD-KT4-1979, provision is made for the effect of a longitudinal force without impact as determined in Table 2.2.6.1 of the standard (refer to Table 7.15).

Table 7.15 Longitudinal Force by Span

Length of the portion of the loaded span	Longitudinal force
L = 25m	0.3W
25m < L < 50m	0.6W
L > 50m	0.9W

In the above table : W = Total weight of truck = 30 ton for all lanes carrying traffic headed in the same direction. Any lane is considered as "loaded" in the event that vehicles extend from one end to the other in one direction. The longitudinal force will be assumed to be located at road surface level.

(7) Shake Force

From Article 2.19 of Vietnamese Bridge Design Code, provision will be made for the effect of transverse force of 0.4 T/m of the truck loading without impact (for all lanes carrying traffic one value of force is loaded). The transverse force will be assumed to be located at road surface level or at top of curb.

(8) Centrifugal Forces

From Article 2.18 of Vietnamese Bridge Design Code 2057/QD-KT4-1979 bridge on curves with R < 600m is designed for a horizontal radial force equal to the following percentage of the live load, without impact for one lane traffic :

$$C = \frac{15}{100 + R} \cdot \frac{\Sigma p}{L} \; ; \quad \text{but not less than,} \quad \frac{0.15P}{L} \quad \text{when } R < 250\text{m}$$

$$\frac{40}{R} \cdot \frac{P}{L} \quad \text{when } R > 250$$

Where : C = the centrifugal force in T/m of the live load without impact
P = total weight of truck = 30 ton
Σp = Subtotal weight of H30 trucks (uniform load) in convoy (Standard truck of Vietnamese bridge design code)
L = length of influence line but not greater than span length (in meter)
R = the radius of the curve in meter.

(9) Friction Force

From Article 2.28 of Vietnamese Bridge Design Code bearing shoe and pier supported on stone foundation are designed to resist friction effect in longitudinal direction. The friction force will be assumed to be applied transferred through bearing shoes.

The friction force shall be derived from the following formula :

Ff = f.N

where :

Ff = Friction force in tons
N = Breaking reaction force due to dead load and live load without impact
f = Friction coefficient

- for free bearing shoes of roller type or sliding type or sector type f = 0.05
- for other types, f = 0.5

(10) Collision Force

1) River Bridges

For the bridges of crossing over navigable rivers and waterways, piers supporting superstructures must be designed to resist accidental collision loads applied at design level of navigation. From Article 2.26 of Vietnamese Bridge Design Code 2057/QD-KT4-1979 values of collision loads are given in the Table 7.16

Table 7.16 Collision Force due to Navigational Collision

Total weight of Ship (ton)	Loads in ton			
	Longitudinal Force from the Direction of		Transverse Force from the Direction of	
	Span Within Navigational Width	Span Outside Navigational Width	Upstream	Downstream, but for stagnant water force applied from the direction of upstream
12,000	100	50	125	100
8,000	70	40	90	70
4,000	65	35	80	65
2,000	55	30	70	55
500	25	15	30	25
250	15	10	20	15
100	10	5	15	10

Notes :
- When piers are within a protective barrier system, collision forces are not be considered.
- Total weight of ship permissable to the river class is given in the temporary criteria table classifying Vietnamese rivers.

2) Grade Separation Bridges and Viaducts

Piers supporting grade separation bridges over other roads or railways are designed to resist accidental collision loads. Alternately a protective barrier system shall be designed and installed.

a. Collisions of Vehicles and Other Equipment

Where the piers supporting an overpass are not located behind traffic barriers, they are designed to resist a static load of 100 ton applied at angle of 10^{o} from the direction of the centerline of the road that passes under the bridge. The load shall be applied 1.8m above ground level.

b. Train Collisions

Where piers are necessary they comply with the requirements of clearance, loading and other provisions by the railway authority.

(11) Thermal Effects

Differential temperatures also cause both longitudinal and transverse secondary load effects. Variation in average bridge temperature is based on the locality in which the structure is to be constructed. Due consideration will be given to the lag between air temperature and the interior temperature of massive concrete members or structures.

The range of average temperature will generally be as shown in Table 7.17:

Table 7.17 Range of Average Temperature in Northern Vietnam

Concrete Structures	Temperature Max.	Temperature Min.
Northern of Vietnam	30°C	10°C

The effects of temperature differential applied satisfy Article 2.27 and Appendix 11 of Vietnam Bridge Design Code 2057-QD-KT4 1979.

(12) Force Induced by Debris / Logs

Piers supporting river bridges in mountain areas where influence of floating debris is present should include the impact of such in design calculation. They will be designed to resist the force due to debris, and calculated by the formula.

$F = 0.05\, Cd\, V^2 Ad$

Where : F = Design force due to debris (tons)

Cd = 1.04 (the drag coefficient)

Ad = the projected area of debris (m^2) acting on the piers will be calculated assuming the depth of debris is 1.2m below flood level, the length of debris mat shall be taken as one half the sum of the adjacent spans or 20m, whichever is smaller.

V = mean velocity of water flow for design flood level (m/s)

(13) Buoyancy

Buoyancy is considered where it affects the design of substructure including piling.

(14) Other Design Loadings

For other design loadings relevant specifications of the Vietnamese Standard are applied. For those aspects of loading details not covered by the specifications of the Vietnamese standard. The following specifications will be referred to :

- Specifications for Highway Bridge, Japan.
- Standard Specifications for Highway Bridges adopted by the American Association of State Highway and Transportation Officials (AASHTO).

7.3.2 Seismic Design

(1) General

In the past, seismic activity has not been a significant design factor in Vietnam. However, geological conditions have indicated certain areas which require considerations of seismic effects, especially in the northern part of Vietnam.

(2) Seismic Design in the Study Area

Table 7.18 indicates the relations among seismic intensity scale, acceleration coefficient and seismic performance category.

Table 7.18 Seismic Intensity Scale and Earthquake Coefficients

Seismic Intensity Scale shown in the Map	6	7	8
Acceleration Coefficient	0.04	0.07	0.17
Seismic Performance Category	A	A	B

In the region which falls in the Seismic Performance Category A, no detailed analysis is required for any bridge structures, except that the longitudinal connections of girders must be designed for specified forces. The seismic Performance Categories are defined in AASHTO Div. IA-Section 3.4 (Table I, P. 341).

7.3.3 Materials and Basic Strengths

The use and basic strengths of concrete, reinforcing steel and prestressing steel are presented in Appendix A-7.1.

7.4 Flood and Navigation Clearances

7.4.1 Frequency of Design Flood

The frequencies of design flood are determined in accordance with Article 1.29 of Vietnam Bridge Design Code 2057/QD-KT4-1979 and Article 4.6 of Design Criteria of Highway TCVN-4054-85. Table 7.19 gives the frequencies of design flood by size of bridge and by class of highway.

Table 7.19 Frequency of Design Flood

Size of Bridge	Class of Highway	Design frequency
All sizes of Bridges	I; II and Town Road	1%
Bridges L ≥ 25 m	All classes	1%
Small Bridges	III	2%
L < 25m	IV to VI	4%

7.4.2 Flood Clearance

The flood clearances for bridge design are given in Table 7.20 for rivers not utilized for navigation (Article 1.27 of Vietnam Bridge Design Code 2057/QD-KT 4-1979).

Table 7.20 Minimum Clearance Above Design Flood Level

Structure			Minimum clearance above Design flood level (m) for Highway Bridges
Girder	Water level rising by influence of piers	less than 1 m	0.50
		over 1m	0.50
	Flooded Material	Wooden logs and debris	1.00
		Roll stone	1.00
Bearing plate			0.25

Notes : Water level rising by piers is taken into account of flood level in the area, where there is water stagnating or reservoir, minimum clearance is ≥3/4 of water depth.

7.4.3 Navigation Clearances

(1) Classification of Waterways

Classification of waterways (i.e. rivers and canals) are determined in accordance with TCVN - 5664 - 1992 (refer to Table 7.21).

Table 7.21 Classification of Waterway and Navigation Clearance

Class	Waterway size					Navigation Clearance		
	Natural River		Canal		Curvature	Horizontal		Vertical
	Water Depth	Width of Water Surface	Water Depth	Width of Water Surface		River	Canal	
I	> 3.0	> 90	> 4.0	> 50	> 700	80	50	10
II	2.0 - 3.0	70 - 90	3.0 - 4.0	40 - 50	500 - 700	60	40	9
III	1.5 - 2.0	50 - 70	2.5 - 3.0	30 - 50	300 - 500	50	30	7
IV	1.2 - 1.5	30 - 50	2.0 - 2.5	20 - 30	200 - 300	40	25	6 (5)
V	1.0 - 1.2	20 - 30	1.2 - 2.0	10 - 20	100 - 200	25	20	3.5
VI	< 1.0	10 - 20	< 1.2	10	60 - 150	15	10	2.5

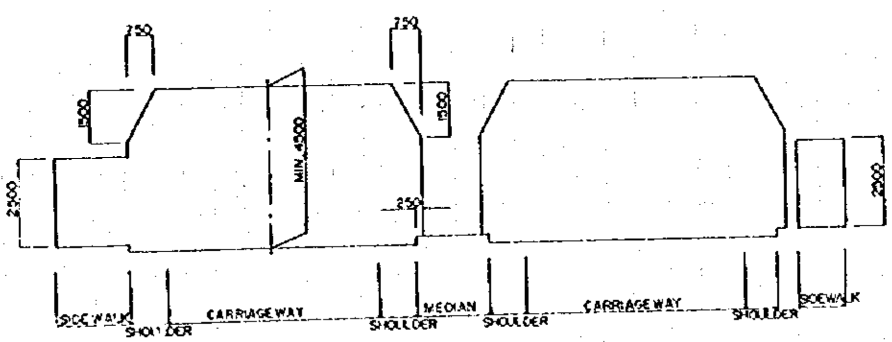
Notes :

1. Figure in ( ) may be applied with approval of official agencies.
2. Horizontal clearance : span length.
   Vertical clearance : height between water level and bottom of girder
3. Water depth and width of water surface shown on the table are based on low water level of waterway with a frequency of 95% in dry season.

7.4.4 Road and Railway Clearances

(1) Road

The clearances for the design of bridges crossing over any class of roads or pedestrian path are determined in accordance with the Design Criteria of Highway TCVN-4054-85 (refer to Figure 7.1). According to the regulation, the vertical clearance for carriageway must be kept at a minimum of 4.5 m. But considering overlays in the future, it is desirable to provide 4.75 m of vertical clearance in design. This standard is considered reasonable when compared with Japanese standards.



(2) Railway

The clearances for the design of bridges crossing over railways are determined depending on the railway gauges in accordance with Decision of the Railway Authority No. 288/CDKT (refer to Figure 7.2).

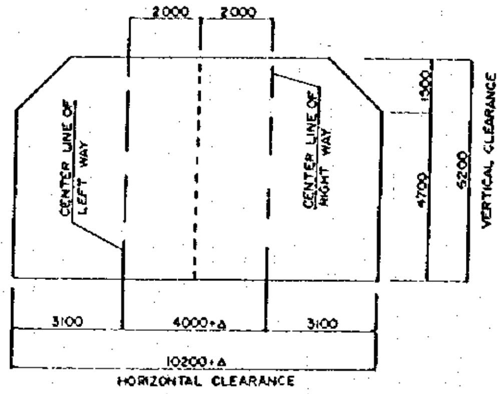


Figure 7.2 **Clearances Diagram for Bridges of Future Dual Railway Gauge 1,435 mm**

7.5 Pavement Design Standard

7.5.1 General

Pavement design should consider the following conditions :

- There are two types of design, designs of flexible pavements and rigid (concrete) pavements;
- Two categories of road construction are involved in the project, widening or overlay of existing pavement, and new construction of bypass road;
- In the selection of pavement type, investment efficiency sometimes should be considered in addition to the construction cost; and
- Construction aspects and local conditions sometimes govern the selection of pavement type when the reconstruction/adjustment of related roads is necessary.

7.5.2 Selection of Pavement Type

(1) Pavement Characteristics and Local Situations

Characteristics of flexible pavement and rigid pavement are compared together with local situations as summarized in Table 7.22.

Table 7.22 Flexible Pavement vs Rigid Pavement

Item	Flexible Pavement	Rigid Pavement
Stage development	Two stages for 20 years	Single stage for 20 years
Maintenance	Frequent maintenance	Almost maintenance-free
Quality control	Difficult especially in rainy situations	Easy
Sensitivity to overloading of trucks	Sensitive	Not sensitive
Material source	Imported asphalt	Locally produced cement
Adaptability to related road	Easy widening and reconstruction	Careful traffic management is necessary

(2) Road Construction Type

Both flexible and rigid pavement types are available for the construction of bypass roads which will not be affected by existing traffic, however the adoption of rigid pavement could eliminate down time and material loss from rains, as well as minimize maintenance cost.

(3) Consideration from the Investment Efficiency Standpoint

Generally the total cost of construction and maintenance of rigid pavement will be lower than that of flexible pavement since bituminous materials have been maintaining a high cost level in recent years.

(4) Selection of Pavement Type

As a result of the study, the flexible type pavement is to be employed in consideration of :

a. The fact that the present market is suffering from cement shortages;
b. The fact that flexible design will ensure expeditious construction especially in unfavorable soils areas; and
c. Lower initial cost.

7.5.3 Design Standard of Flexible Pavement

The thickness design of the pavement will be based on the "AASHTO Interim Guide for Design of Pavement Structures, 1972". The "AASHTO Guide for Design of Pavement Structures, 1986" will also be used to determine percent of 18-kip ESAL in design lane.

Chapter 8

OPTIMUM SOLUTION OF HIGHWAY NO.18 IMPROVEMENT

CHAPTER 8 OPTIMUM SOLUTION OF HIGHWAY NO. 18 IMPROVEMENT

8.1 Highway No. 18 Improvement Policy

The improvement of the Highway No. 18 will require an enormous investment. A method which will ensure optimum investment efficiency needs to be selected in consideration of initial investments and road structure which satisfies traffic demand; therefore it is necessary to adopt the stage construction approach. In conjunction with the project, sufficient consideration must be taken for the highway's involvement with the road network plan of the surrounding area. In particular, it is necessary to clarify the planning policies for the proposed Alternate Highway and for National Highway No. 18.

8.2 Road Capacity and Number of Lanes

8.2.1 Summary of the Results of Traffic Forecast

The forecast traffic volumes for the target years of 2005 and 2015 were calculated as described in Chapter 5 and are summarized in Table 8.1 together with existing traffic volumes in the year 1995.

Table 8.1 Summary of Traffic Volume

Section		Noi Bai - Bac Ninh	Bac Ninh - Chi Linh	Hong Gai - Cua Ong	Cua Ong - Tien Yen	Tien Yen - Bac Luan
Road Length (km)		31.3	36.4	38.7	43.5	86.9
(pcu/day)	1995	1,800	2,800	4,900	600	700
	2005	7,600	14,800	21,300	3,200	3,400
	2015	22,700	37,100	49,800	9,700	9,900

Note: pcu: Passenger car unit

8.2.2 Road Capacity

(1) Methodology

The concept and methodology used for the road capacity analysis are based on the "Highway Capacity Manual of Highway Research Board, U.S.A". However, some adjustment was made to reflect local conditions based on the results of studies undertaken by the "Highway Research Board, Japan", since much resemblance is found in the types of sizes of vehicles, and in operating conditions in Vietnam and Japan.

The flow diagram in Figure 8.1 shows the procedure and the factors to be considered depending on the conditions of the area, type of vehicle, quality of the traffic flow and the cross section of the roads.

To attain hourly design capacity of the roads, basic capacity, potential capacity and service level were discussed. The result of traffic capacity analysis is shown in Table 8.2.

(2) Daily Design Capacity

1) Peak Ratio (K)

The actual traffic flow on roads is not always constant but has characteristics that change by year, season, month, day and hour, depending on the nature of the road.

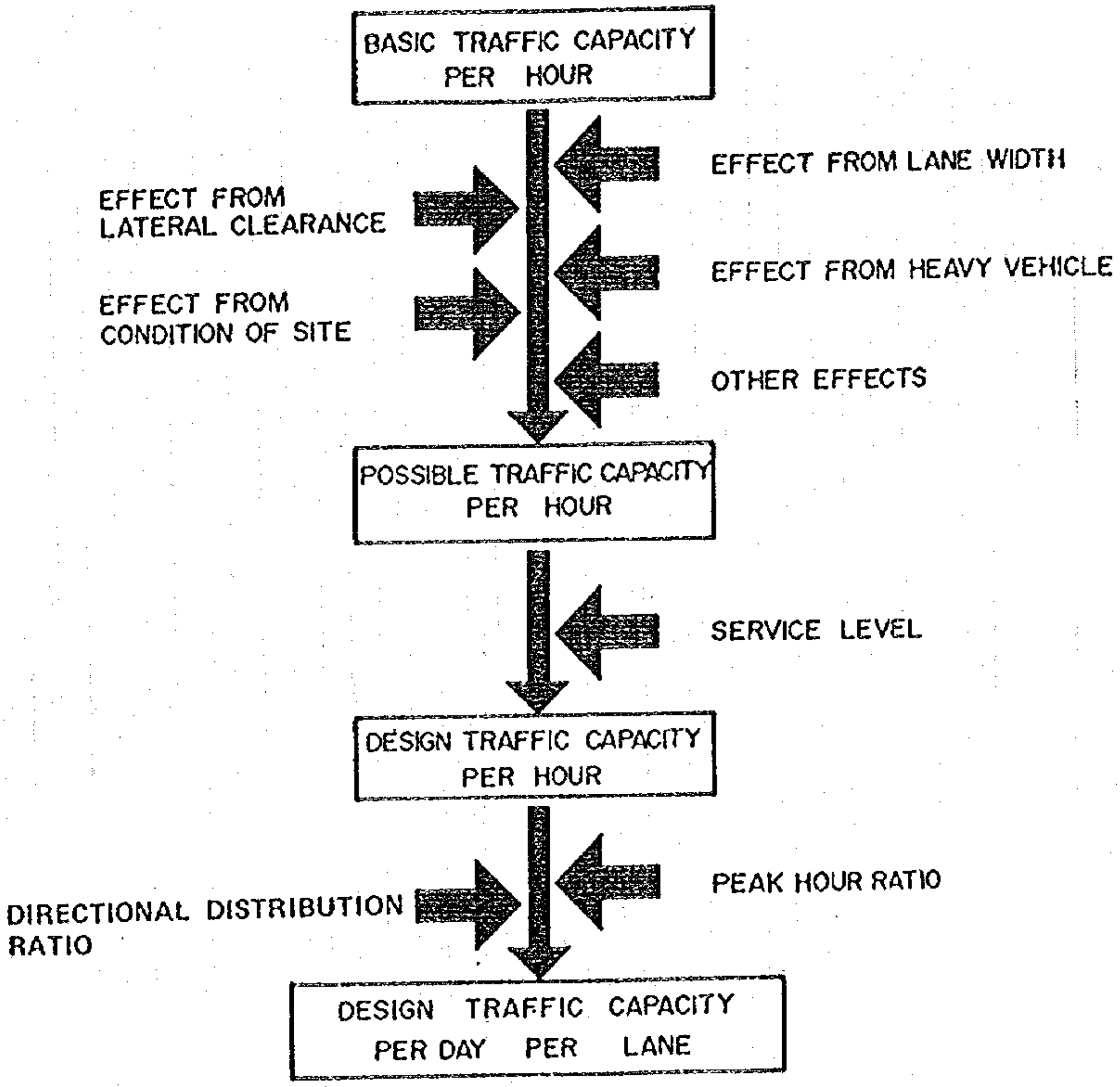
Normally the 30th highest annual hourly traffic volume is applied for estimation of the capacity. The convention factor from daily to hourly "K" is defined as the ratio of the 30th highest annual hourly traffic volume against the average annual daily traffic volume (AADT). In accordance with the results of the survey, a "K" value of 9.0 ~ 10.0% was used for the roads.

2) Directional Distribution Ratio (D)

Generally speaking, traffic volume is shown by total volume in two directions. However, the traffic volume in each direction is not usually the same, especially in the morning and evening peak hours. A "D" value of 55% is adopted in accordance with the result of the survey.

3) Design Capacity

Design capacity per day, per single lane is therefore equal to 5,000 x Design Traffic Capacity per hour ÷ (K x D). Table 8.2 shows the results of the calculations following the design concept and procedure presented in the footnotes for both cases of Service Level - 1[1] and Service Level - 3[2]



HIGHWAY NO. 18 IMPROVEMENT	Figure 8.1 Flow of Road Capacity Analysis

Table 8.2 Road Traffic Capacity Analysis in the Study Area

ITEM	DESIGN SPEED (Km/hr)	LANE WIDTH (m)	LATERAL CLAER-ANCE		HEAVY VEHICLE		COEFFICIENT OF ADJUSTMENT					BASIC CAPACITY (PCU/hr.)	POSSIBLE CAPACITY (PCU/hr.)	SERVICE LEVEL	ADJUSTMENT OF SERVICE LEVEL	DESIGN CAPACITY(PCU/hr)	PEAK FACTOR (%)	RATE OF DIRECTION (%)	DESIGN DAILY CAPACITY (PCU/Day)PER LANE
			Right	Left	% of H.V.	Passr. car Equiva.	Lane Width	Lateral Clear-ance	Heavy Veh.	Cond. of Sight	Total								
			(m)	(m)	Pt	Et	L	c	T	I		CB	C			CD	K	D	ADT
2-lane 2-way (Typical National Road)	60	6.0	1.0	1.0	—	—	0.85	0.86	—	0.95	0.694	2 500	1 735	2	0.85	1 475	10.0	—	15 000*
2-lane 2-way (Typical National Road)	80	7.0	2.0	2.0	—	—	1.0	0.75	—	0.85	0.637	2 500	1 592	2	0.85	1 353	9.0	—	15 000*
4-lane 2-way National Road/ Urban Area	80	3.5	2.5	0.5	—	—	1.0	0.90	—	0.70	0.63	2 500	1 575	2	0.85	1 339	9.0	55	13 500
4-lane 2-way (Typical Freeway)	120	3.5	2.5	1.5	—	—	1.0	1.0	—	1.0	1.0	2 500	2 500	1	0.75	1 875	9.0	55	18 900

NOTE:

(1) $T = \frac{100}{100 - Pt + ET \cdot Pt}$

$C = CB \cdot L \cdot c \cdot I \cdot T$

$ADT(\text{MULTIPLE LANES}) = \frac{5.000 \times CD}{K \cdot D}$

(2) The figure with a asterisk indicates design daily capacity of 2 lane/2 way road.

(3) The figure with two asteriaks is decided as the result of consideration of bicycles.

WHERE:

T: COEFFICIENT OF ADJUSTMENT FOR HEAVY VEHICLES
Pt: PERCENTAGE OF HEAVY VEHICLES
ET: PASSENGER CAR EQUIVALENT OF HEAVY VEHICLES
L: COEFFICIENT OF ADJUSTMENT FOR LANE WIDTH
C: COEFFICIENT OF ADJUSTMENT FOR LATERAL CLEARANCE
I: COEFFICIENT OF ADJUSTMENT FOR CONDITION OF SIGHT
K: PEAK FACTOR (%)
D: RATE OF DIRECTION (%)
CD: DESIGN CAPACITY (VEH/HOUR)
CB: BASIC CAPACITY (PCU/HOUR)

Service Level 1: In the target year of design, the annual maximum peak hour traffic volume is less than the road's attainable capacity per hour. Vehicles in the 30th highest annual hourly volume can keep stable flow at certain speeds, but selection of speed is restricted.

Service Level 2: In the target year of design, the 10th highest annual hourly traffic volume reaches the road's attainable capacity and this sometimes causes serious traffic jams during these peak ten hours. Vehicles in the 30th highest annual hourly traffic volume are unable to keep uniform speeds and the attainable speed changes at random.

Service Level 3: In the target year of design, the 30th highest annual hourly traffic volume exceeds the road's attainable possible capacity and this causes serious traffic jams during these peak 30 hours. A vehicle in the flow of the 30th highest annual hourly traffic volume is continually forced to change speed and sometimes is forced to stop.

Even if Service Level 3 is adopted, it is theoretically possible to say that during only 30 hours in one year (8,760 hours) does the traffic volume exceed possible capacity.

(3) Determination of Required Number of Traffic Lanes (2015)

Taking into account physical limitations of Highway No. 18, the number of traffic lanes of the highway was calculated based on the year 2015).

The number of lanes of the respective highway road section was proposed as shown in Table 8.3.

Table 8.3 Summary of Required Number of Traffic Lanes

	Highway Section	Number of Lanes
1)	Noi Bai - Bac Ninh	2 (Initial Stage, 2001) and 4 (Final Stage, 2013)
2)	Bac Ninh - Chi Linh	2 (Initial Stage, 2001)
3)	Hong Gai - Cua Ong	4 (Initial Stage, 2001)
4)	Cua Ong - Bac Luan	1 - 2 (Initial Stage, 2000) and 2 (Final Stage, 2010)

(4) Adopted Number of Traffic lanes

1) Noi Bai - Bac Ninh Section

Adoption of class-I highway for the final stage of development discussed in Paragraph 7.2.3 (1) in Chapter 7. The minimum number of lanes for Class-I highway is four (4), however as far as right-of-way acquisition is concerned, an adoption of six (6) lanes will be recommended for the ultimate stage development of Noi Bai - Bac Ninh highway.

2) Bac Ninh - Chi Linh Section

As discussed in Paragraph 7.2.3 (2) the adoption of 4-lane improved highway and the 2-lane improved highway with 4-lane alternate highway was compared. As a result of the comparison of the above two alternates, it was found that the adoption of 2-lane improved highway together with the construction of the alternate highway is advantageous. Therefore 2-lane 2-way highway will be adopted for the entire section of Bac Ninh - Chi Linh Section in the preliminary design.

3) Hong Gai - Cua Ong Section :

Basically, an urban highway design approach will be adopted in this section. 4-lane highway with side lanes for slow moving bicycle or oxcarts, a center median and sidewalks will be adopted.

4) Cua Ong - Bac Luan Section

2-lane 2-way highway will be adopted to meet the requirement of the results of future traffic demand projection.

8.2.3 Stage Construction

The improvement of Highway No. 18 requires a very large investment due to various construction requirements. For this reason and to optimize the investment, it was necessary to adopt the stage-construction approach.

For the determination of the order of priority of the improvement level, factors such as traffic demands and the need of the build-up of a continuous Highway No. 18 were taken into account.

8.3 Consideration for the Development of Alternate Highway

8.3.1 Necessity of Alternate Highway and the Government's Highway Development Policy

The need for improving the road network in the Red River delta through provision of a new highway system (i.e., alternate highway) is primarily a product of the recent rapid economic development and forecasted drastic rise in future vehicle traffic demand. To cope with this situation, the government recently decided to develop an alternate highway in the Ha Noi - Ha Long corridor, since even the upgrading of Highway No. 18 and four-lane widening of Highway No. 5 together will not be sufficient to meet this demand, which includes greater shipping and speed capacities as well. It will take approximately ten years from planning stage to completion. Experience of other Asian countries has shown that Vietnam is at an economic stage appropriate for the development of expressway, based on the GDP per capita of the nation.

8.3.2 Alternate Highway Development Policy of the Government

The development policy of the alternate highway (expressway) which was recommended in the "Master Plan Study on the Transport Development in the Northern Part in Vietnam (1994, by JICA)" was accepted, although the adoption of the original route directly connecting Ha Noi and Hai Phong has been modified to run the northern area generally parallel to the Highway No. 18 between Noi Bai - Ha Long. The improvement project proposed for Highway No. 18 will be directly effected where the alternate highway passes through its vicinity. This influence is reflected in the policies of this survey, as concluded in Subsection 8.2.1.

Presently the government intends to provide the alternate highway in the corridors of the following highways:

- National Highway No. 1 in Ha Noi and its vicinity areas;
- Provincial Highway Nos. 286 and 410 (i.e. Noi Bai - Bac Ninh Section of the Highway No. 18); and
- National Highway No. 18 between Bac Ninh - Ha Long.

8.3.3 Observation concerning the Planning of Alternate Highway

(1) Planning

The alternate highway (expressway) network should be developed with a basic understanding that the services of arterials and expressways differ. Vehicles on shorter trips use arterials and expressways are generally utilized by vehicles bound for further destinations. Expressways such as the proposed alternate highway are required to maintain higher standards of traffic capacity and driving speed.

(2) Service level

High capacity and high speed as on the regional expressway should be maintained for the alternate highways.

8.3.4 Inception Study of the Alternate Highway between Bac Ninh and Chi Linh

In response to the request of PMU No. 18, the Study Team conducted the inception study of the alternate highway between Bac Ninh and Chi Linh (hereinafter referred to "The Alternate Highway"). Refer to Appendix A - 8.1 for the working paper concerning the alternate highway.