CHAPTER 7 TRAFFIC DEMAND FORECAST

7.1 Traffic Survey

7.1.1 Outline of the survey

To understand the characteristics of present traffic movement of the Tribhuvan Highway, which is the alternate path of the Project Road and for the preparation of basic data for future traffic demand forecast, the following traffic surveys were conducted in April 2000.

a) Traffic Count Survey
b) Roadside OD (Origin-Destination) Survey
c) Vehicle Speed Survey
  - Passenger Car Speed Survey by Floating Car Method.
  - Heavy Vehicle Speed Survey by Number Plate Observation.
  - Vehicle Speed Survey with Speed Gun.

7.1.2 Zoning in the study area

All of Nepal was divided into 38 traffic zones. Area in vicinity of the Project Road was divided into small zones and area far from the Project Road was divided into bigger zones, as follows.

Table 7.1 Zoning Level

Area	Zoning Unit	Remarks
Central Development Region	District Level	
Western Development Region	Administrative Zone	
Eastern Development Region	Regional Level	
Mid Western Development Region	Regional Level	
Far Western Development Region		
Kathmandu/Dhading District	VDC Level	Including the Project Area

Table 7.2 Zone Table

Seq. No.	Traffic Zone Name	Region	Zone	District	City/Village
1	Kathmandu City	Central Dev. Region	Bagumati	Kathmandu	Kathmandu City
2	Kathmandu Rural North				Refer Figure-1 Zoning Map
3	Kathmandu Rural South				of Kathmandu Rural Area
4	Bhimdhunga				Bhimdhunga
5	Ramkot				Ramkot
6	Sitapaila				Sitapaila, Icahnghu, Narayan
7	Syuchatar				Naikap Purano Bhanjyan, Syuchatar,
8	Thankot				Thankot, Bad Bhanjyan
9	Dahachok				Dahachok
10	Balambu				Mahadev Sthan, Matatirtha, Balambu, Satuungal
11	Tinthana				Naikap Naya Bhanjyan, Tinthana
12	Chharredeurari			Dhading	Chhatredeurari
13	Jiwanpur				Jiwanpur
14	Naubise				Naubise
15	Other Dhading				Other Dhading
16	Lalitpur			Lalitpur	
17	Bhaktapur			Bhaktapur	
18	Sindhupalchok			Sindhupalchok	
19	Kabrepalanchok			Kabrepalanchok	
20	Nuwakol			Nuwakol	
21	Rusawa			Rusawa	
22	Dhanusha		Janakpur	Dhanusha	
23	Mahottri			Mahottri	
24	Sarlahi			Sarlahi	
25	Sindhuli			Sindhuli	
26	Ramechhap			Ramechhap	
27	Dolakha			Dolakha	
28	Makawanpur		Narayani	Makawanpur	
29	Rautahat			Rautahat	
30	Bara			Bara	
31	Parsa			Parsa	
32	Chitawan			Chitawan	
33	Gandaki	Western Dev. Region	Gandaki		
34	Dhawalasin		Dhawalasin		
35	Lumbini		Lumbini		
36	Eastern Dev. Region	Eastern Dev. Region			
37	Mid Western Dev. Region	Mid Western Dev. Region			
38	Far Western Dev. Region	Far Western Dev. Region			
39	India	India			

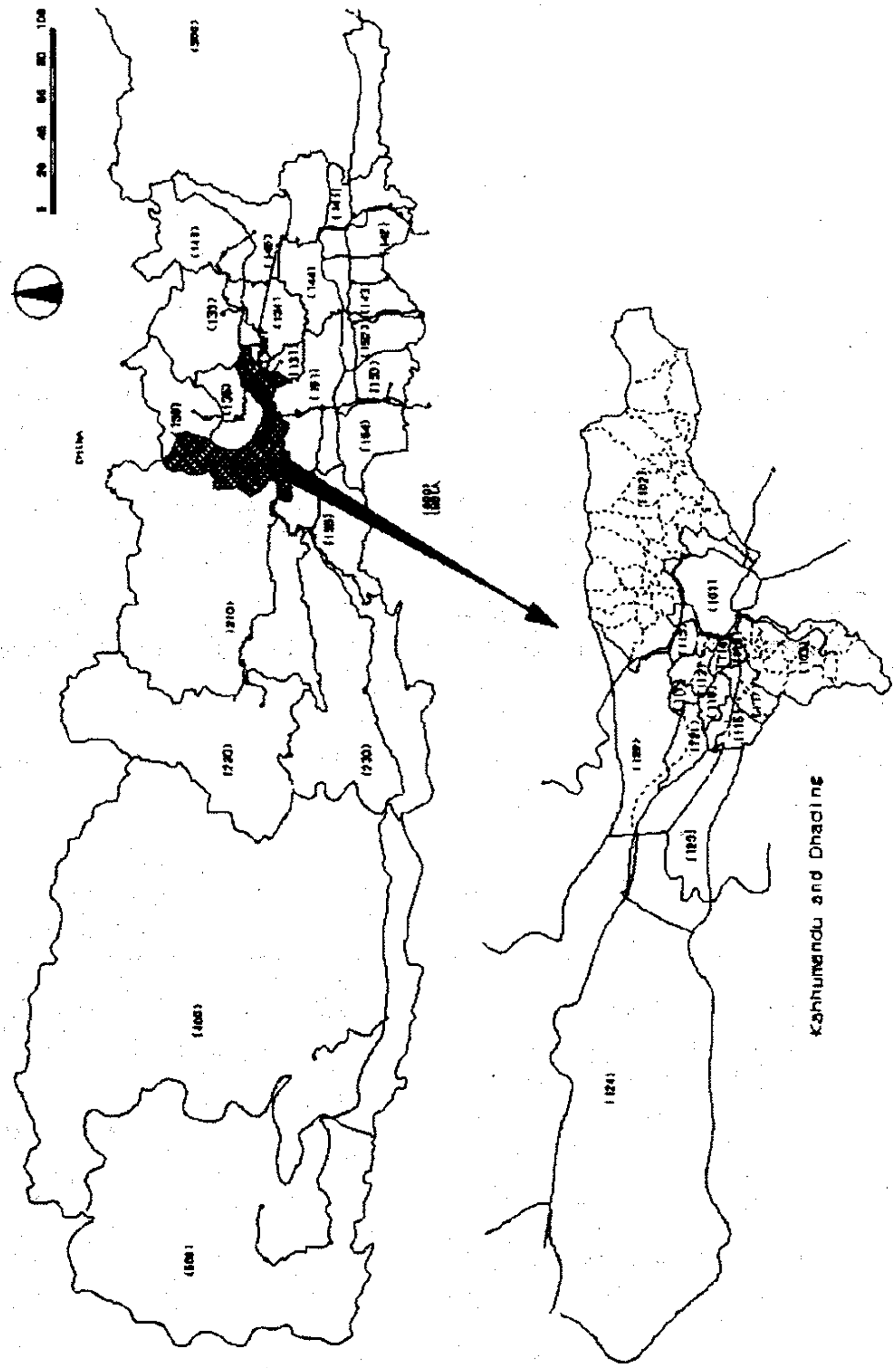


Figure 7.1 Zoning Map

7.1.3 Method of survey

1) Traffic Count Survey

Traffic Count Survey was carried out as follows.

a) Survey Point : Thankot (the same point as roadside OD survey) and Kalanki on Tribhuvan Highway (outside of Ring Road)

b) Survey Days : 23rd (Sunday) - 29th (Saturday) April 2000 at Thankot for one week on a certain weekday

25th (Tuesday) April 2000 at Kalanki for one day on weekday.

c) Survey Time : 24hours

d) Survey method : Surveyors counted passing vehicles with the manual counter

e) Survey contents : Traffic volume in terms of direction different, type of a car different, time belt.

f) Vehicle type : Passenger Car, Jeep, Pick-up, Tempo, Mini Bus, Bus, Mini Truck, Truck, Multi axel truck, Tractor, Motorcycle and others.

Traffic count at Kalanki was conducted to supplement the traffic data at Thankot with the traffic between Kathmandu and Thankot.

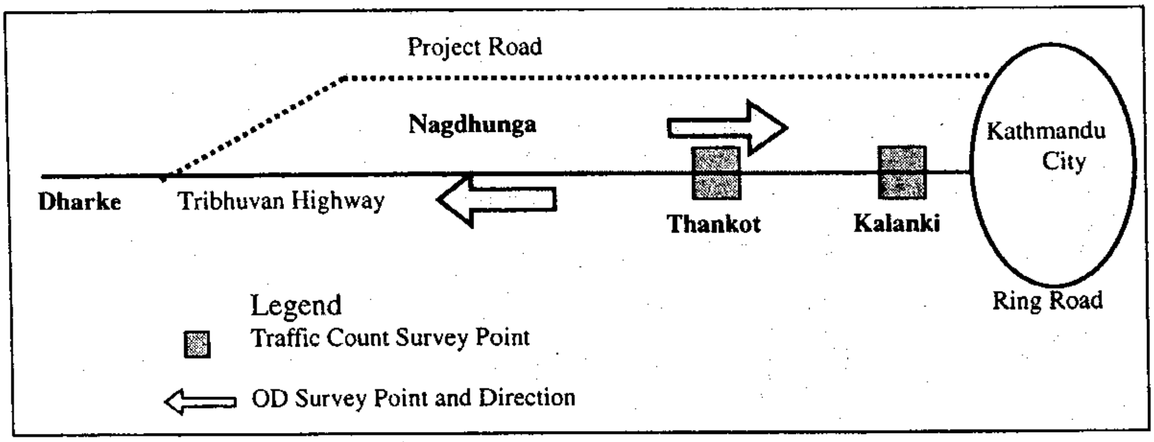


Figure 7.2 Point of Traffic Count Survey and OD Survey

2) Roadside OD Survey

Roadside OD survey was carried out as follows.

a) Survey Point : Thankot and Nagdhunga on Tribhuvan Highway
b) Survey day : 24th April (Monday)～26th April (Wednesday) on three weekdays.
c) Survey time : 12 hours (6:00(AM) ～ 18:00(PM))
d) Survey contents : Information to be collected by the interview are as follows:

- Origin and destination of trip
- Purpose of trip
  (To office, To school, Business, Shopping, Back to home, Sightseeing, and Others)
- Number of passengers including driver
- Kind of goods
- Weight of goods
- Vehicle type (Passenger Car, Jeep, Pick-up, Mini bus, Bus, Tempo, Mini Truck, Truck, Multi axel truck, Tractor, Motorcycle and others)

Thankot is considered to be optimal survey site in order to obtain data on long trip traffic between Kathmandu and other area outside of Kathmandu, since most of these long trip traffic pass this site. There has been two (2) check points operated by the Police Office, one site is located at Thankot to check vehicles coming into Kathmandu Valley and the other site is at Nagdhunga to check vehicles going out from Kathmandu Valley. To minimize disturbance of the current traffic on the Tribhuvan Highway, the survey points were selected at the same places as those of the check points (Thankot and Nagdhunga). As for the classification of vehicle type, similar classification which used in the related previous study was applied.

The form of questionnaire sheet is presented in Table 7.3.

Table 7.3 OD Survey Interview Sheet

Station No.	Date: Day:	Direction 1 to: 2 from:		Time(When interviewed)		Interviewer:				
Sample No.	Vehicle Type 1.Motorcycle 2.Passenger Car 3.Jeep 4.Pickup 5.Tempo 6.Others 7.Mini Bus 8.Bus 9.Mini Truck 10.Truck 11.Multi axel truck 12.Tractor 99.Unknown	Origin Write the place of departure		Destination Write the place of destination		Purpose 1.Go to office/ Working place 2.Go to school 3.Business 4.Shopping 5.Back to home 6.Sightseeing 9.Unknown	No.of Passengers (Including driver)	For Truck		
		Region/ Zone	District/ City,Village	Region/ Zone	District/ City,Village			Capacity ton	Commodity WT 1.Empty 2.1/4F 3.1/2F 4.3/4F 5.Full	Commodity Type 1.Rice 2.Timber 3.Other agriculture 4.Oil 5.Mineral 6.Machinery 7.Chemical 8.Construction material 9.Miscellaneous

3) Vehicle Speed Survey (Passenger Car Speed Survey by Floating Car Method)

Travel time of Passenger car was surveyed as the traveling time of self-driving car under normal driving condition.

a) Survey section : Kalanki Intersection (Ring Road) ~ Dharke period of the Prithivi Highway
b) Survey day : 24th April, 2000 (Monday)
c) Time of a survey : Total of 3 times in the morning/daytime/evenings

4) Heavy Vehicle Speed Survey by Number Plate Identification

The Study Team set up two checkpoints on the Tribhuvan Highway, and the Study Team recorded number plate of heavy vehicle and its passing time. The travel time in between two checkpoints was calculated in time difference between vehicle passing time at each checkpoint.

a) Survey section : Nagdhunga to Naubise
b) Survey day : 24th April, 2000 (Monday)
c) Survey Time : 13:00(PM) ~18:00(PM)
d) Time of a survey : 3 times in morning/daytime/evenings
e) Type of a car classification : The cargo condition of a bus, truck difference

5) Vehicle Speed Survey by Speed Gun

The above two kind of vehicle speed survey shows average traveling speed in a certain section. To analyze the relationship between vehicle speed and road profile grade, vehicle speed survey by Speed Gun was carried out at the some specific point.

a) The survey sections : Between Nagdhunga and Naubise on Tribhuvan Highway as shown in Figure 7.3

b) The survey time : 4^{th} June 2000 (Sunday) 8:00AM - 17:00PM

c) Survey Method : The surveyor measured the passage vehicle with a speed gun
Speed-Gun: *Model UK-15 Hand held Traffic Radar (by Traffic Safety System LTD)*

d) Road Grad : 4% ~ 9.5% (by result of profile survey)

e) Type of a car classification ; Motorcycle, Passenger car, Mini bus, Bus, Mini truck, Truck Multi Axel Truck

f) Loading Situation Classification of Trucks : Full, Construction Materials (Cobble, Stones, Timber, Bar, RC-Pipe etc.), Livestock (buffalo etc.) , Oil / Mineral water, Others

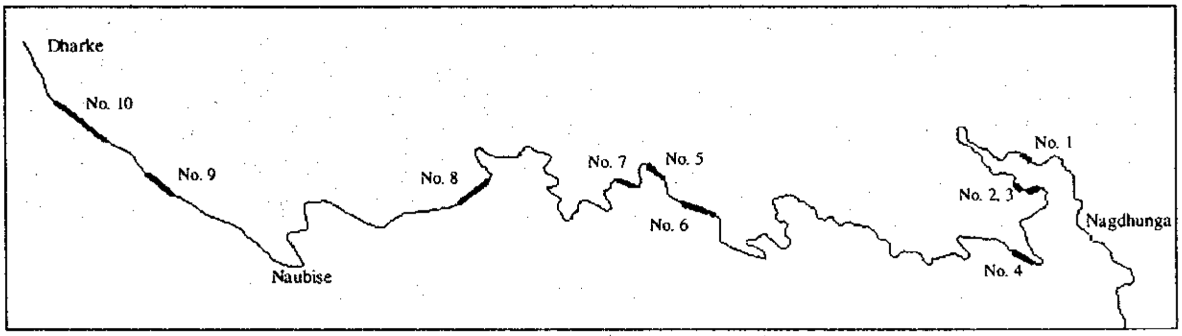


Figure 7.3 Key Plan of Vehicle Speed Survey Section

Table 7.4 Road Grade of Survey Section

Speed Survey Point No.	Grade (%)
1	4.0
2	8.8
3	9.5
4	6.6
5	5.2
6	5.1
7	7.2
8	4.6
9	6.9
10	5.6

7.1.4 Result of traffic count survey

1) Traffic Volume

Result of Traffic count survey at Thankot and Kalanki are shown in Table 7.5 and 7.6, respectively.

Spot traffic volume at Thankot is observed to be about 5,700 Vehicles/day, and traffic volume at Kalanki is about 12,500 vehicles/day on this survey period.

Table 7.5 Result of Traffic Count Survey by Vehicle Type at Thankot

(Vehicle/day)

Location: Thankot	Motorcycle	Car,Van	Jeep	Pick-up	Tempo	Others	Minibus	Bus	Mini Truck	Truck	Multi Axle Truck	Tractor	Total
Sun-Mon	1,188	515	374	205	25	52	602	770	393	1,485	12	14	5,635
Mon-Tue	972	468	330	247	36	60	642	1,023	370	1,517	13	15	5,693
Tue-Wed	805	431	323	198	22	41	606	848	369	1,592	5	12	5,252
Wed-Thu	959	443	333	226	22	55	646	836	378	1,657	7	15	5,577
Thu-Fri	978	432	330	226	19	76	628	784	411	1,664	8	5	5,561
Fri-Sat	1,069	557	371	277	25	50	642	849	351	1,746	15	17	5,969
Sat-Sun	1,479	738	340	191	16	23	545	845	336	1,605	13	14	6,145
Average	1,064	512	343	224	24	51	616	851	373	1,609	10	13	5,690
Ratio	19%	9%	6%	4%	0.4%	1%	11%	15%	7%	28%	0.2%	0.2%	100%

Table 7.6 Result of Traffic Count Survey by Vehicle Type at Kalanki

(vehicle/day)

Location: Kalanki	Motorcycle	Car,Van	Jeep	Pick-up	Tempo	Others	Minibus	Bus	Mini Truck	Truck	Multi Axle Truck	Tractor	Total
Tue-Wed	3574	1819	614	907	394	644	800	1033	689	1928	8	84	12494
Ratio	29%	15%	5%	7%	3%	5%	6%	8%	6%	15%	0.1%	1%	100%

2) Daily Fluctuation of Traffic

Daily Fluctuation of Traffic at Thankot is shown in Figure 7.4.

Traffic fluctuation coefficient within a week at Thankot is 0.92 to 1.06.

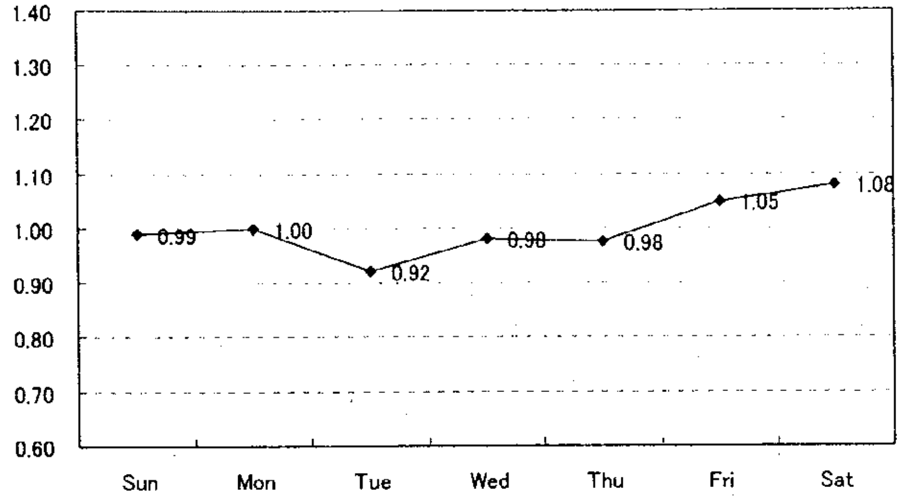


Figure 7.4 Daily Fluctuation of Traffic

3) Hourly Fluctuation of Traffic

a) Hourly Fluctuation of Traffic at Thankot

The Hourly Variation of weekly Average Traffic volume at Thankot is presented in Figure 7.5 and Figure 7.6.

In Tribhuvan Highway the peak traffic volume appears from 16:00-17:00 in the evening for Kathmandu direction and 7:00-8:00 in morning for Naubise direction. The truck traffic for the Kathmandu direction has its peak in morning 8:00-12:00, the truck traffic for the Naubise direction has a gentle peak in afternoon.

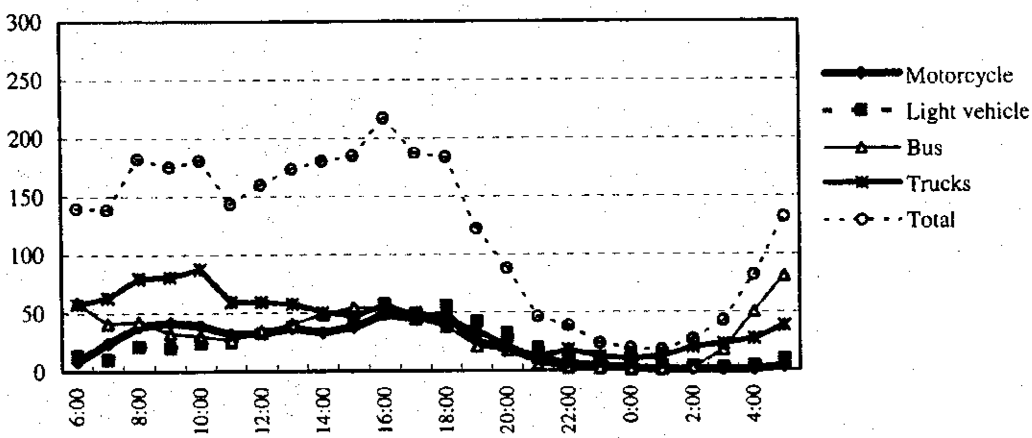
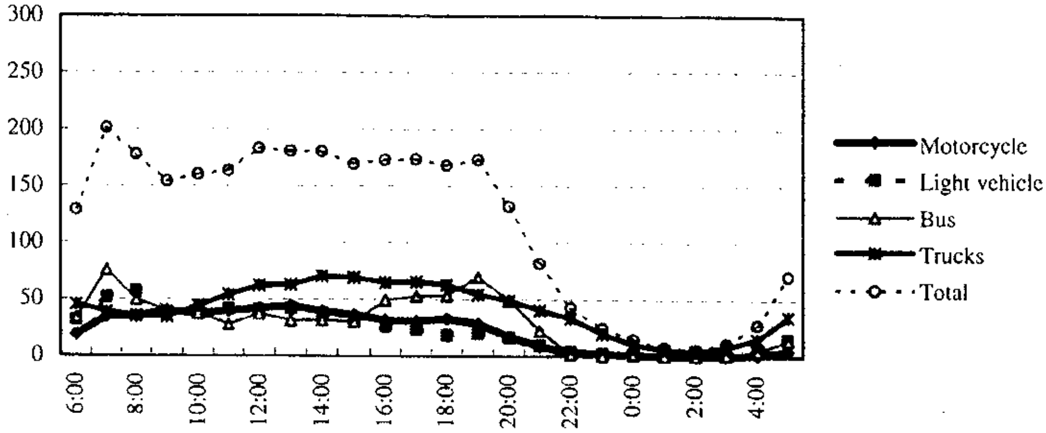


Figure 7.5 Hourly Fluctuation of Traffic (Thankot / from Naubise to Kathmandu)



Note; Light Vehicle includes Passenger Car, Jeep, Pickup, Tempo and Others

Figure 7.6 Hourly Fluctuation of Traffic (Thankot / from Kathmandu to Naubise)

Peak rate in a week average/weekdays/holidays is shown in Table 7.7.

Table 7.7 Peak Ratio at Thankot

Time	Week Average		Weekday		Holyday	
	From Kathmandu To Naubise	From Naubise To Kathmandu	From Kathmandu To Naubise	From Naubise To Kathmandu	From Kathmandu To Naubise	From Naubise To Kathmandu
6:00 - 7:00	0.046	0.049	0.039	0.047	0.058	0.054
7:00 - 8:00	0.072	0.048	0.060	0.048	0.076	0.047
8:00 - 9.00	0.063	0.063	0.053	0.065	0.073	0.052
9:00 - 10:00	0.055	0.061	0.048	0.064	0.061	0.043
10:00 - 11:00	0.057	0.063	0.050	0.063	0.071	0.060
11:00 - 12:00	0.058	0.050	0.051	0.050	0.061	0.049
12:00 - 13:00	0.065	0.055	0.056	0.056	0.075	0.050
13:00 - 14:00	0.064	0.060	0.052	0.060	0.084	0.061
14:00 - 15:00	0.064	0.063	0.056	0.064	0.068	0.057
15:00 - 16:00	0.060	0.064	0.053	0.063	0.065	0.068
16:00 - 17:00	0.062	0.075	0.055	0.077	0.052	0.068
17:00 - 18:00	0.062	0.065	0.055	0.063	0.052	0.076
18:00 - 19:00	0.060	0.064	0.053	0.058	0.048	0.095
19:00 - 20:00	0.062	0.042	0.052	0.041	0.040	0.049
20:00 - 21:00	0.047	0.031	0.039	0.029	0.032	0.037
21:00 - 22:00	0.029	0.016	0.025	0.016	0.020	0.019
22:00 -23:00	0.015	0.013	0.012	0.013	0.015	0.015
23:00 - 24:00	0.009	0.008	0.007	0.008	0.008	0.008
0:00 - 1:00	0.005	0.006	0.004	0.007	0.004	0.005
1:00 - 2:00	0.003	0.006	0.002	0.006	0.002	0.004
2:00 - 3:00	0.002	0.009	0.002	0.010	0.001	0.005
3:00 - 4:00	0.004	0.015	0.003	0.015	0.003	0.014
4:00 - 5:00	0.010	0.028	0.008	0.029	0.008	0.024
5:00 - 6:00	0.025	0.046	0.163	0.047	0.026	0.038

b) Hourly Fluctuation of Traffic at Kalanki

Hourly fluctuation of traffic volume on April 25 (Tuesday) in Kalanki is shown in Figure 7.7 and Figure 7.8.

The peak of traffic for Kathmandu direction appears in 9:00-10:00 and 16:00-17:00. As for the traffic for Naubise direction, there is no obvious peak. Almost of traffic was distributed in the day time (8:00 - 18:00).

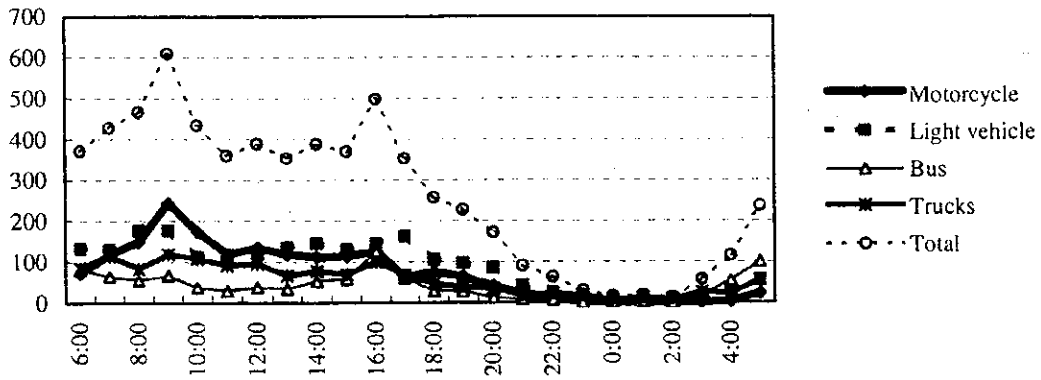


Figure 7.7 Hourly Fluctuation of Traffic (Kalanki / from Naubise to Kathmandu)

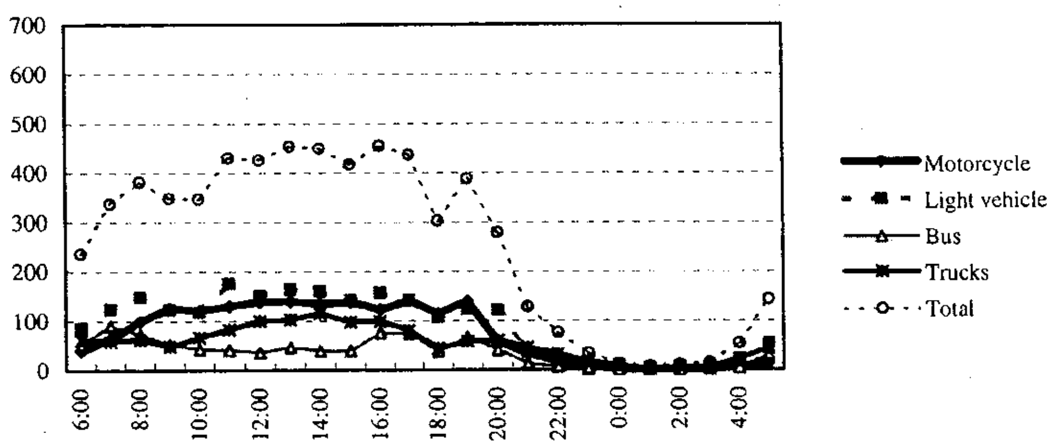


Figure 7.8 Hourly Fluctuation of Traffic (Kalanki) / from Kathmandu to Naubise)

Peak rate in Tuesday-Wednesday at Kalanki is shown in Table 7.8.

Table 7.8 Peak Ratio at Kalanki

	Tuseday-Wednesday	
Time	**From Kathmandu To Naubise**	**From Naubise To Kathmandu**
6:00 - 7:00	0.038	0.059
7:00 - 8:00	0.055	0.068
8:00 - 9.00	0.062	0.074
9:00 - 10:00	0.057	0.096
10:00 - 11:00	0.056	0.069
11:00 - 12:00	0.070	0.057
12:00 - 13:00	0.069	0.062
13:00 - 14:00	0.074	0.056
14:00 - 15:00	0.073	0.061
15:00 - 16:00	0.068	0.059
16:00 - 17:00	0.074	0.079
17:00 - 18:00	0.071	0.056
18:00 - 19:00	0.049	0.041
19:00 - 20:00	0.063	0.036
20:00 - 21:00	0.045	0.027
21:00 - 22:00	0.021	0.014
22:00 - 23:00	0.012	0.010
23:00 - 24:00	0.006	0.005
0:00 - 1:00	0.002	0.002
1:00 - 2:00	0.001	0.003
2:00 - 3:00	0.002	0.002
3:00 - 4:00	0.002	0.009
4:00 - 5:00	0.009	0.018
5:00 - 6:00	0.023	0.037

c) Daytime Traffic Ratio

The daytime traffic ratio (24h/12h) at Thankot and also Kalanki is shown in Table 5.9. The daytime traffic ratio at Thankot and Kalanki are 1.3 and 1.4 respectively.

Table 7.9 Daytime Traffic Ratio

Location: Thankot

		To Naubise			To Kathmandu		
	Traffic Volume (24hours)	Traffic Volume (12hours)	Daytime Traffic Ratio	Traffic Volume (24hours)	Traffic Volume (12hours)	Daytime Traffic Ratio	Total
Sun - Mon	2803	2123	1.32	2832	2029	1.40	1.36
Mon - Tue	2699	1878	1.44	2994	2187	1.37	1.40
Tue - Wed	2635	1894	1.39	2617	1908	1.37	1.38
Wed - Thu	2741	1963	1.40	2836	2023	1.40	1.40
Thu - Fri	2781	1938	1.43	2780	1984	1.40	1.42
Fri - Sat	3005	2079	1.45	2964	2084	1.42	1.43
Sat - Sun	2988	2371	1.26	3157	2165	1.46	1.35
Week Average	2807	2035	1.38	2883	2054	1.40	1.39

Location: Kalanki

		To Naubise			To Kathmandu		
	Traffic Volume (24hours)	Traffic Volume (12hours)	Daytime Traffic Ratio	Traffic Volume (24hours)	Traffic Volume (12hours)	Daytime Traffic Ratio	Total
Tue - Wed	6172	4723	1.31	6322	5022	1.26	1.28

4) AADT in 2000 Year

a) Seasonal Factor

The seasonal factor that is used for the calculation of AADT are refered to the value of shown in Table 7.10.

Table 7.10 Seasonality Factor by DOR

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Factor	0.97	0.94	0.96	0.95	0.95	0.99	1.09	1.07	0.97	1.10	1.05

Source: Department of Road (1999)
Station No. NAGD2A (Thankot)

b) Calculation of AADT at Thankot in 2000

AADT at Thankot was calculated by the next formula.

AADT = Weekly Average of surveyed Traffic Volume by vehicle type /Seasonal Factor(0.95 for May)

Table 7.11 AADT at Thankot in 2000

(Vehicle/day)

Motorcycle	Passenger Car	Mini Bus	Bus	Mini Truck	Truck	All Vehicle
1,120	1,210	650	900	410	1,700	5,990

c) Calculation of AADT at Kalanki in 2000

AADT at Kalanki was calculated by the next formula.

AADT = Surveyed Traffic Volume by vehicle type(Tuesday)
/Weekly factor (0.92 for Thankot)
/Seasonal Factor(0.95 for May)

Table 7.12 AADT at Kalanki in 2000

(Vehicle/day)

Motorcycle	Passenger Car	Mini Bus	Bus	Mini Truck	Truck	All Vehicle
4090	5010	920	1180	880	2220	14300

As a result of the aforementioned estimation process, AADT in year 2000 is calculated as shown in Figure 7.9.

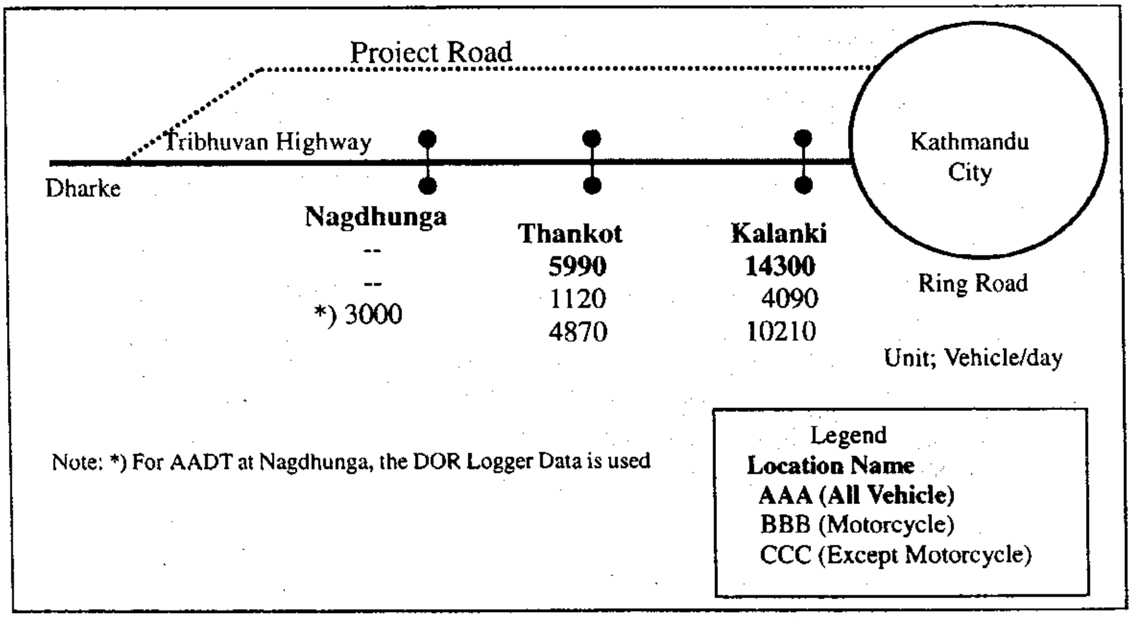


Figure 7.9 AADT on the Tribhuvan Highway

Table 7.13 Detail of AADT by Vehicle Type

Vehicle Type	Thankot	Kalanki
Motorcycle	1,120	4,090
Passenger Car	1,210	5,010
Mini Bus	650	920
Bus	900	1,180
MiniTruck	410	880
Truck	1,700	2,220
All Vehicle	5,990	14,300

Note: For AADT of Nagdhunga is based on the DOR data and for reference only.

7.1.5 Result of roadside OD survey

1) Number of Surveyed Vehicle

The extraction rate, which is the ratio of traffic volume of roadside OD survey versus volume of traffic count survey, are shown in Table 7.14.

The minimum extraction rate was 77% for truck. Other extract rate is above 80%.

Table 7.14 Extract Ratio by vehicle Type

Vehicle Type	Extract Ratio
Motorcycle	0.87
Passenger Car	0.93
Mini Bus	1.00
Bus	0.79
Mini Truck	0.99
Truck	0.77

where; Extract Ratio = (Traffic Volume by OD survey) / (Traffic Volume by Traffic Count Survey)

2) Trip Purpose

Trip composition by trip purpose of passenger car and motorcycle traffic are presented in Figure 7.10.

As shown in the Figure, business related trip (Business and Commuter traffic) is major part in the total traffic and it can be acknowledged that the existing Tribhuvan Highway has role of life line.

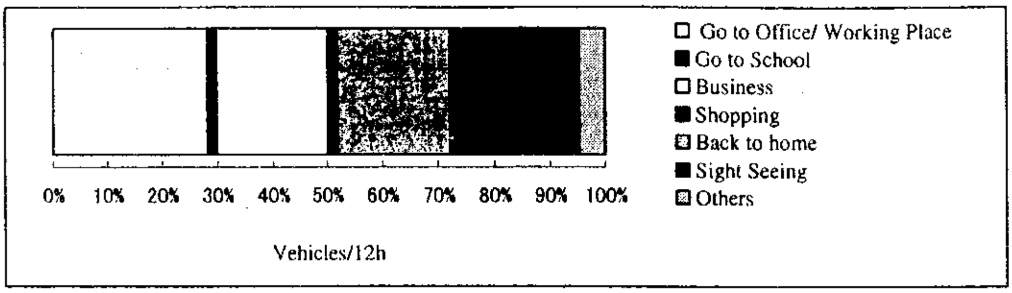


Figure 7.10 Trip Composition by Purpose (Motorcycle and Passenger Cars)

3) Number of Passenger

Average number of passenger by vehicle types is shown in Table 7.15.

Table 7.15 Average number of passenger by each vehicle type

Unit\Vehicle Type	Motorcycle	Passenger Car					Mini Bus	Bus
		Car,Van	Jeep	Pick-up	Tempo	Others		
Number of passenger	2,225	2,707	3,118	1,180	94	39	7,285	32,467
Vehicles	1,410	747	763	346	44	10	916	1,447
Person / Vehicle	1.58	3.62	4.09	3.41	2.14	3.90	7.95	22.44
		3.74						

Note: Number of passenger include a driver

4) Freight Traffic by Kind of Loaded Goods

Freight traffic by vehicle type and kind of loading goods is shown in Table 7.16. It is found that 95% of total freight traffic to Kathmandu is occupied by loaded truck. On the other hand, only 13% loaded truck are recorded for the traffic going to the Naubise direction. It is also noteworthy that construction material loaded truck has highest share ratio among other loaded material in the traffic to Kathmandu.

Table 7.16 Modal Share by Commodities of Trucks

Location Nagdhunga	Mini Truck		Truck		Multi Axle Truck		Tractor		Total	
	Vehicles/12h	(%)	Vehicles/12h	(%)	Vehicles/12h	(%)	Vehicles/12h	(%)	Vehicles/12h	(%)
Rice	4	1	1	0	0	0	0	0	5	0
Timber	2	1	2	0	0	0	0	0	4	0
Other Agriculture	4	1	27	2	0	0	0	0	31	2
Oil	0	0	4	0	0	0	0	0	4	0
Mineral	3	1	11	1	0	0	0	0	14	1
Machinery	3	1	7	1	1	8	0	0	11	1
Chemical	3	1	6	0	0	0	0	0	9	1
Construction Material	6	2	23	2	0	0	0	0	29	2
Misscellaneous	23	6	79	6	2	17	0	0	104	6
Empty	316	86	1220	88	9	75	1	100	1546	87
Total	364	100	1380	100	12	100	1	100	1757	100

Location Thankot	Mini Truck		Truck		Multi Axle Truck		Tractor		Total	
	Vehicles/12h	(%)	Vehicles/12h	(%)	Vehicles/12h	(%)	Vehicles/12h	(%)	Vehicles/12h	(%)
Rice	4	1	123	9	0	0	1	14	128	8
Timber	2	1	35	3	0	0	0	0	37	2
Other Agriculture	10	3	132	10	0	0	1	14	143	8
Oil	2	1	69	5	0	0	0	0	71	4
Mineral	8	2	52	4	0	0	0	0	60	4
Machinery	1	0	53	4	2	18	0	0	56	3
Chemical	4	1	51	4	0	0	0	0	55	3
Construction Material	241	71	535	40	4	36	0	0	780	46
Misscellaneous	20	6	258	19	5	45	0	0	283	17
Empty	49	14	38	3	0	0	5	71	92	5
Total	341	100	1346	101	11	99	7	99	1705	100

7.1.6 Result of vehicle speed survey

1) Passenger Car Speed Survey by Floating Car Method

In the section to Dharke from the Kalanki intersection (Ring Road), the result of speed survey of passenger car is shown in Table 7.17. The average travel speed in the round trip is 37 km/h. In the steep slope section between Nagdhunga and Naubise, the travel speed is lower than that in other section by 7~11 km/h. The difference of the travel speed between uphill and downhill direction not significant.

Table 7.17 Travel Speeds between Kalanki and Dharke

Section	Length (km)	Morning		After noon		Evening		Average travel speed (km/h)
		To Dharke	To Kalanki	To Dharke	To Kalanki	To Dharke	To Kalanki	
Kalanki-Tinthana	3.0	51	41	41	46	34	45	43
Tinthana-Thankot	3.0	42	48	37	32	40	33	39
Thankot-Nagdhunga	4.0	37	43	47	47	48	37	43
Nagdhunga-Naubise	12.0	34	35	30	32	32	34	33
Naubise-Dharke	3.0	45	42	45	39	45	46	44
Average travel speed	25.0	38	39	35	36	36	37	37

Morning (8:00~10:00)
After noon (12:00~15:00)
Evening (16:00~18:00)

2) Vehicle Speed Survey by Number Plate Observation.

The survey results are summarized in Table 7.18. The results show average travel speed of about 15km/hr and 20km/hr for truck and bus, respectively.

Table 7.18 Travel Speeds of Heavy Vehicle on Uphill Slope from Naubise to Nagdhunga

Vehicle type	Kind of goods	Travel time (h:m)	Travel speed (km/h)
Truck	Unknown (Full)	0:48	15
	Construction materials (Stone & Gravel)	0:46	16
	Buffalo	0:53	14
Bus	(TATA)	0:31	23

Length to Nagdunga from Nauise: 12 km

3) Vehicle Speed Survey with Speed Gun.

The relationship between vehicle travel speed and road profile grade is shown in the Figure 7.11 and Table 7.19 as a result of the survey.

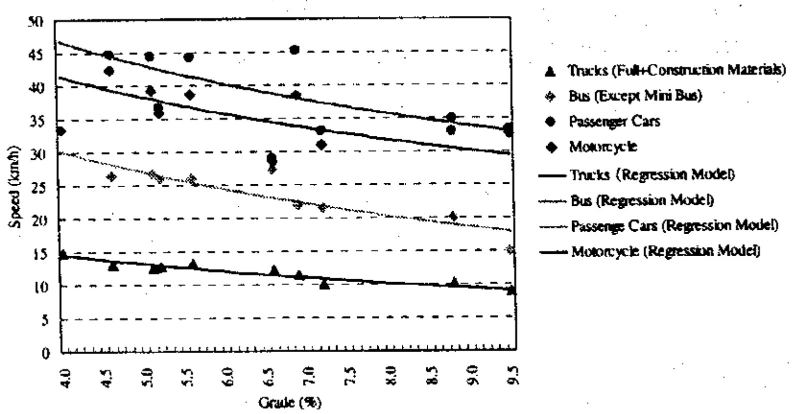


Figure 7.11 Travel speeds of Vehicles by Grade

Table 7.19 Travel Speeds Regress ional Model by Grade

	Regressional Model	Correlation Coefficient
Trucks	Y= -6.3898 ln(X) +23.4859	r=0.9630
Bus	Y= -14.2698 ln(X) +49.9948	r=0.8770
Passenger Cars	Y= -15.8614 ln(X) +68.7093	r=0.7329
Motorcycle	Y= -13.9011 ln(X) +60.6711	r=0.7301

where: Y is Vehicle Speed (km/h)
X is Road Grade (%)

7.2 Demand Forecast Methodology

Based on the results of traffic survey and future socio-economic framework, future traffic demand of the Project Road was estimated. The target year in this estimate is 2020, and the year 2010 is also considered as the midterm target year. The process for the traffic demand forecast is illustrated in Figure 7.12. For this traffic demand forecast, "JICA STRADA", the software for traffic demand forecast established by JICA, was used.

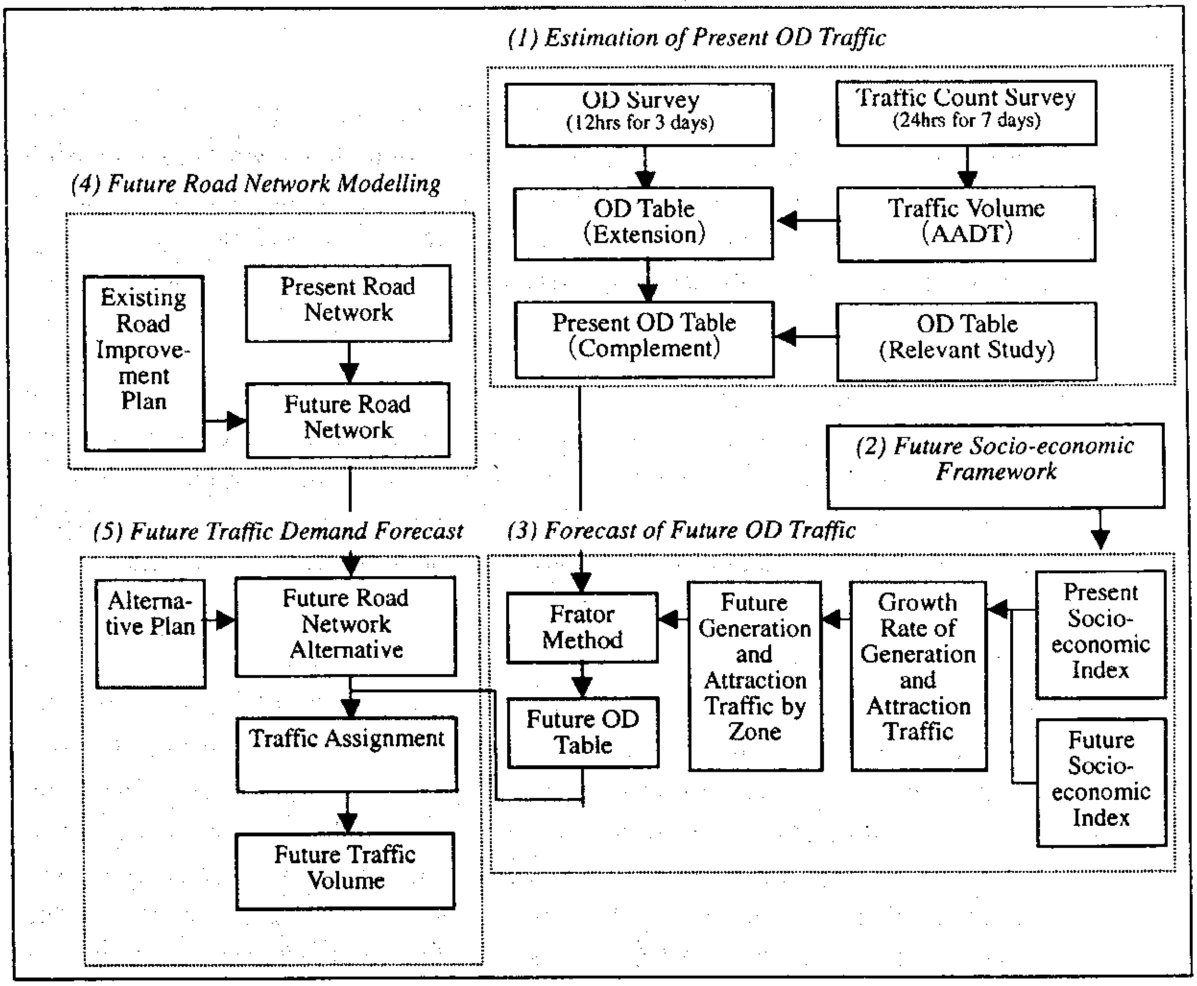


Figure 7.12 Procedure for Future Traffic Demand Forecast

7.2.1 Estimation of present OD (Origin/Destination) traffic

Present OD (origin/destination) traffic volumes are estimated based on the results of traffic survey. Procedure to establish present OD table is as follows:

i) To prepare average 12 hours OD table by conversion from the results of 12 hours OD survey for three days.

ii) To estimate the annual average daily traffic (AADT) at Thankot using 24 hours traffic count survey for seven days and taking weekly and annual traffic fluctuation into consideration.

iii) To prepare initial annual average daily OD table extending the 12 hours OD table by AADT at Thankot.

iv) To prepare final present OD table modifying initial annual average daily OD table by supplementation with Kalanki traffic data and OD table established by the Kathmandu Valley Urban Road Development Study (JICA,1993).

7.2.2 Future socio-economic framework

Future socio-economic framework, which is the base condition for the future traffic demand forecast, has been established. The socio-economic framework is set up using such parameters as forecasted population growth, economic growth, regional development plan, future land use plan, etc. In some indices of this Study, growth rates between present and future conditions are only shown, and real values are not described because these are not necessary for the estimate.

Socio-economic indices by traffic zone, which is established for traffic survey, were estimated on the basis of the above socio-economic conditions and future development plans. Present socio-economic data were collected by subdivided administrative units such as region, zone, district, and so on. Future socio-economic data were set up using the change from the past, future socio-economic frame or projected growth rate.

1) Population

Ministry of Population and Environment has predicted the future population by district every five year until 2016, based on the 1991 Population Census. Population by traffic zone in this study was calculated from this predicted data. While population in the year 2010 was calculated from the average growth rate of the predicted population in 2001 and 2011, population in the year 2020 was calculated from that of 2011 and 2016. As for the traffic zones of the village development committee (VDC) in Kathmandu and Dhading district, the population of VDC was calculated using the same growth rate as that of the district total.

2) Gross Zonal Products

Growth rate of per capita gross zonal products was estimated considering the GDP growth rate, future population projection by zone and regional economic differences.

3) Zonal Products Volume

Zonal freight tons of both agricultural and non-agricultural products were estimated based on the PIP study. According to the PIP report, the freight movement between cities has been predicted by item from the interview of producers and public sectors or statistical data. The predicted zonal products volumes were used for the estimation of future freight traffic on OD basis.

7.2.3 Forecast of future OD traffic

Future OD traffic was made based on the present OD table and the future socio-economic frame. From the present and future socio-economic frame, the growth rate of generated and attracted traffic was estimated. This growth rate was adapted to the present OD table, and the future generation and attraction traffic by zones was estimated. Future OD table was obtained based on the present OD pattern and future generations and attraction traffic by zones using Fratar Method. The methods of estimating the growth rate were various by vehicle type, by trip purpose and by location of trip ends. Methods of estimation are shown in Table 7.20.

Generally inside the Study area, both 'developed traffic' and 'induced traffic' should be considered because the construction of the Project Road generates the opportunities for regional development or the opportunities for people movement. In this Study, however, 'developed traffic' was not considered, because there is no definitive plan nor development project. On the other hand, 'induced traffic' generated by increase in car-use opportunities due to the Project Road was taken into consideration. The induced traffic was estimated by a factor of change in accessibility and the factor was estimated using difference in zone-to-zone time distance between with and without project case.

Table 7.20 Basic Methods of Estimating Generated and Attracted Trips

Location \ Type, Purpose	Passenger Car		Freight Car	
	Non-public Vehicle	Public Transport	Agricultural	Non-agricultural
All Area (Through Traffic)	Estimate from the growth rate of vehicle ownership	Estimate from the population growth	Estimate from the growth rate of agricultural freight tons	Estimate from the growth rate of non-agricultural freight tons
Inside Area (Intra-area Traffic)	Estimate from the potential (population) and the accessibility (reciprocal number of time)		Estimate from the growth rate of agricultural production	Estimate from the growth rate of industrial production (no consideration in this study)

Growth rates for the trips of through traffic, in which both trip-ends were outside the Study area, were assumed by the following methods.

1) Passenger Car: Non-public Vehicle

Growth rate for the trips of the non-public vehicles (passenger car, jeep, pick-up and motorcycle in the classification of the traffic survey in this Study) was assumed to correspond with that of car possession numbers. Car possession numbers are deemed to be same number of vehicle registered, and its growth rate was estimated correlating with GDP per capita.

2) Passenger Car: Public Transport

Growth rate for the trips of the public transport (tempo (three wheeler), mini bus and bus in the classification of the traffic survey), was deemed to be same as the average of growth rates in both zonal population which trip-ends were in.

3) Freight Car

As for the freight car (light truck, truck, large truck with 3-axles and tractor in the classification of the survey), its traffic was estimated dividing the traffic into agricultural and non-agricultural trips. Growth rate for the agricultural freight trips was deemed to be equivalent to the growth rate of agricultural products volume while the growth rate for the non-agricultural freight trips was deemed to be equivalent to the growth rate of industrial products volume.

7.2.4 Future road network modeling

Road network in the year 2000 was established on the basis of road development plan in the 9th National Plan and through consultation with DOR. Basic road network for traffic demand forecast is established by 'Strategic Road Network', which consists of national highways and feeder roads. Road network in the year 2010 is prepared including the Project Road and Sindhuli Road. The Kathmandu-Terrai new road was added to the road network in the year 2020 accordig to the DOR's request on the

Interim Report.

The future road network is shown in Figure 7.13.

7.2.5 Future assigned traffic volumes

For the purpose of forecasting future traffic demand of each road link, traffic assignments in some alternative cases are conducted. This procedure requires, as input data, the complete modeling of future road network and future OD table. Toll rates by vehicle type on the Project road and existing Tribhvan Highway are used for trafic assignment. Motorcycle is 5 NRs, Passenger car 25 NRs, Bus 35 NRs, and Truck 35 NRs. Future traffic volumes on various sections of road can be obtained as the result of traffic assignment.

JICA STRADA has several assignment methods such as Incremental Assignment, Equilibrium Assignment, LP Assignment and Transit Assignment. In this study Incremental Assignment with Q-V formula (relation between traffic volume and travel speed) was adopted, since the method is generally used for traffic assignment on simple road network without any other traffic modes. Each origin-destination traffic was divided by the number of caluculation steps and the traffic of each step was assigned to the shortest path considering congestion level and travel speed of all links.

In case to take toll fare into account, the tool fare was converted into equivalent travel time and added to the travel time of the tolled link as impedance. For the conversion following parameters of time value were adopted.

i) Time value of passenger

Following time values of passenger were used applying the results of the ADB Fourth Road Improvement Project

- for car passenger: 11.7 NRs/hour
- for bus passenger: 4.7 NRs/hour

ii) Time value by type of vehicle

Time value by type of vehicle was estimated based on the above time values of passenger and average occupancy rate of respective type of vehicle obtained by the OD survey.

- for passenger car: 43.3 NRs/hour
- for bus: 105.3 NRs/hour
- for minibus: 37.3 NRs/hour
- for motorcycle: 18.3 NRs/hour

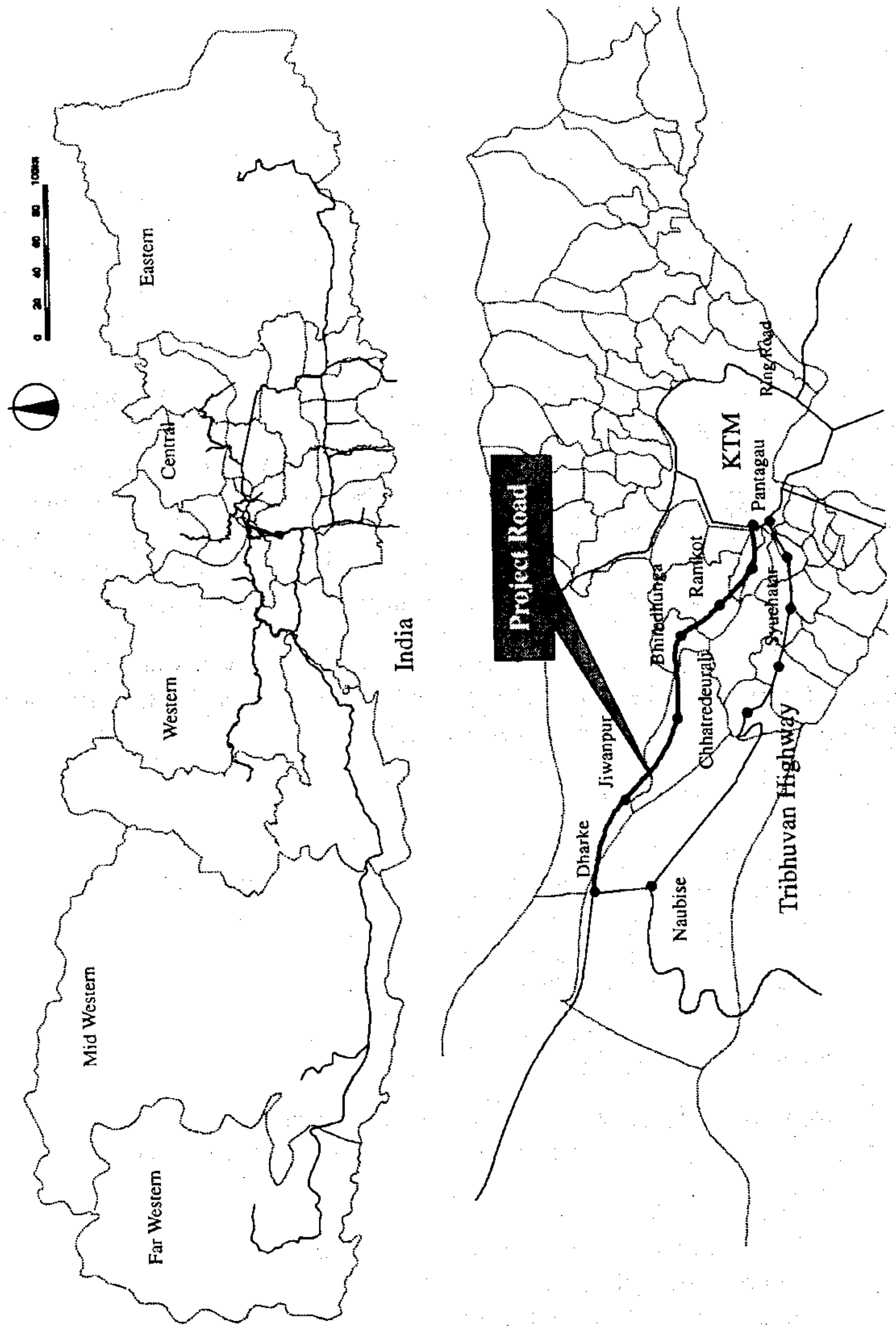


Figure 7.13 Future Road Network

OD tables by vehicle type (motorcycle, passenger car, mini bus, bus, mini truck and truck) were assigned on each of the road networks of 2010 and 2020, respectively. Traffic assignment method was Incremental Assignment with Q-V formula (relation between traffic volume and travel speed). For each link of the road network on which vehicles were assigned, Q-V formula was set up as shown in Table7.21 and Figure7.14.

As for the existing Tribhuvan Highway, the Q-V formula of Feeder Road (Q-V code No. 7 to No. 9) was applied since the highway does not satisfy the National Highway standard. While Q-V formula of National Highway (Q-V code No. 1 to No. 3) was applied to the Project Road.

Table 7.21 Q-V Formula

Q-V Code	Road Classification	Location	Number of Lanes	Vmax (km/h)	Qmax (PCU/day)
1	National Highway	Rural Plain	2	60	15,000
2	National Highway	Rural Rolling	2	60	10,000
3	National Highway	Rural Mountainous	2	50	7,000
4	City Road	Urban Plain	2	60	12,000
5	City Road	Urban Rolling	2	60	8,000
6	Feeder Road	Rural Plain	2	40	13,500
7	Feeder Road	Rural Rolling	2	40	9,000
8	Feeder Road	Rural Mountainous	2	40	6,300
9	Feeder Road	Rural Steep	2	30	4,500
10	Feeder Road	Rural Mountainous	1	30	1,600
11	Feeder Road	Rural Steep	1	30	800
12	Feeder Road	Rural Steep&ZigZag	1	15	800
13	Ring Road	Urban	2	60	19,000

Source: JICA Study Team

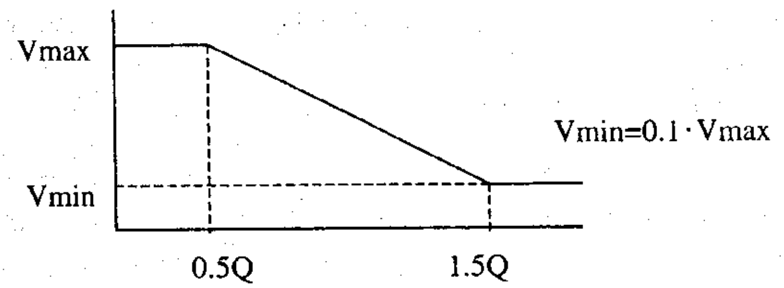


Figure 7.14 Q-V Formula

7.3 Traffic Demand at the Boundary of Kathmandu Valley

Traffic volume at Nagdhunga in the year 2000, that means trips between area inside Kathmandu Valley and area outside the Valley, is approximately 3,000 vehicle/day, in which 2,600 vehicle/day is through traffic of the Study area. Almost half of the total trip ends outside the Valley is in Dhading District and in Gandaki Zone including Pokhara. One-third of total trip ends is in the south area including Narayani Zone and India. Moreover, 13% is in the west including Mid Western Development Region and Far Western Development Region, 3% is in Janakpur Zone, and 10% is in Eastern Development Region.

According to the methodology of forecasting described in the previous section of this chapter, growth rate of socio-economic framework, future trip generation and future OD table was estimated. Summary of the growth rate of socio-economic framework is shown in Table 7.22.

Table 7.22 Summary of Growth Rate

Item		Annual Average Growth Rate	
		2000-2010	2010-2020
GDP		6.9%	8.1%
Population		2.3%	2.0%
Trip Production	Passenger Car	11.1%	10.6%
	Motorcycle	13.4%	11.4%
	Public Transport	2.3%	2.0%
	Freight Car (Agricultural)	2.3%	2.8%
	Freight Car (Non-agricultural)	3.6%	5.4%

Source: National Plan, PIP

Future OD table was calculated using the above growth rate and the present OD table, which was established based on the traffic survey described in 7.1. Future OD traffic demands in the year 2010 and 2020 are shown in Figure 7.15.

Traffic demand at Nagdhunga in the year 2010 is 5,500 vehicle/day, 6.2% in annual average growth rate between 2000 and 2010. Traffic demand at Nagdhunga in the year 2020 is 12,200 vehicle/day, 8.3% in annual average growth rate between 2010 and 2020.

Table 7.23 Traffic Demand at the Boundary of Kathmandu Valley

(Vehicle/day)

Year	2000	2010	2020
Traffic Demand	3,000	5,900 (6.2%)	12,400 (8.3%)

Note: Number of ratio is an annual average growth rate

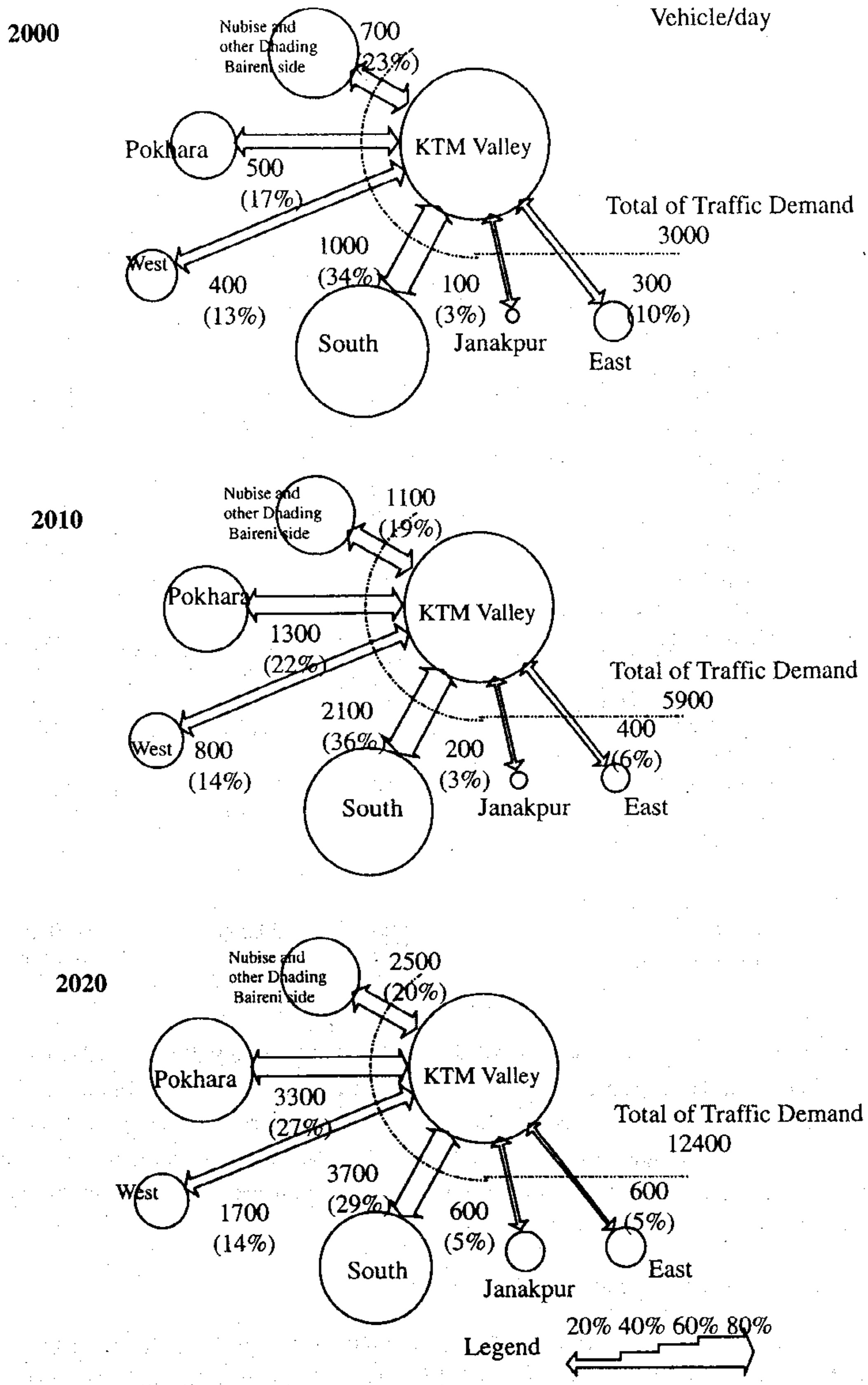


Figure 7.15 Traffic Demand between Kathmandu and Other Area

According to the Nepal Road Standard, capacity of 2-lane black-topped road in rolling terrain is 5,000 vehicle/day, and that in mountainous terrain is 3,500 vehicle/day. In PIP study, capacity was calculated based on the NAASRA Guide line. Capacity as the result of calculation by NAASRA Guide line and that in Nepal Road Standard were nearly same.

Table 7.24 Capacity in Nepal Road Standard (National Highway)

S.No.	Category	Design Capacity in both directions		
		Vehicle/hour	Vehicle/day	TU/day(PCU/day)
1	Single-lane black-topped;			
	a)Plain terrain	100	1,000	2,000
	b)Rolling terrain	90	900	1,800
	c)Mountainous terrain	90	900	1,800
	d)Steep terrain	70	700	1,400
2	Single-lane water-bound macadam road:			
	a)Plain terrain	90	900	1,800
	b)Rolling terrain	80	800	1,600
	c)Mountainous terrain	75	750	1,500
	d)Steep terrain	40	400	800
3	Intermediate lane black-topped road:			
	a)Plain terrain	300	3,000	6,000
	b)Rolling terrain	285	2,850	5,700
	c)Mountainous terrain	260	2,600	5,200
	d)Steep terrain	225	2,250	4,500
4	Two-lane black-topped road:			
	a)Plain terrain	750	7,500	15,000
	b)Rolling terrain	500	5,000	10,000
	c)Mountainous terrain	350	3,500	7,000
	d)Steep terrain	250	2,500	5,000
5	Four-lane divided carriageway road:			
	a)Plain terrain	5,000	50,000	100,000
	b)Rolling terrain	4,000	40,000	80,000

Source: Nepal Road Standard (2027) (First Revision-2045), DOR

Total road capacity at the boundary of the Valley in 2010 is 8,900 vehicle/day (3,500 vehicle/day on Tribhuvan Highway, 5,000 on the Project Road and 400 on Sindhuli Road). Since total traffic demand in 2010 is 5,500 vehicle/day, demand is less than the road capacity. And total traffic demand of 12,200 in 2020 is less than the road capacity of 15,100 vehicle/day at the the boundary of the Valley if the Kathmandu-Terrai new road will be constructed in around 2015.

7.4 Results of Future Assigned Traffic Volume

The assigned traffic volumes in 2010 and 2020 on the Project Road, Tribhuvan Highway and Kathmandu-Terrai new road are shown in Figure7.16 and Table 7.25.

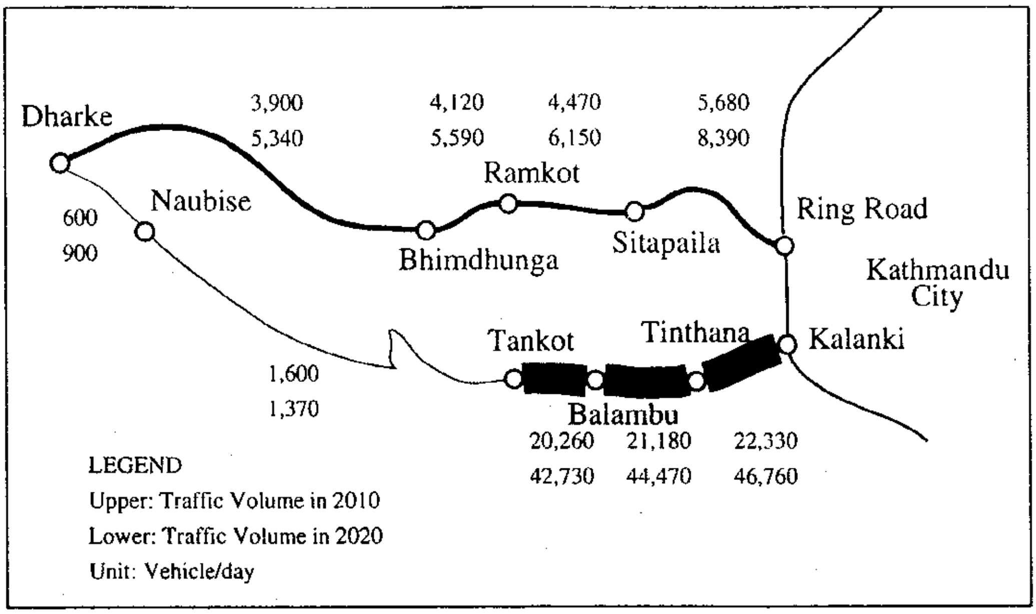


Figure 7.16 Assigned Traffic Volume in 2010 and 2020

Table 7.25 Assigned Traffic Volume by Vehicle Type in 2010 and 2020

(Vehicle/Day)

Road	2010 Year Section	Motorcycle	Passenger Car	Mini Bus	Bus	Mini Truck	Truck	All Vehicle
Project Road	Ring Road - Sitapaia	980	1,720	320	620	620	1,420	5,680
	Sitapaila - Ramkot	750	1,460	180	490	450	1,140	4,470
	Ramkot - Bhimdhunga	680	1,410	140	460	390	1,040	4,120
	Bhimdhunga - dharke	630	1,390	110	440	340	990	3,900
Tribhuvan Highway	Kalanki - Tinthana	8,490	9,290	960	780	890	1,920	22,330
	Tinthana - Balambu	8,310	8,840	900	730	750	1,650	21,180
	Balambu - Tankot	8,190	8,490	790	620	670	1,500	20,260
	Tankot - Naubise	330	380	20	170	110	590	1,600
	Naubise – Dharke	110	140	10	30	70	240	600

(Vehicle/Day)

Road	2020 Year Section	Motorcycle	Passenger Car	Mini Bus	Bus	Mini Truck	Truck	All Vehicle
Project Road	Ring Road - Sitapaia	1,960	3,000	360	530	940	1,600	8,390
	Sitapaila - Ramkot	1,440	2,430	170	340	670	1,100	6,150
	Ramkot - Bhimdhunga	1,320	2,320	120	300	580	950	5,590
	Bhimdhunga - dharke	1,250	2,290	100	290	530	880	5,340
Tribhuvan Highway	Kalanki - Tinthana	19,860	21,120	1,190	800	1,290	2,500	46,760
	Tinthana - Balambu	19,460	20,080	1,110	730	1,060	2,030	44,470
	Balambu - Tankot	19,140	19,280	980	590	970	1,770	42,730
	Tankot - Naubise	490	430	10	10	110	320	1370
	Naubise – Dharke	300	240	10	10	90	250	900

In case of without Kathmandu - Terai Road the traffic volume between Bhimdhunga - Dharke in 2020 is estimated at 7,700 vehicle/day.

CHAPTER 8 APPLIED DESIGN STANDARDS

8.1 General

Application of proper design standard will fulfill the following objectives:

- Ensure safety, service level and comfort for road users by the provision of adequate sight distance and roadway space,
- Ensure that the roadway is designed economically
- Ensure uniformly in design
- Ensure safety of structures like bridges and tunnels.

The uniformity in design, especially the cross section of roadway, is important not only along the roadway section, but also through structures like bridges and tunnels such that sudden unexpected change in width of road is not faced by the drivers, and that the change is gradually applied if needed for technical or economical reasons.

The selection of design standards is greatly influenced by the topography, traffic characteristics and the function of road itself. Special attention is also required in consideration to treatment of potential hazards.

The design standard available in Nepal is reviewed and is compared to the Japanese design standards. Review of the other international design standards like AASHTO and from Transport Road Research Laboratory, is also done. Applicable design standards suitable for the conditions of the Project Road are then selected.

8.2 Classification of the Project Road

Currently, parts of the Trivuban Highway from Kathmandu to Naubise, the sole corridor connecting Kathmandu Valley to other parts of the nation and to India, has problems due to steep longitudinal gradient and sharp horizontal curves, as well as slope failures during rainy seasons. While the difficult geometric conditions are leading to traffic congestion, delay and traffic hazards, the slope failures during rainy seasons keep the capital in isolation from other parts of the country. Under such circumstances, a new alternative route is required not only for socio-economic reasons but also from the viewpoints of national security.

The alternate road in this corridor has thus two main purposes:

- To provide better level of service than the existing Trivuban Highway from Kathmandu to Naubise, by providing relatively higher geometric design standards that will reduce the vehicle operating cost and increase the traffic safety.

- To provide alternate access to Kathmandu valley from the rest of the nation and Indian border, within this corridor, in view of national security.

Due to these reasons, the Kathmandu-Naubise alternate road (the study road) can be categorized in the most strategic road network and will be classified as the National Highway according to the classification of Nepal Road Standards. The design standards will be selected accordingly. The design standards, those that are not covered by NRS will be followed from other standards, mentioned above for the following corresponding classes.

According to the Japanese road classification system given by Japan Road Association (JRA), the Project Road can be classified to Type 3 Class 3 roads that correspond to the National Highway of rural and mountainous area with design traffic volume of 4,000 to 20,000 vehicles per day.

The Project Road can be classified into Rural Principal Arterial Road in terms of the AASHTO classification system.

According to the classification system of Overseas Road Note 6, the Project Road can be classified into arterial road of design class A, the traffic volume (ADT) of which is 5,000 to 15,000 vehicles.

8.3 Highway Design Standards

8.3.1 Relevant current design standards

Mainly, the following design standards have been reviewed to establish the highway design standards for this Study.

1) Nepal Road Standards (NRS); First Revision-2045 to Third Revision-2054.
2) Road Structure Ordinance by Japan Road Association (JRA), 1983.
3) A Policy on Geometric Design of Highways and Streets, AASHTO, 1994.
4) A Guide to Geometric Design, Overseas Road Note 6, TRRL, 1988.

8.3.2 Applied geometric design standards

A summary of proposed geometric design standard is given in Table 8.1.

Table 8.1 Proposed Geometric Design Standard for Highway Design

No.	Group	Design Elements	Rolling	Mountain	Steep	Reference
1		Highway Classification	National Highway (Strategic Road)			NRS
2		Design Speed (Km/h)	60	50	40	NRS/JRA
3		Design Vehicle (L × W × H) m	16 × 2.5 × 4 (WB-15 equivalent)			AASHTO
4	Cross Section Elements	Number of Lanes	2	2	2	NRS
		Formation Width (m)	12	12	12	
		Lane Width (m)	7 (2×3.5)	7 (2×3.5)	7 (2×3.5)	NRS
		Outer Shoulder Paved Width (m)	1.5	1.5	1.5	NRS
		Outer Shoulder Earthen Width (m)	1.0	1.0	1.0	
		Cross Slope of Roadway (%)	2	2	2	JRA/AASHTO
		Slope of Earthworks				
		Fill	V:H = 1:1.5			JRA
		Cut	V:H = 1:1.2 to 1:0.8			JRA
5	Sight Dist	Stopping Sight Distance (m)	85	65	45	NRS
6	Horizontal Alignment	Minimum Radius of Horizontal Curve (m)				
		Desirable Minimum	200	150	100	JRA
		Absolute Minimum	150	100	60	JRA
		Unavoidable Condition	135	90	55	AASHTO
		Superelevation				
		Maximum Superelevation (%)	6	6	6	JRA
		Transition Curve				
		Minimum Length of Transition Curve (m)	35	35	35	
7	Vertical Alignment	Maximum Average Vertical Grade (%) section	3	4	5	NRS
		Maximum Vertical Grade (%) in Limited length	5	6	7	NRS/JRA
		Critical Length of Grade (m)				
		For less than equal maximum average	No limit			NRS
		For greater than maximum average	250	210	150	NRS
		Minimum Radius of Vertical Curve (m)				
		Crest Curve (m)	1800	1000	500	NRS/AASHTO
		Sag Curve (m)	1800	1200	800	NRS/AASHTO

8.3.3 Design speeds

The design speeds given in AASHTO and Overseas Road Note 6 are considerably higher in the Nepalese context, as set by Nepal Road Standards. If all the length of the Project Road would lie in the same rolling terrain, the design speed of 80 km/h set by NRS would have been applicable. But, since the Project Road passes through different terrain conditions, application of design speed of 80 km/h in rolling terrain creates a large gap between mountainous and steep conditions, where the design speed is only 50 km/h and 40 km/h according to NRS. In this respect, the design speed ranges of 60 km/h, 50 km/h, and 40 km/h, set by JRA seem to be more practical.

- Design speeds of 60 km/h, 50 km/h and 40 km/h are proposed to be applied for rolling, mountainous, and steep/difficult terrain conditions. The application of 40 km/h is also proposed to be applied at hairpin bends. However, the identification of the sections will be done for the best possible balance.

8.3.4 Design vehicle

The design vehicle applicable for the Project Road is proposed to be semi-trailer. The dimension of semi-trailer from Japanese standard (JRA) is 16.5 m long, 2.5 m wide, and 3.8 m high. WB-15 (large semi-trailer) is proposed to be applied in reference to AASHTO specifications, the size of which is 16.7 m long, 2.6 m wide, and 4.1 m high.

8.3.5 Cross section elements

1) Number of lanes

The number of lanes in the Project Road is proposed to be two.

2) Outer shoulder paved width (m)

The width of the outer paved shoulder is proposed to be 1.5 m for the Project Road in general. Under unavoidable conditions, the width is proposed to be at least 0.5 m as allowed by JRA, at bridges etc.

3) Outer shoulder earthen width

The width of the outer earthen shoulder is proposed to be 1.0 m in view of installation of guardrails and guard posts. This is also in view of the requirement of constructing side ditches.

4) Cross slope of roadway (camber slope)

The cross slope of the roadway (camber slope) recommended by NRS is 3% for bituminous surface in rural areas. JRA recommends 1.5 to 2% of cross slope for cement concrete and asphalt concrete paved roads. AASHTO states that on high-type two-lane roadways, crowned at the center, the accepted rate of cross slope is from 1.5 to 2%. In areas of intense rainfall, AASHTO allows 2.5% as the cross slope on high-type pavements. Overseas Road Note 6 does not provide any specific value for cross slope.

The cross slope in the Project Road is proposed to be 2% in view of application of asphalt concrete pavement surface.

5) Slope of Fill

The slope of the fill is proposed to be 1:1.5 which is applicable for most of the filling materials and all fill heights according to JRA standards.

6) Slope of Cut

Following cut slopes for different cut heights on different types of soil types are proposed for the study road.

Table 8.2 Slope of Cut on Different Soil Types along the Project Road

	H<3m	3<H<7m	7<H<15m	H>15m
Talus including terrace deposits				
Without wall	1:0.8	1:1.0	1:1.2 with vegetation	
With concrete, masonry or gabion wall		any practical slope	1:1.0 with vegetation	1:1.2 with vegetation
Lacustire deposits				
Without wall	1:0.8	Not recommended		
With concrete, masonry or gabion wall		1:1.0 with vegetation	1:1.2 with vegetation	
Weathered peltic and psamitic altenated phyllitic rocks				
Without wall	1:0.8		1:1.0 consider vegetation	1:1.2 with vegetation
With concrete, masonry or gabion wall		any practical slope	1:1.0 consider vegetation	1:1.2 with vegetation

8.3.6 Horizontal Alignment

1) Horizontal curve and superelevation

The maximum superelevation of 6% is proposed to be applied in the Project Road based on JRA recommendation as well as in view of expected large percentage of fully loaded heavy vehicles in the Project Road. Superelevation higher than 6% may be dangerous for slow moving fully loaded heavy vehicles.

The minimum radius of curvature in this study road is proposed to be 150, 100, and 60 m for design speeds of 60, 50, and 40 km/h, respectively, and these values may be decreased to 135, 90, and 55 m for unavoidable conditions. A minimum value of 55 m is proposed to be applied at hairpin bends. The values of 200 m, 150 m, and 100 m will be used as desirable minimum radius for the design speeds of 60, 50 and 40 km/h if situation permits.

2) Transition curve

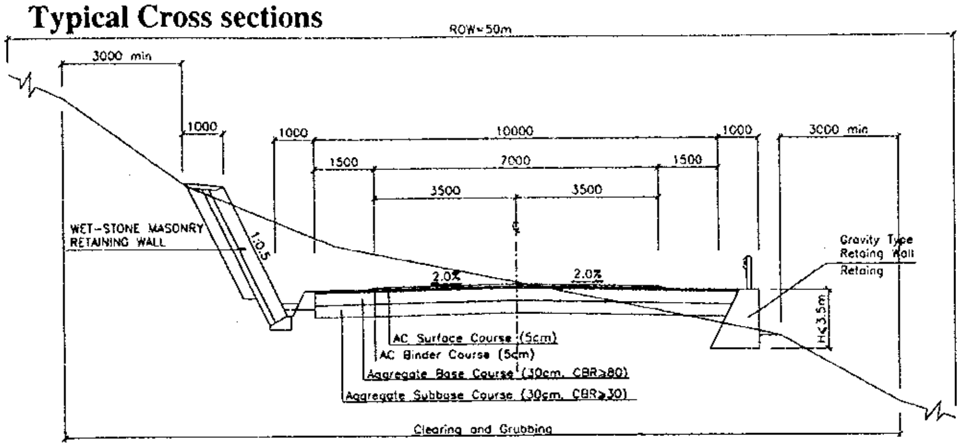
The minimum length of transition curve is proposed to be 50 m for all design speeds, in view of ease in application and the length required for super-elevation runoff. However, an absolute minimum of 35 m is also considered based on the recommendation by JRA, in view of difficulty of application at hairpin bends and other sharp curves.

8.3.7 Vertical alignment

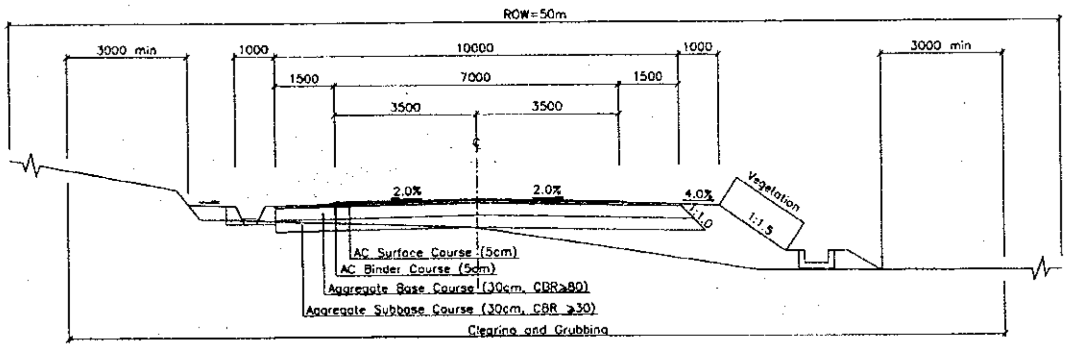
1) Maximum gradient

Maximum average gradients of 3, 4, and 5% are proposed for rolling, mountainous, and steep topographic conditions, respectively. Provisionally, 5, 6 and 7% will also be applicable in rolling, mountainous and steep terrain conditions, respectively. However, the length of the grade in excess of maximum average grade will be limited to 250, 210, and 150 m for rolling, mountainous and steep conditions, respectively as recommended by NRS. A minimum length of recovery at 2, 2, and 3% is desirable to be applied for a length of 600, 300, and 210 m for rolling, mountainous and steep terrain conditions, respectively.

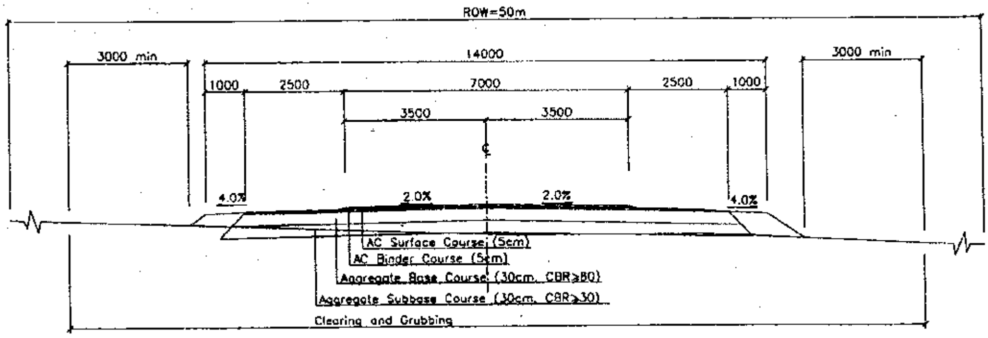
8.3.8 Typical Cross sections



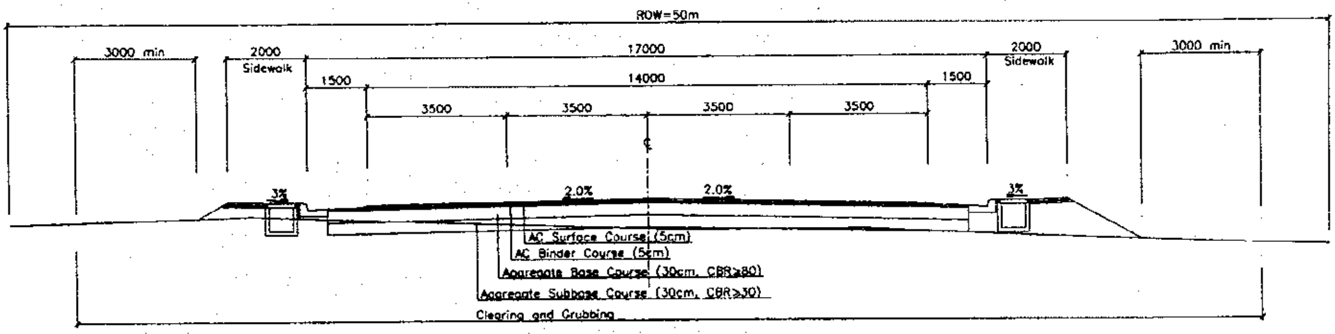
TYPE D – MOUNTAINOUS TERRAIN



TYPE C – ROLLING/PLAIN TERRAIN

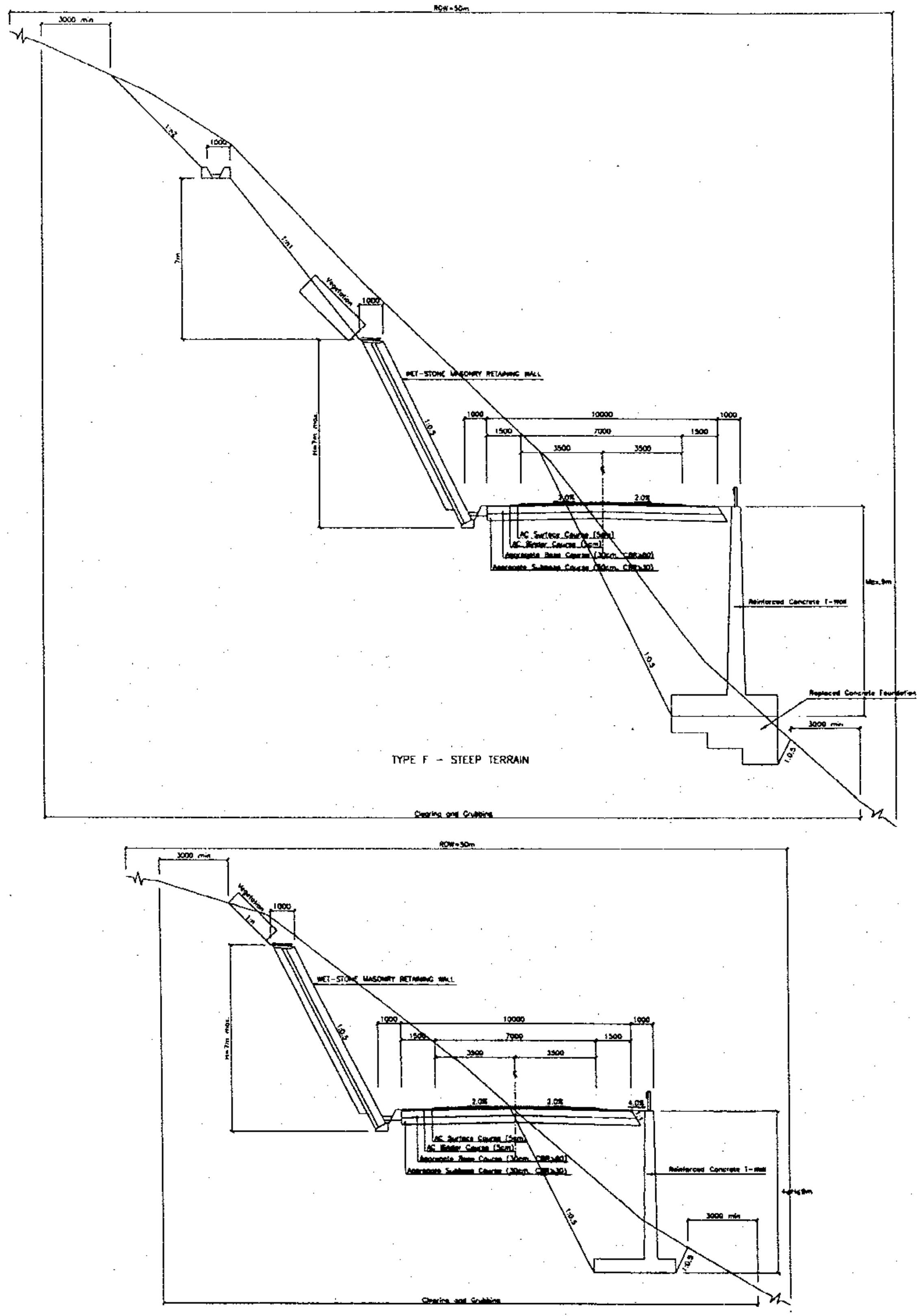


TYPE B – URBAN AREA
(0+200 to 1+000)
(21+200 to 21+355)



TYPE A – INTERSECTIONS AT RINGROAD AND DHARKE
(SIDEWALK NOT INCLUDED AT DHARKE)

Figure 8.1 (1/2) Typical Cross Sections on Roadway



TYPE E - STEEP TERRAIN

Figure 8.1 (2/2) Typical Cross Sections on Roadway

8.3.9 Pavement design standards

The design of pavement structures will be based on the method given by AASHTO Guide for Design of Pavement Structures, as well as the Manual for Asphalt Pavement given by Japan Road Association. However, other design methods such as Asphalt Institute Method will also be referred wherever relevant.

In consideration to the higher initial cost and difficulty in widening in future if required, the flexible pavement is recommended for the Project Road. In Nepal, Double Bituminous Surface Treatment (DBST) is very common due to lower construction cost. However, for the expected traffic level, presence of very large percentage of heavy vehicles and the functional importance of the Project Road, DBST is not recommended, and Asphalt Concrete (AC) pavement is recommended instead.

The AASHTO method of pavement design is briefly described below:

The AASHTO method of pavement design requires basically the following four types of design input requirements:

1) Design variables; the design variables include the performance and analysis period, traffic and the selection of parameters like reliability and overall standard deviations. The traffic data includes the estimation of total application of traffic load during pavement life (as obtained from the performance and analysis period) in terms of Equivalent Single Axle Load of 8.2 tones. The directional distribution factor and lane distribution factors are also required as the input design data.

2) Performance criteria; it is based on the concept of serviceability index. The initial serviceability index (p_0) is the serviceability of pavement immediately after construction and the terminal serviceability index (p_t) is the least acceptable serviceability of the pavement near the end of the pavement life before rehabilitation is required. The difference in these two parameters gives the design serviceability loss (ΔPSI).

3) Material properties; the material properties of various layers of the pavement structures from subgrade to subbase, base and surface courses are required in terms of resilient modulus. The resilient modulus of subgrade, subbase and base courses can be derived from the widely used CBR values of the material for these layers.

4) Pavement characteristics; it includes mainly the drainage coefficients for the subbase and base course layers.

For a set of the design input data, the required Structural Number (SN) is estimated from the AASHTO Nomograph or by solving the equation of the Nomograph as shown in Figure 8.2.

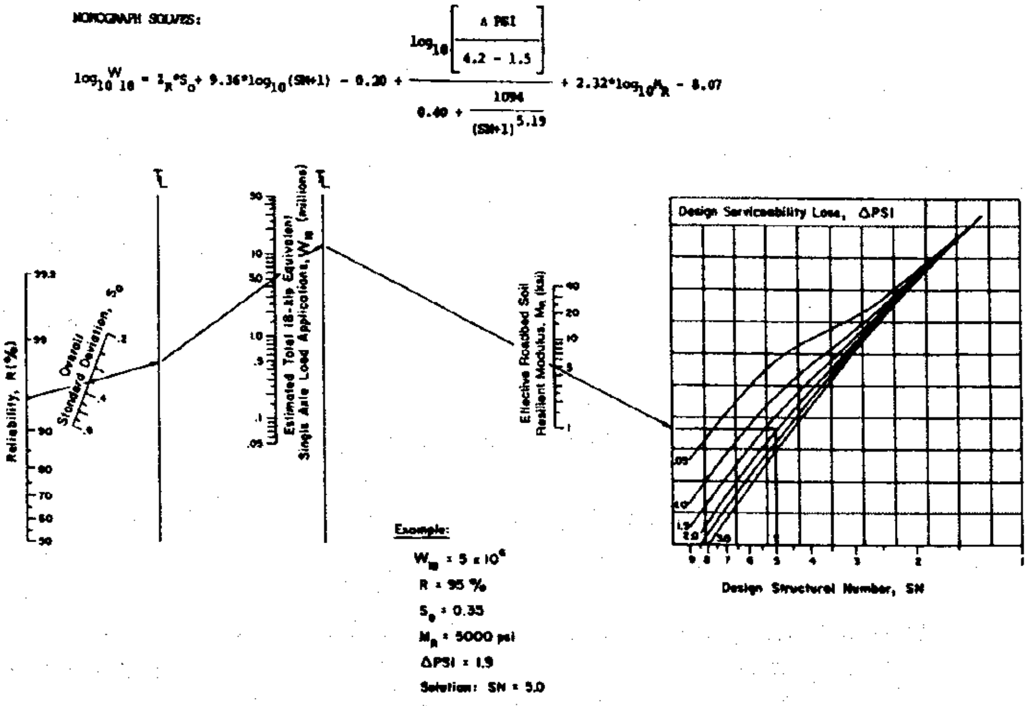


Figure 3.1. Design Chart for Flexible Pavements Based on Using Mean Values for Each Input

Note: The values of R, S_0 and ΔPSI shown in Figure are examples given in figure of AASHTO and are not the values used in this Study.

Figure 8.2 AASHTO Design Equation, Nomograph

A set of the pavement layer thicknesses is then identified which, when combined, will provide the load-carrying capacity corresponding to the design SN. The following equation provides the basis for converting SN into actual thicknesses of surface, base and subbase layers:

$$SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3$$

Where, a_1, a_2, a_3 = layer coefficients representative of surface, base, and subbase courses, respectively

D_1, D_2, D_3 = actual thickness (in inches) of surface, base, and subbase courses, respectively

m_2, m_3 = drainage coefficients for base and subbase layers, respectively

The design criteria that will be applied in the pavement design based on the AASHTO method is given in Table 8.3.

Table 8.3 Summary of Design Criteria for Pavement Design

Design Input Requirements			Value	Reference
1	Design Variables	Performance Period (years)	15	General
		Analysis Period (years)	15	General
		Traffic		
		Equivalent Single Axle Load (ton)	8.2	AASHTO
		Directional Distribution Factor, D_D	0.6	AASHTO
		Lane Distribution Factor, D_L	1.0	AASHTO
		Reliability (%)	90	AASHTO
		Overall Standard Deviation	0.45	AASHTO
2	Performance Criteria	Initial Serviceability Index, p_0	4.2	AASHTO
		Terminal Serviceability Index, p_t	2.2	AASHTO
		Design Serviceability Loss, ΔPSI	2.0	AASHTO
3	Material Properties	Effective Roadbed Soil Resilient Modulus, M_R (psi)	1500 × CBR	General
		Layer Coefficient for Subbase Course, a_3	from CBR	AASHTO chart
		Layer Coefficient for Base Course, a_2	from CBR	AASHTO chart
		Layer Coefficient for Asphalt Concrete, a_1	Resilient Mod.	AASHTO chart
4	Pavement Characteristics	Drainage Coefficients for Base and Subbase Course, m_2, m_3	1.25	AASHTO

8.4 Bridge and Culvert Design Standards

8.4.1 Review of current design standard

The current design standard for Bridges in Nepal is Nepal Road Standards (NRS 2027, First Revision-2045) published in 1988. The new standard is being prepared by DOR and draft of it is available. These NRS standards refer to the following AASHTO and IRC codes.

- AASHTO : Standard specifications for Highway Bridges 1977
- IRC : 5-1985
- IRC : 6-1966
- IRC : 21-1987
- IRC : 83-1982(Part I)
- IRC : 83-1987(Part II)
- IRC : 24-1967 Section V (Steel Road Bridges)
- IRC : 22-1986 Section VI (Composite Construction)

8.4.2 Applied Design Standard

The design standard applied in the Project basically follows the NRS's. Japanese Standard is applied for the items not covered by NRS standards. IRC is also referred in natural condition such as wind, seismic, rainfall and temperature.

The applied Japanese standards are as follows:

- Japan Road Association (JRA) : Specification for Highway Bridge I-IV 1996
- Japan Society of Civil Engineering : Standard Specification for Design and Construction of Concrete Structure

8.4.3 Concept of Bridge Planning

1) General

The Study area is broadly divided into plain and mountain areas. In the plain area, the total and the span length of bridge should be determined to provide enough opening for river flow. In the mountainous area the topography is steep and landslides and slope failure are also found at various locations. In such areas, the vertical and horizontal clearance should be determined considering the debris flow and rock fall, as well as to less cutting of slopes.

2) Bridge Length

The river width is calculated by Lacey's equation, as given below.

$$L = 3.3\sim4.9\ Q^{1/2}$$

Where, L : Required River Width (meter)
Q : Maximum Flood Discharge (cu m/sec.)

3) Minimum Span Length

The span length is important for keeping enough opening to avoid blockage by the drifting logs. Usually it is required that the minimum span length needs to be 4 times as long as the length of drifting logs from upstream.

The minimum span length is estimated by the following formula (Source: The Standard on River Control and River Facilities, Japan River Association)

$$L = 20 + 0.005Q$$

Where; L : Minimum span length (meter)
Q : Peak flood discharge (m^3/sec)

- In the case that peak flood discharge is less than 500 m^3/sec and river width is less than 30 meter, the minimum span length can be reduced to 12.5 meter.
- In the case that peak flood discharge is less than 500 m^3/sec and river width is more than 30 meter, the minimum span length can be reduced to 15 meter.

4) Vertical Clearance

Required Vertical Clearance should be maintained from the design flood level or design debris flow level, which ever is higher, to the lowest point of the superstructure. The required minimum clearance is in accordance with the following table.

Table 8.4 Minimum Clearance

Design Flood Discharge (m^3/sec)	Clearance (meter)
− 200	0.6
200 – 500	0.8
500 – 2,000	1.0
2,000 − 5,000	1.2

Source: JH Standard Part II

4) Seismic Force

According to the IRC, the horizontal seismic coefficient is calculated by the following formula.

$kh = \alpha\beta\lambda$

Where kh = Horizontal seismic coefficient

α = 0.08 (Zone V): A coefficient depending on the location

β = 1.0 to 1.5: A coefficient depending upon the soil foundation system and standard penetration test value

λ = 1.5 (Important bridges): A coefficient depending upon the importance of the bridge

According to draft of the new NRS, the horizontal seismic coefficient is as follows:

- Important bridges : 0.15
- Ordinal bridges : 0.10

8.4.4 Type of Bridge

Type of bridges is selected taking the following major items into account:

- Less construction cost
- Less maintenance cost
- Maximum usage of local materials
- Easy construction

1) Definition of structure

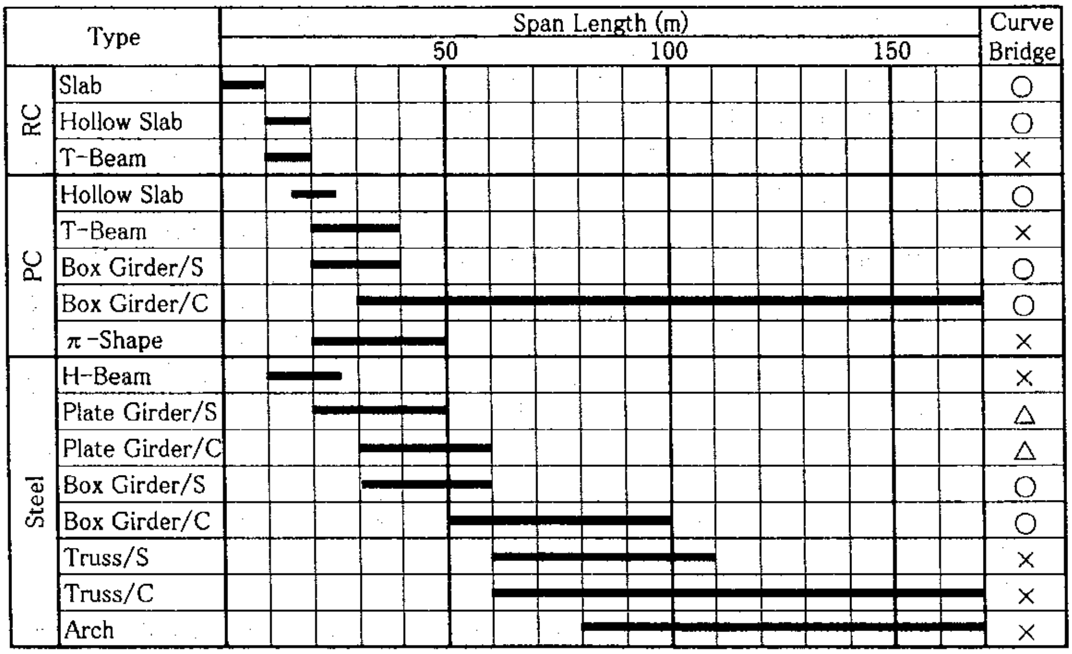
According to the NRS, the classification of structures is as follows:

- Culvert : Up to 6 meters length.
- Minor Bridges : More than 6 meters and unto 20 meters length.
- Medium Bridges : Above 20 meters length, span lengths less than 20 meters.
- Major Bridges : Bridges with span lengths greater than 20 meters.

2) Superstructure

Type of superstructure is determined taking into account the availability of construction yards, accessibility, ease of transportation and ease of erection.

The applicable superstructures in relation with the span length are shown in Figure 8.3.



Note: /S Simple, /C Continuous
Source: JH Standard Part II

Figure 8.3 Applicable Superstructures by Span Length

Concrete bridges (PC & RC bridges) can use much local materials and they have an advantage in maintenance works. There is few experience of the construction of PC bridges in Nepal and most construction and erection equipment would need to be imported from other countries.

On the other hand, steel bridges are fabricated in factories and the required quality of girders is maintained easily. The erection at site is easier and the construction period is shorter than concrete bridges. But there are no steel fabricators in Nepal and steel girders would need to be imported from neighboring Asian countries. Steel bridges will be more costly than PC bridges.

Due to the above consideration, it is judged that concrete bridges are suitable in plain area, and steel bridges are suitable in steep mountainous areas where easy access to enough construction yards are not available.

The conceivable types of superstructures are shown in Table 8.5.

Table 8.5 Conceivable Types of Superstructures

Category	Bridge Length (meter)	Span Length (meter)	Type of Superstructure	
			Concrete	Steel
Culvert	L ≤ 6	Ls ≤ 6	- Culvert	
Minor Bridge	6 < L ≤ 20	6 < Ls ≤ 20	- RC T Beam - RC Hollow Slab	- Steel H Beam
Medium Bridge	20 < L	Ls ≤ 20		
Major Bridge	20 < L	20 < Ls ≤ 40	- PC T Beam - PC Hollow Slab	- Steel I Girder - Steel Box Girder - π Rigid Frame
		40 < Ls ≤ 60	- PC Box Girder	
		60 < Ls		- Truss - Arch

Source: JICA Study Team

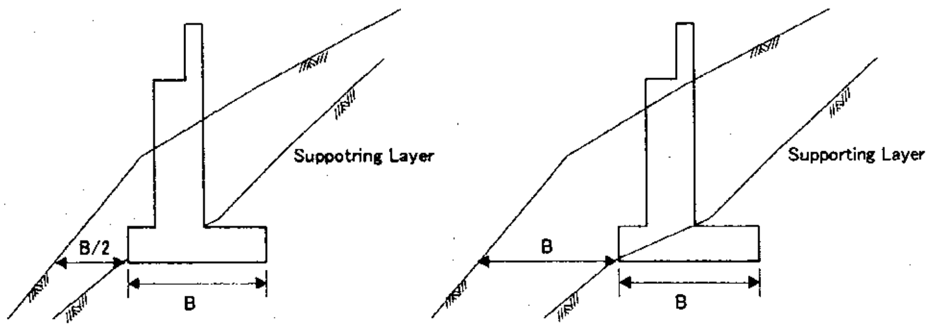
3) Type of Substructure

i) Abutment

There are mainly three types of abutment, invert T type, box type, and rigid frame type. The type of individual abutment is selected from geographical condition, cost, and ease in construction.

The invert T type abutment is comparatively lighter in weight. This type is most economical, generally, for a height range of 6-15 m.

The setting of footing on the steep slope is as shown in Figure 8.4.



(a) Supporting layer is hard rock (b) Supporting layer is stable

Source: JH Standard Part II

Figure 8.4 Setting of Abutment on Steep Slopes

ii) Pier

The types of piers are selected by geographical conditions. The following types are applicable.

- In the River : Wall type (Oval shape)
- Mountain Valley Area : Pillar type, Wall type and Rigid frame type
- Plain Area : Pillar type, Wall type and Rigid frame type

4) Type of Foundation

Type of foundation is selected by the geological conditions, geographical condition, reactions of superstructure, and construction workability.

The selection criteria of foundation is shown in Table 8.6.

Table 8.6 Selection Criteria of Foundation

Condition \ Type of Foundation				Sprend Foundation	Driven Pile			Cast-in-situ				Caisson	
					RC	PC,PHC	Steel	All Casing	Reverse	Earth Drilling	Sinso	Pneumatic	Open
Geographical Condition	Intermidiate Layer	Intermidiate Layer is Soft Layer		△	○	○	○	○	○	○	×	○	○
		Intermidiate Layer is Hard Layer		○	×	△	△	△	○	△	○	○	△
		Intermidiate Layer is Gravel	Dia -5cm	○	△	△	○	○	○	○	○	○	○
			Dia 5-10cm	○	×	△	△	○	○	△	○	○	○
			Did 10-50cm	○	×	×	×	△	×	×	○	○	△
		Liquefaction		△	△	○	○	○	○	○	○	○	○
	Supporting Layer	Depth	- 5m	○	×	×	×	×	×	×	○	×	×
			5 - 10m	△	○	○	○	○	△	○	○	○	○
			15 - 25m	×	△	○	○	○	○	○	○	○	○
			25 - 40m	×	×	○	○	○	○	△	△	○	○
			40 - 60m	×	×	△	○	△	○	×	×	△	○
			60m -	×	×	×	△	×	○	×	×	×	△
		Soil Classification	Clay (20≦N)	○	○	○	○	○	○	○	○	○	○
			Sand, Gravel (30≦N)	○	○	○	○	○	○	○	○	○	○
		Steeply (above 30 degree)		○	×	△	○	○	△	△	○	○	△
		Sopporting Layer is uneveness		○	△	△	○	○	○	○	○	○	△
	Ground Water	Ground Water exists near Ground Surfase		△	○	○	○	○	○	△	△	○	○
		Seepage Water is much		△	○	○	○	○	○	△	×	○	○
		Confined Ground Water is deeper than 2m		×	○	○	○	×	×	×	×	△	△
		Ground Water Velocity is above 3m/mim		×	○	○	○	×	×	×	×	○	△
Structural Condition	Reaction	Vertical Reaction is small		○	○	○	○	○	○	○	○	×	△
		Vertical Reaction is normal		○	△	○	○	○	○	○	○	○	○
		Vertical Reaction is large		○	×	△	○	○	○	△	○	○	○
		Horizontal reaction is less thanVertical Reaction		○	○	○	○	○	○	○	○	△	△
		Vertical reaction is less thanHorizontal Reaction		○	×	△	○	○	○	○	○	○	○
	Bearing Pile			–	○	○	○	○	○	○	○	–	–
	Friction Pile			–	○	○	○	○	○	○	–	–	–
Construction	Water Depth is less than 5m			○	○	○	○	×	○	△	×	△	△
	Water Depth is more than 5m			×	△	△	○	×	△	×	×	△	△
	Less Working Area			○	△	△	△	△	△	△	○	△	△
	Batter Pile			–	△	○	○	△	×	×	×	–	–
	Poisonous Gas			△	○	○	○	○	○	○	×	×	○

○:Well Applicable △:Applicale ×:Not Applicable

Source: Pile Foundation Standard by JRA

The applicable length of piles is shown in Table 8.7.

Table 8.7 Applicable Length of Piles

		Pile Length (meter) 10 20 30 40 50
Driven Pile	RC	
	PHC	
	Steel	
Cast-in-Situ Pile	All Casing	
	Reverse Circulation Drill	
	Earth Drilling	
	Sinso	

Source: Pile Foundation Standard by JRA

8.4.5 Design Criteria

1) Loading

Dead load, live load, impact friction, prestress, creep and shrinkage of concrete, dynamic water pressure, earth pressure, buoyancy, wind load, thermal effects and seismic force, are considered in designing bridges and culverts.

Live load applied is the B live load of JRA standard.

2) Typical Cross Section

The typical cross section of bridges is shown in Figure 8.5.

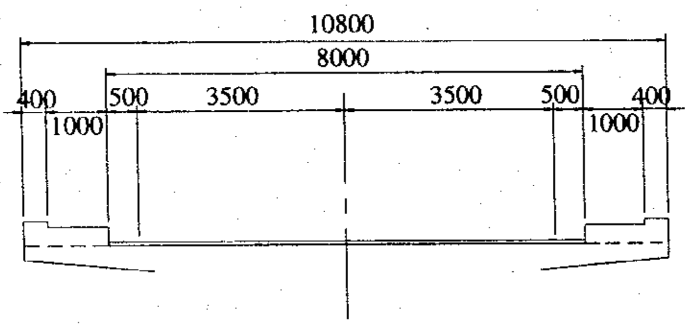


Figure 8.5 Typical Cross Section of Bridges

8.5 Tunnel Design Standards

8.5.1 General

Highway Tunnels are constructed to short cut the section where steep slope and/or potential disaster spots exist. It can be highly recognized that the tunnel will be constructed aiming at additional economical benefit mainly resulted from distance shortening but also secure disaster proof of the highway.

Due to a tunnel's particular characteristics, the following facilities are required.

- Ventilation system
- Lighting system
- Emergency facilities

The air inside a tunnel is polluted by exhaust gas from the traffic since fresh air can not be supplied naturally. The natural wind in tunnel is developed merely by the pressure difference between the two portals and also because of movement of traffic. This kind of phenomena to provide natural ventilation is possible only in short tunnels. But in long tunnels, mechanical ventilation system producing continuous air supply, is required for proper ventilation.

Sunlight is always blocked inside the tunnel. Sun light can enter into the tunnel only up to about 10 m from the portal. The tunnels with a total length of about 50 m may not require lighting system from this consideration. However, proper lighting system is required for tunnels longer than 50 m. Besides, to adapt car driver for the difference in brightness between inside and outside of tunnel, a part of portal should be arranged with adaptation lighting zone with a gradual change in brightness of light.

In case accidents occur inside tunnels, evacuation and rescue operations are very difficult because of space constraint. In this regard, proper emergency facilities must be installed.

8.5.2 Review of international design standards

1) Rock classification and support

About 20 years ago, Roadway tunnel construction was mainly based on conventional tunnelling method. This method is based on using H-shape steel support with logging, ensuring enough open space for large and powerful machines.

Around 1980, Dr. Rabce-wicz proposed NATM (New Austrian Tunneling Method) method that used rock bolts and shotcrete for support. This method makes maximum use of arch action of surrounding ground for tunnel support. The method has been widely used in advanced countries and is the standard in many countries these days. Many tunnels have already been constructed successfully by this method.

Advantages of the NATM, in comparison with the conventional tunneling meathead, can be summarized as follows:

a) Since the NATM uses shotcrete and rock bolting as major support of excavated surface, machinery construction can be maximized.

b) By means of the above a), progress of the tunnel excavation work can be expedited

c) Initial supports by shotcrete and rock bolting just after excavation work can minimize development of loosen zone of the surrounding rock and well reduce increase of subsequent load

d) With monitoring during excavation work, supporting pattern can be adjusted flexibly. Therefor economical supporting pattern can be employed as initial support.

e) As a results of the above, more reliability and less total construction cost can be expected

In the case of NATM, the standards are almost same in the world current international standards that are introduced below, and their rock classification for tunnel support design are shown in Table 8.8.

i)	Germany and Austria	ONORM B2203, Rabce-wicz-Pacher
ii)	Switzerland	SIA198 Standard
iii)	France	AFTES (f-value)
iv)	Norway	NMT (Norwegian Method Tunneling, Q-value)
v)	Japan	Road Tunnel Technical Standard.

The first two standards, Germany/Austria and Switzerland, are classifying tunnel support type according to the classification of rock type encountered during tunnel excavation. Determination of tunnel support type in the other standard is basically based on the rock type classified by geological investigation prior to the construction.

"f – value" and "Q-value" are used for the classification of rock in France and Norwegian standards, respectively, on the other hand seismic velocity is used in Japanese Standard.

2) Ventilation system

Basically there are two types of ventilation system for the road tunnel, namely "transversal system" and "longitudinal system".

Transversal system facilitated ventilation duct for its exclusive use, on the other hand, longitudinal system utilizes vehicle running space for ventilation duct as well (Ref. Figure 8.6). Transversal system used to be the prevailing ventilation system of long tunnel in Europe, while longitudinal ventilation system had been used for short tunnel.

Recently, electric dust collection system have been improved, especially in Japan, and this makes it possible to use in longitudinal system for long tunnel.

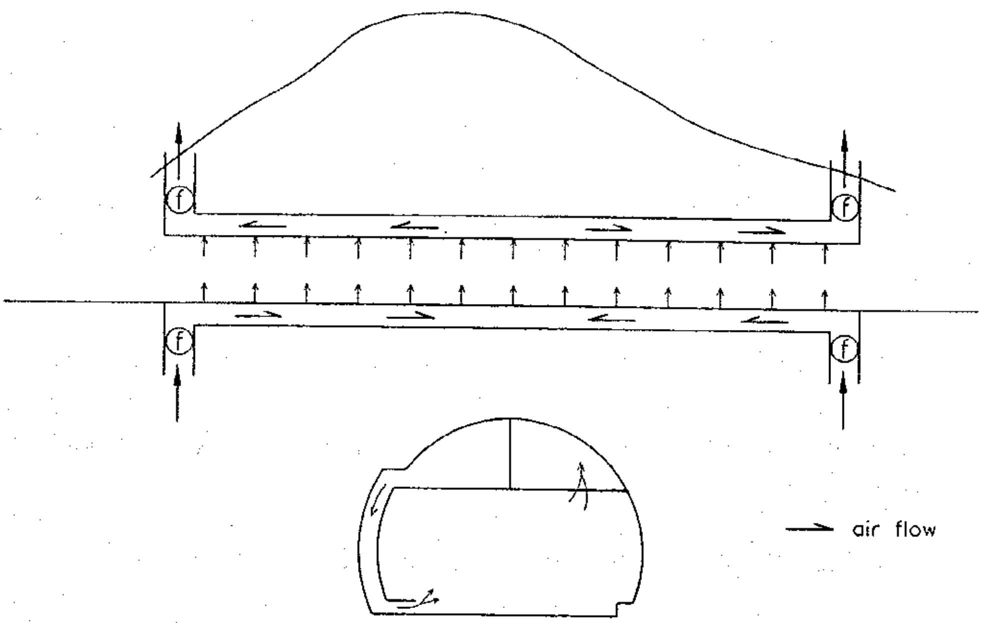
Design of the ventilation system is based on the air flow analysis, of which calculation method and parameters are quite similar among these international standards, while regarding emission rate per vehicle, various values are proposed by these standard. Among several standards, the PIARC (Permanent International Association of Road Congress) recommends emissions rate with classification of vehicle type and domestic regulation status see in the (Table 8.9)

PIARC emission standard have been often used for the tunnel countries other than Europe, USA, and Japan. The Study Team recommend to use emission rates in the category of "no regulation" condition of the PIARC standard for the Project Road.

Table 8.8 Standards of Rock Classification and Support

	National	Germany, Austria	Germany, Austria	Switzerland	France	Norway	Japan
Name of Standard		ONORM	Rabcewicz-Pacher	SIA 198	AFTES	NMT	Road Tunnel Technical Standards
Rock Classification	number of class	7	6	6	10	9	7
	index	qualitative descriptions	qualitative descriptions	qualitative descriptions	f value	Q value	seismic velocity
	index				(ϕ : angle of internal friction)	(RQD)	strength-earth pressure rate
	index				(c : cohesion)	(Jn, Jr, Ja, Jw)	RQD
	index				(σc : unconfined compression strength)	(SRF)	pitch of crack
	index				(σk : unconfined compression strength)		qualitative descriptions
	note	Classified by qualitative descriptions (Strong ground, Ground that be opening fissure ~ Big pressure ground, Flowiy ground)	Almost same at ONORM	Almost same at ONORM	Classified by f value	Classified by Q value	Classified by seismic velocity, RQD etc.

TRANSVERSE VENTILATION



LONGITUDINAL VENTILATION

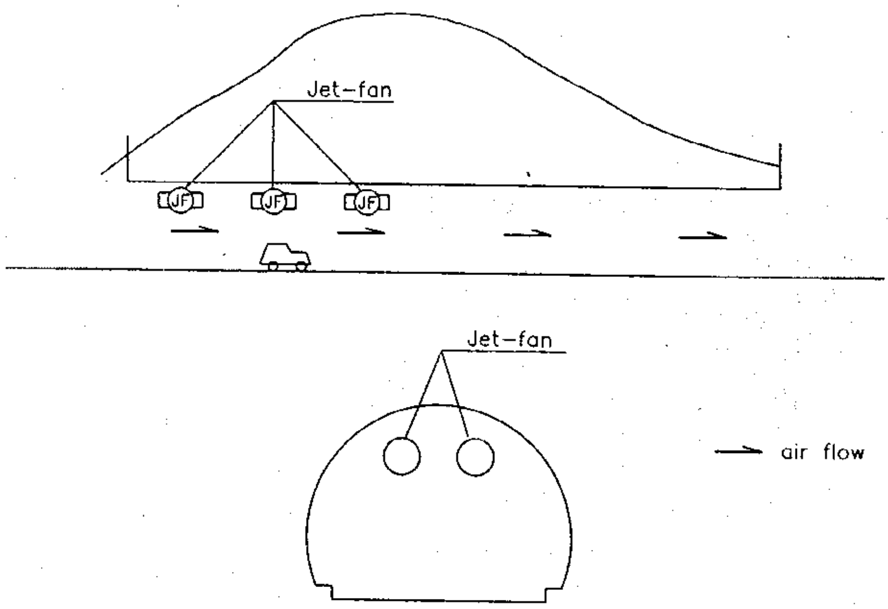


Figure 8.6 Ventilation System

Table 8.9 Limit for Exhaust Gas from PIARC (for V = 60 km/h)

Trucks,buses with deisel motors (m>3.5t)									
Emission law	Control	q^{OT} (V=60km/h) (m2/h,veh) Truck weght (t)				$q^{O\,NOX}$ (V=60km/h)		
		5	10	20	40	5	20	40
No Low	No	80-130	160-250	300-400	400-600	500	1400	1900
EEC R49+24	No	80	160	240	280	500	1400	1900
EEC R49+24	Yes	65	130	240	240	470	1300	1800
EEC 88/77	Yes	50	100	160	200	360	1000	1400
US Transient 88	Yes	50	100	160	200	330	900	1200
US Transient 91	Yes	30	60	100	140	270	750	1000
US Transient 94	Yes	20	40	70	110	220	600	800

Emission law	Control	$q^{O\,CO}$ (m^3/h,pc)
No Low	No	1-1.5
EEC R 15/04	No	0.70
EEC R 15/04	Yes	0.50
EEC 89/458	Yes	0.16
FTP75	Yes	0.12
diesel engine		0.08

3) Lighting system

Generally, lighting system will be provided for the tunnel longer than 50 m. If the tunnel is longer than 100 m, lighting system has to be provided in most of the tunnel.

There are various standards for the tunnel lighting established in Europe and Japan. These standards are comparatively presented in Table 8.10.

Table 8.10 (1/3) Standards of Lighting System

Country	Europe	Europe	England	Japan
Standard	CIE	CEN	BS	JRA

Basic lighting — Required luminance of road surface — Day

CIE:

Traffic density	Heavy	Normal	Light
Stopping distance (m)	≦100veh/h	＞100veh/h ＜1000veh/h	≧ 1000veh/h
160	5	10	15
100	2	4	6
60	1	2	3

CEN:

Stopping distance(m)			
Class	60m	100m	160m
7	3	6	10
6	3	5	8
5	2	4	6
4	2	3	6
3	1.5	2	4
2	1	1.5	—
1	0.5	1.5	—

Class	Total
7	14 -15
6	12 -13
5	10 -11
4	8 -9
3	6 -7
2	4 -5
1	0 -3

BS:

Design speed (km/h)	Average luminance (cd/m2)
110 over	10
80 ～100	5
50 ～70	3

JRA:

Design Speed (km/h)	Average luminance(cd/m2)
100	9．0
80	4．5
60	2．3
40 or under	1．5

Basic lighting — Required luminance of road surface — Night

CIE: 1cd/m2 or same luminance of adjacent road

CEN:

Class	Requirement average luminance (cd/m2)
4～7	1.0cd／m2以上
1～3	0.5cd／m2以上

BS: 2～5cd/m2

JRA: 0.7 cd/m2 over

Basic lighting — Uniformity of luminance

CIE:

At any places 0.4 over
Along center line 0.6 over

(Imin/Imax)

CEN:

Class	At any place	Along center line
6 -7	0.4	0.7
4 -5	0.4	0.6
2 -3	0.3	0.5
1	0.2	0.4

BS:

At any places 0.4 over
Along center line 0.6 over

JRA:

Interval of lighting fitting(s)
Opposite arrangement S≦2.5H
Staggered arrangement S≦1.5H
Center arrangement S≦1.5H
where H: hight from road surface

Basic lighting — Requirements during power failure

CIE: None

CEN:

Class	Standard
2 ～ 7	10% of basic lighting requirement or 0.2cd/m2
1	every five luminary

BS: 10% of basic lighting requirement for one hour

JRA:

Emergency power supply	Min. requirement against basis lighting
Generator	25%
Accumulation	12.50%

Basic lighting — Maintenance factor

Standard	Maintenance factor
CIE	None
CEN	0.7 (for road surface) 0.5 (for wall)
BS	0.7 (for road surface) 0.5 (for wall)
JRA	0.5～0.7

Table 8.10 (2/3) Standards of Lighting System

Lighting in Entrance Transition

National Country	Europe	Europe	England	Japan
Standard	CIE	CEN	BS	JRA
Division of Zone	- Access Zone - Threshold Zone - Transition Zone	- do-	- do-	- Access Zone - Threshold Zone - Transition Zone - Mitigatory Zone

Threshold Zone

Europe – CIE

$Lth = k * L_{out}$

Stopping distance	k: Symmetric lighting (L/Ev≦0. 2)	k: Counter beam (L/Ev≧0. 6)
60	0.05	0.04
100	0.06	0.05
160	0.10	0.07

Required length of Threshold Zone shall be longer than stopping distance.

Europe – CEN

$Lth = k * L_{out}$

Stopping distance (m)	k: Symmetric lighting (L/Ev≦0. 2)			k: Counter beam (L/Ev≧0. 6)		
SD(m)	60	100	160	60	100	160
Class						
7	40	50	70	50	60	100
6	35	45	60	40	55	80
5	30	40	55	35	50	65
4	25	35	50	30	40	50
3	20	30	45	25	35	45
2	15	20	40	20	25	40
1	10	15	35	15	20	35

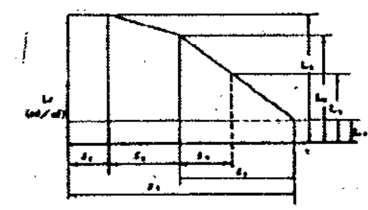
England – BS

$Lth = k * L_{out}$

Limitation of Speed	k
110 over	0.07
80 ~100	0.06
50 ~70	0.05

Japan – JRA

Each value be selected by under table



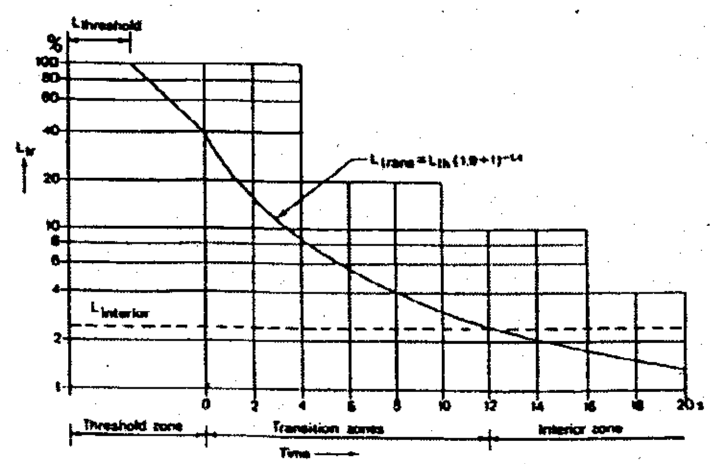
design speed(km/h)	Length of tunnel(m)	Luminance of road surface(cd/m2) L1	L2	L3	L4	Length(m) l1	l2	l3	l4	l5
100	75under	116	—	—	—	40	0	0	0	40
	100	111	106	—	—	55	10	0	0	65
	125	105	91	—	—	55	35	0	0	90
	150	103	77	—	—	55	55	0	0	110
	175	99	67	—	—	55	80	0	0	135
	200	95	58	—	—	55	105	0	0	160
	250	95	47	—	—	55	150	0	0	205
	300	95	47	27	—	55	150	45	0	250
	350	95	47	15	—	55	150	90	0	295
	400over	95	47	—	9.0	55	150	0	135	340
80	75under	112	—	—	—	40	0	0	0	40
	100	105	94	—	—	40	25	0	0	65
	125	100	76	—	—	40	45	0	0	85
	150	94	62	—	—	40	70	0	0	110
	175	88	51	—	—	40	90	0	0	130
	200	83	46	37	—	40	100	15	0	155
	250	83	46	19	—	40	100	55	0	195
	300	83	46	10	—	40	100	100	0	240
	350	83	46	5.3	—	40	100	145	0	285
	400over	83	46	—	4.5	40	100	0	155	295
60	75under	107	99	—	—	25	15	0	0	40
	100	94	71	—	—	25	35	0	0	60
	125	83	53	—	—	25	55	0	0	80
	150	74	46	34	—	25	65	15	0	105
	175	66	40	20	—	25	65	35	0	125
	200	58	35	12	—	25	65	55	0	145
	250	58	35	5.2	—	25	65	95	0	185
	300over	58	35	—	2.3	25	65	0	135	225
40	75under	94	74	—	—	15	20	0	0	35
	100	73	51	38	—	15	30	10	0	55
	125	58	40	18	—	15	30	25	0	70
	150	46	33	8.6	—	15	30	45	0	90
	175	36	25	4.0	—	15	30	60	0	105
	200	29	20	1.8	—	15	30	80	0	125
	250over	29	20	—	1.5	15	30	0	85	130

Transition Zone / Mitigatory Zone

Europe – CIE / CEN

$Ltr = Lth(1.9 + t)^{-1.4}$

t=Travel time after Threshold Zone(s)



England – BS

Each value be selected by under Fig.

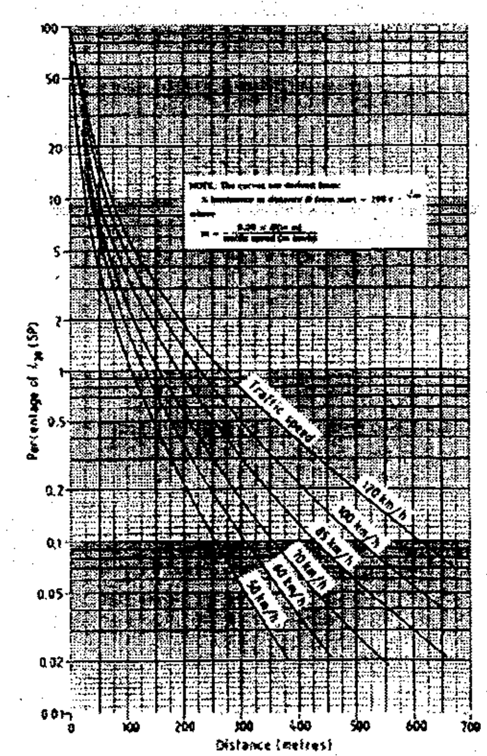


Table 8.10 (3/3) Standards of Lighting System

National	Commission of International Electric Lighting	Commission of Europe Normalization	England	Japan
Standard	CIE	CEN	BS	Standard of road Lighting System

Field luminance

CIE / CEN

Method 1

Used at the case that cannot use detail data of entrance.

	Average luminance of 20° conic view(cd/m2)															
	The ratio sky															
	35 %				25 %				10 %				0 %			
	Normal		Snow		Normal		Snow		Normal		Snow		Normal		Snow	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Condition of view	1)		1)		1)		1)		2)		3)		2)		3)	
Stopping distance 60m	4)		4)		4000	5000	4000	5000	2500	3500	3000	3500	1500	3000	1500	4000
Stopping distance 100~160m	4000	6000	4000	6000	4000	6000	4000	6000	3000	4500	3000	2500	1500	3000	2500	5000

1)Effect of direction of tunnel
- Low : south entrance
- High : north entrance
- middle value at east and west entrance

2)Effect of circumference brightness
- Low : low circumference reflection
- High : high circumference reflection

3)Effect of direction of tunnel
- Low : north entrance
- High : south entrance
- middle value at east and west entrance

4)no case at stopping distance 60m

Method 2

Used at the case that be able to use detail data of entrance.

there L_C: Luminance of sky(cd/m2) α : Ratio of sky (%)

L_R: Luminance of road surface(cd/m2) ρ : Ratio of road surface (%)

L_E: Luminance of circumference entrance(cd/m2) ξ : Ratio of circumference entrance (%)

L_{th}: Luminance of boundary(cd/m2) τ : Ratio of entrance (%)

$$\alpha+\rho+\varepsilon+\tau=1$$

Decide the value from sketch and photograph of examples at the case that be able to confirm the value of α、ρ、ε and τ.

Used under table at the case that not be able use the value of luminance of site.

driving direction	Lc(sky) kcd／m2	Lc(road) kcd／m2	L_EE(situation)kcd／m2 rock	building	snow	grass
north	8	3	3	8	15 (V,H)	2
east-north	12	4	2	6	10 (V)	2
					15 (H)	
south	16	5	1	4	5 (V)	2
					15 (H)	

BS

Method 1

Use the direct data at most luminous season of year.

Method 2

Use the grid method.

Calculate the average luminance using table as follows.

Average luminance L20=AL／A

there

A: area of each part (m2)

L: Luminance of each part (cd/m2)

General luminance	
Back	Luminance (cd/m2)
sky (fine weather)	8000
south sky (cloud)	20000
grass	2000
hill (rock cliff, cliff)	3500
soil/sand	3500
tree	1000
entrance (dark)	1000
wall (dark)	1000
wall (light)	6000
surface (asphalt)	4000
surface irradiating southern sunlight (asphalt)	6000
surface (concrete)	8000
house (brick)	3500

note: these are value at midsummer and daylight. (At 1000000lx horizontal face illumination)

Method 3

Decide the value from examples

Japan

Condition	Field luminance
(1) Case that be occupied 50% over by high bright area like sky or sea against the all view. (2) Case that be spread out at near the tunnel entrance and have south facing entrance. (3) Case that be expected high brightness near the tunnel entrance.	6000
(1) Case be that occupied 25% over by high bright area like sky or sea against the all view. (2) Case that be spread out relatively at near the tunnel entrance and have south facing entrance.(±25°) (3) Case of the normally mountain and urban tunnel	4000
(1) Case that be occupied a little by high bright area like sky against the all view. (2) Case that be not spread out at near the tunnel entrance and have near mountain and woods. (3) Case of the urban tunnel that enclosed high building. (4) Case of tunnel entrance that not irradiation of daylight through an year	3000

4) Emergency facilities

Tunnel emergency facilities are provided to mitigate damage in the event that fire or any other accidents occur inside of the tunnel. There are many kinds of facilities to be considered.

Emergency facilities are categorized as information and alarm equipment, fire extinguishing equipment, escape and guidance equipment, and others.

a) Information, alarm equipment

i) Emergency Telephone: to be used exclusively for notifying the occurrence of an accident to tunnel maintenance authority by persons involved in or discovering the accident.

ii) Pushbutton type information equipment: to be pressed by persons involved in or discovering an accident in order to inform the authorities of the occurrence of the accident.

iii) Emergency Alarm Equipment: When something goes out of order in the tunnels drivers running in the access zone as well as in tunnel are promptly notified through this alarm equipment. The system includes entrance information boards at tunnel entrances and the in tunnel information boards in emergency parking areas in tunnels.

b) Fire Extinguishing Equipment

i) Fire Extinguishers: installed for initial control of small scale fires. Portable powder type fire extinguisher equipped.

ii) Fire Plug: hose – reel water plugs are installed for initial control of ordinary fires. Designed even for road users to be able to handle them.

c) Escape and Guidance Facilities

i) Guide board: these show road users in the tunnel the distance/direction to an exit or evacuation route, the current position, and other information.

ii) Evacuation Passage: there are evacuation tunnels and evacuation adits for the evacuation of road users in the tunnel to a safe place, when it is considered necessary.

d) Other Equipment

i) Hydrant: supply water for fire fighting activities by fire service crew.

ii) Radio Communication Auxiliary Equipment: used for communication with the outside of the tunnel by fire squads engaging in rescue or fire fighting activities in the tunnel.

iii) Radio Rebroadcasting Equipment: an introduction antenna is installed in the tunnel so that radio broadcasting can be received in it. When a cut-in function is added, the highway authorities can transmit information in an emergency.

iv) Loudspeaker Equipment: reliable information is supplied to those who have alighted from their vehicles.

v) Water Sprinkler System: Sprinkle fine particles of water from water spray heads in order to prevent fire from spreading, support fire – fighting activities.

vi) CCTV: CCTV are installed for observation of inside of tunnel.

8.5.3 Applied design standard

1) Rock classification and support

The tunnel standards of European countries are suitable for hard rock but not directly applicable to this Study. Japanese standards, which utilizes seismic velocity and RQD, can be applied to any kind of rock so it is proposed to be applied in this Study.

2) Ventilation system

Necessary ventilation systems are proposed to be designed based on PIARC requirements, since it covers wider range of traffic condition.

3) Lighting system

The standards for lighting system used in Europe require bigger scale of lighting system than that in Japan. In this context, the design standards of Japanese may be more practical to be used in this Study and are proposed to be applied.

4) Emergency facilities

Emergency facilities are required during accidents. The extent of the requirements of facilities is based on the length of the tunnel and the traffic volume. Requirements of parking bays and U-turn spaces will be studied. Japanese standard is proposed to be used for the design of emergency facilities in this Study, since the standard covers wider and more detail than other standards.

	unite	CIE	CEN	BS	Japan
L1	cd/m²	200	120	200	58
L2	cd/m²	80	48	-	35
L3	cd/m²	2	2	3	2.3
D1	m	-	-	70	25
D2	m	60	70	-	65
D3	m	418	285	265	135
ΣD	m	478	355	335	225

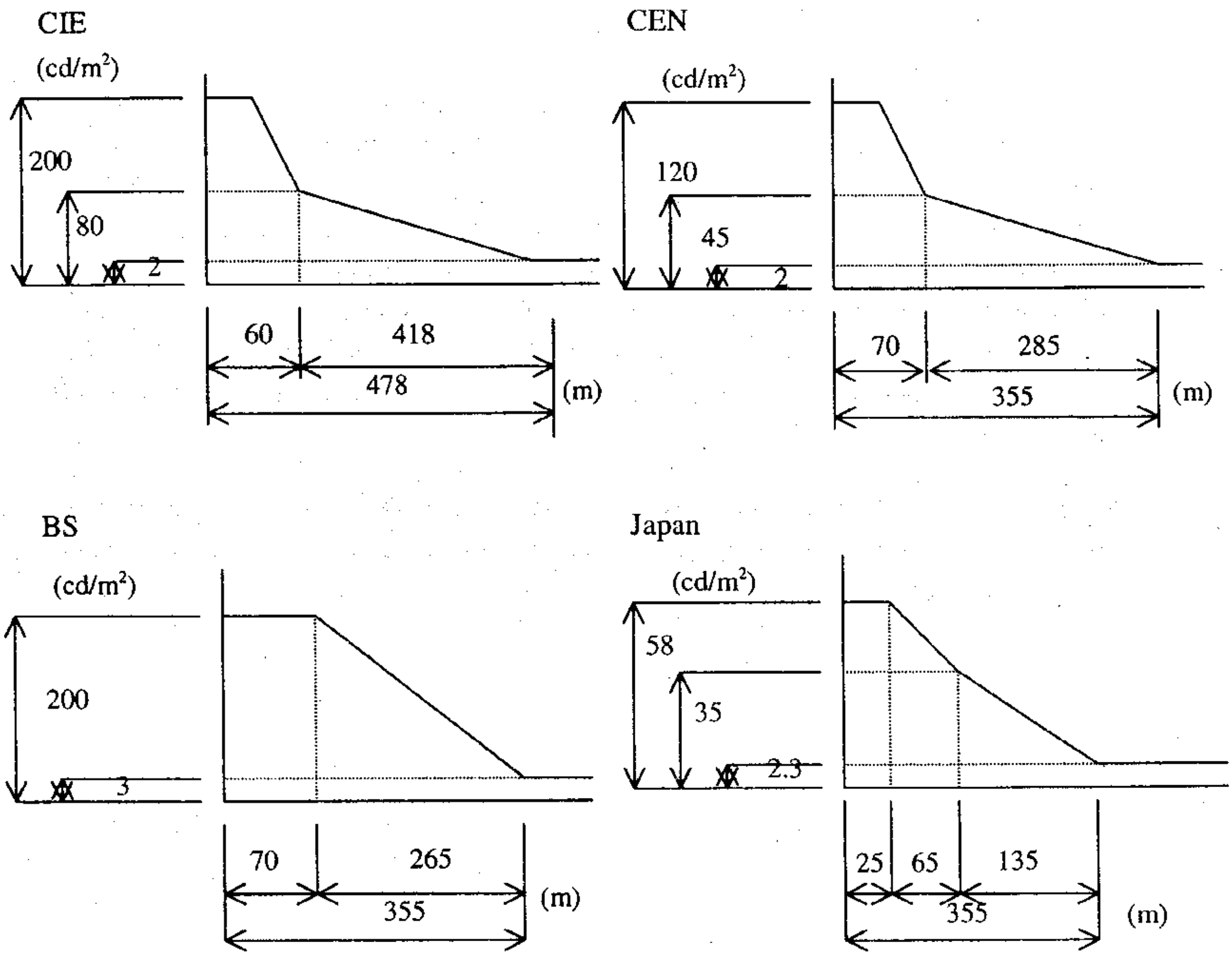


Figure 8.7 Comparison of Intensity of Lighting
(Field luminance 400cd/m²)

8.5.4 Cross section of tunnel

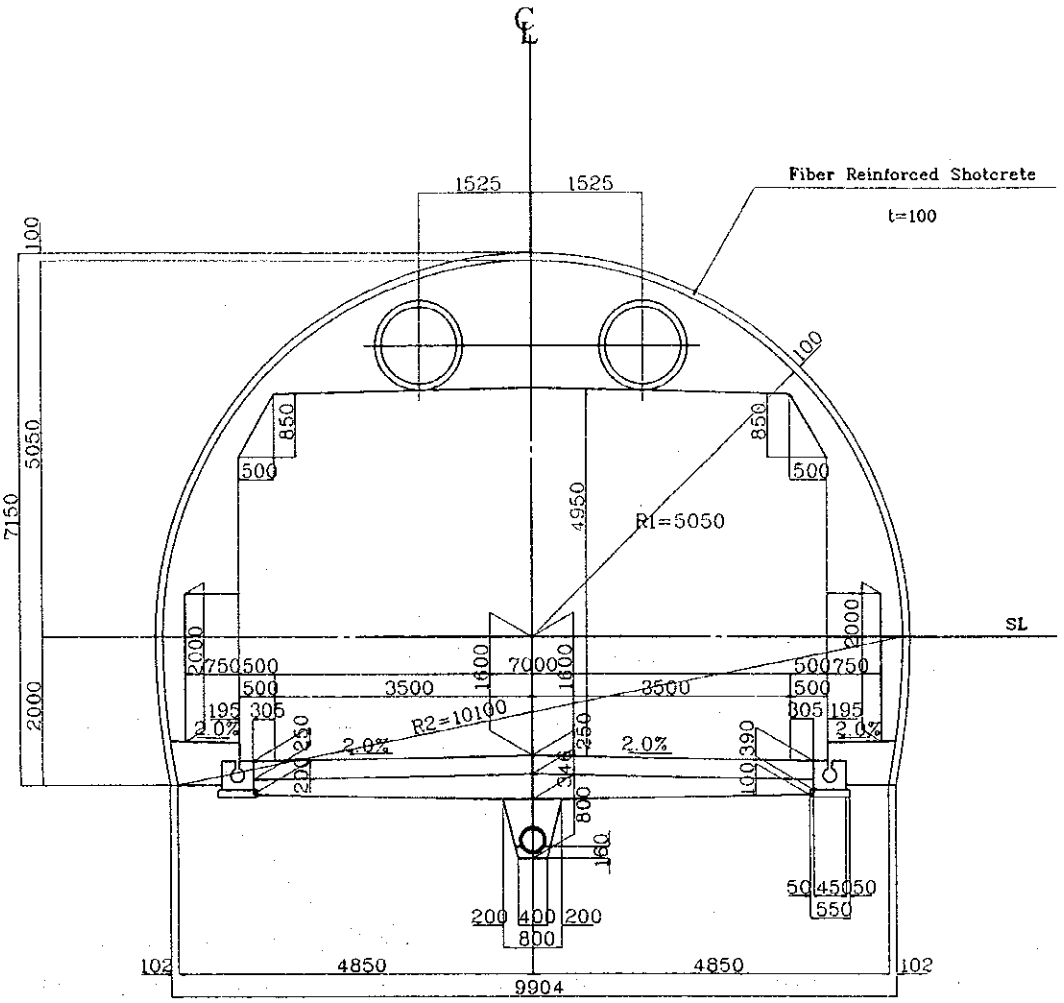
The width of pavement inside tunnel is proposed to be 8 m consisting of two lanes with 3.5 m width and a hard shoulder with 0.5 m on each side. An inspection gallery is also proposed to be provided.

The vertical clearance of 4.75 m is proposed to be applied, as required by the Nepal Road Standards.

The inner section of tunnel will be enough to cover the required clearance both for vertical and horizontal, and will ensure enough space for facilities.

Normally, the inner section of tunnel has three-centered-arch, since this shape is stable against ground pressure. In the route of the long tunnel alternative a sound limestone zone exists. So the secondary lining will not be required. In such cases application of fiber-reinforced shotcrete are commonly used. However, in the portions near portal, secondary concrete lining will be provided due to relatively poor geology anticipated. In case of the short tunnel alternative, the tunnel runs through sheared zone composed of phyllite in whole tunnel stretch, so the condition will be much more difficult than that of the long tunnel alternative. Secondary concrete lining will be provided at all sections.

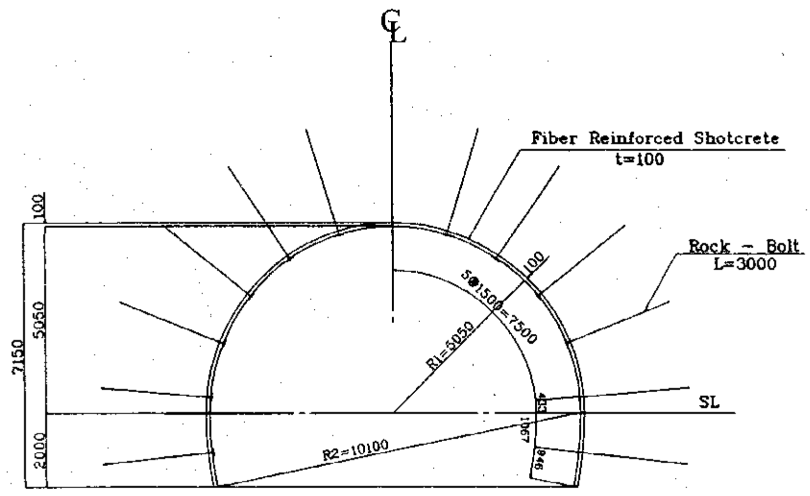
Recent advance NATM can be considered applicable to this short tunnel alternative, however, conventional tunneling method may be considered as an alternative method from a respect of cost performance.



Typical Cross Section of C1 Route Tunnel (Scale; 1:100)

TYPE A (Hard Rock)

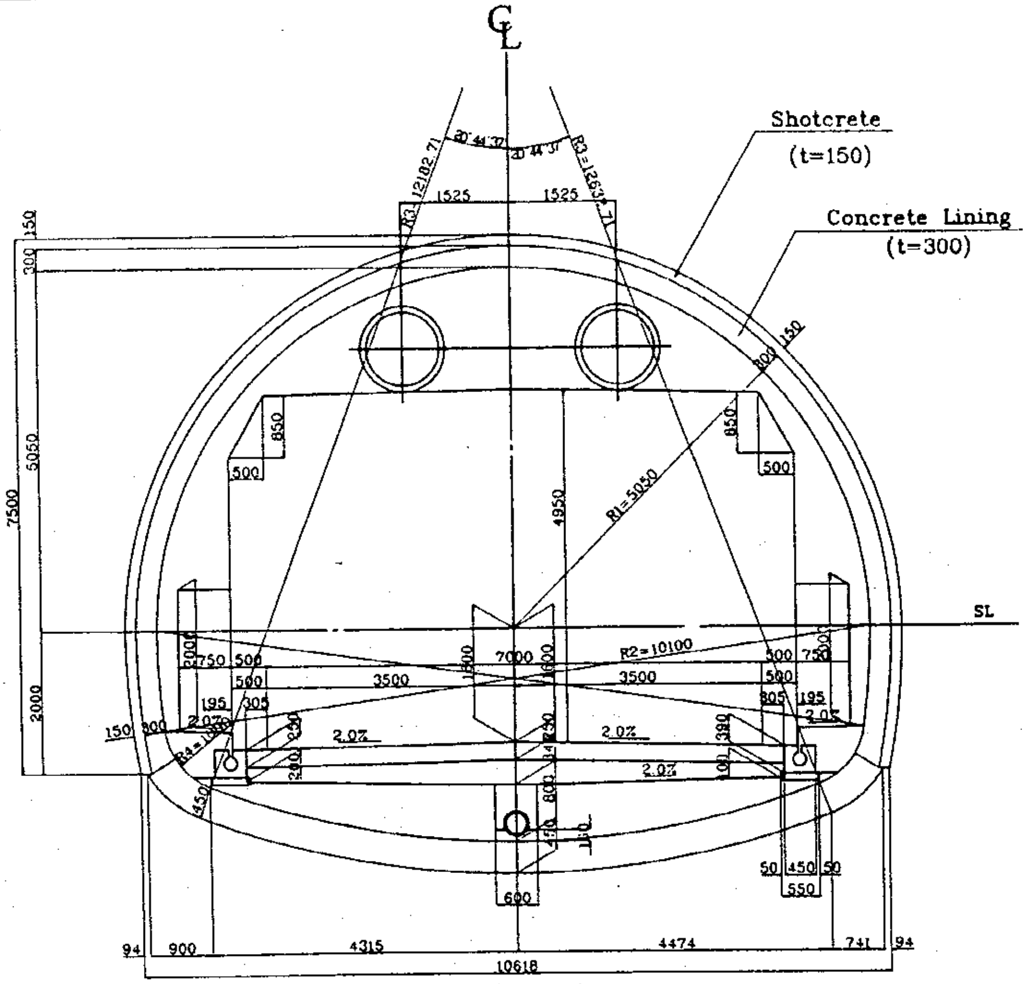
Shotcrete & Rock - Bolt



Tunnel Support (Scale; 1:200)

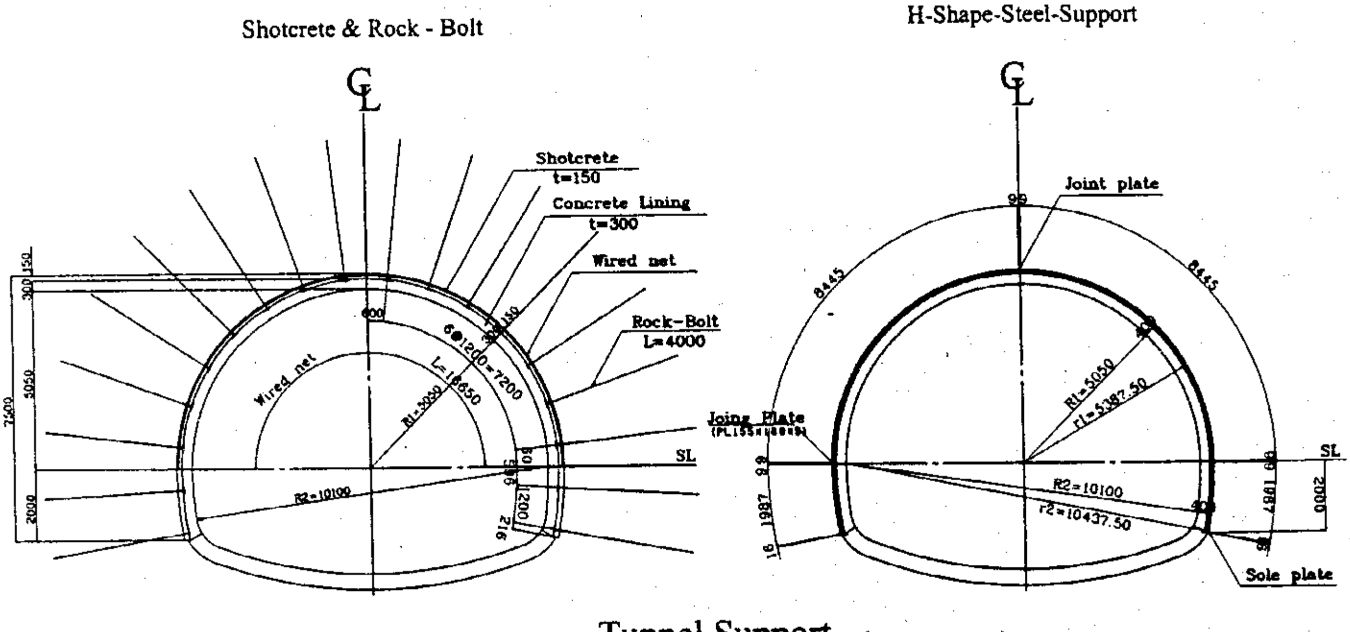
TYPE A (Hard Rock)

Figure 8.8 Typical Cross Section of C-1 Route Tunnel (Hard Rock)



Typical Cross Section of C1 Route Tunnel (Scale; 1:100)

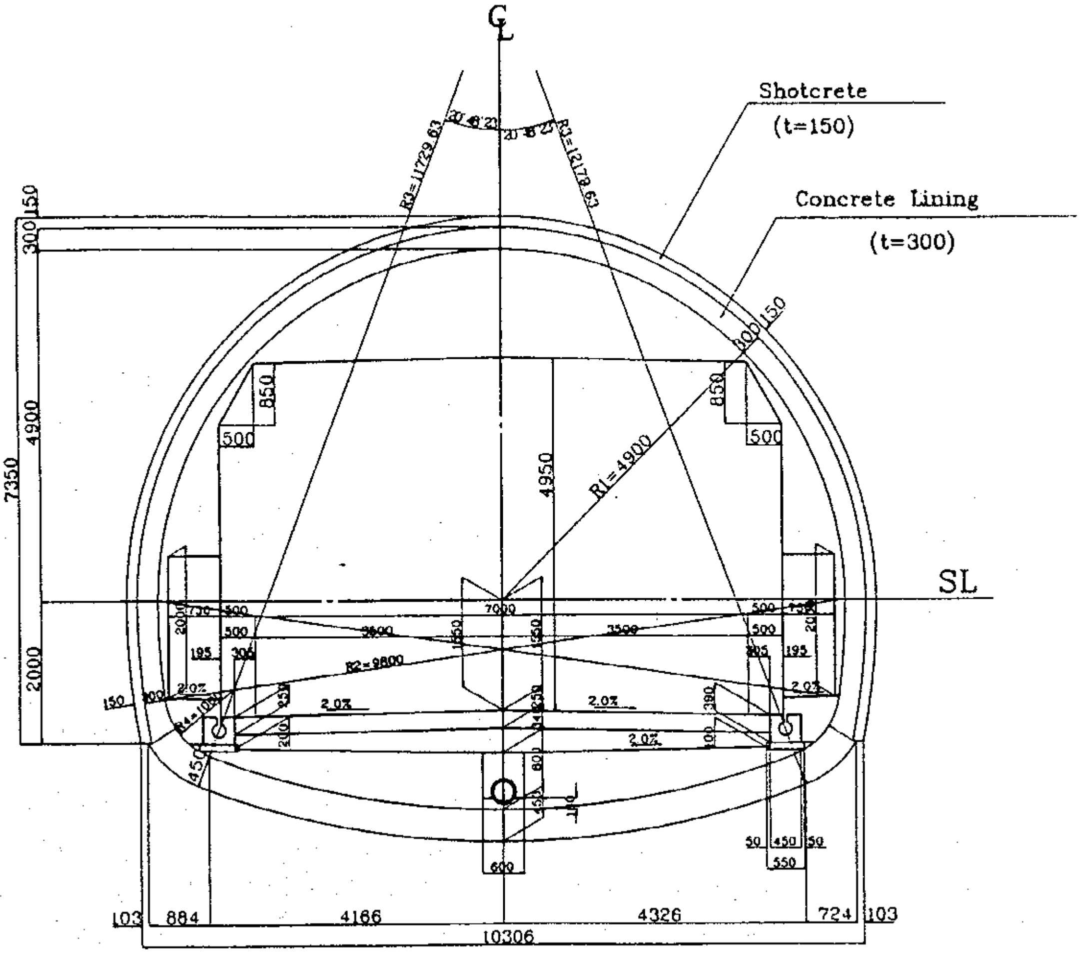
TYPE B (Soft Rock)



Tunnel Support (Scale; 1:200)

TYPE B (Soft Rock)

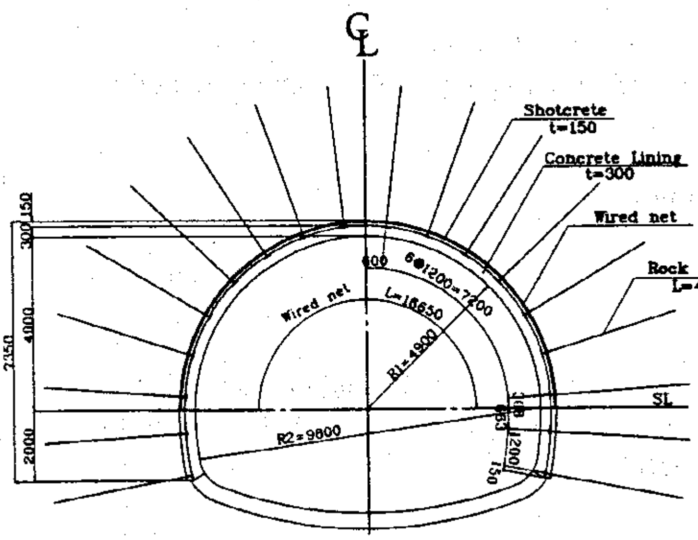
Figure 8.9 Typical Cross Section of C-1 Route Tunnel (Soft Rock)



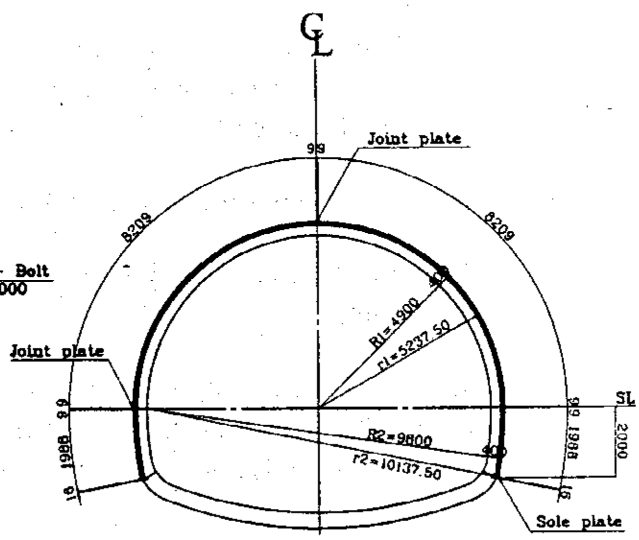
Typical Cross Section of C2 Route Tunnel (Scale; 1:200)

TYPE C (Soft Rock)

Shotcrete & Rock - Bolt



H-Shape-Steel-Support



Tunnel Support (Scale; 1:200)

TYPE C (Soft Rock)

Figure 8.10 Typical Cross Section of C-2 Route Tunnel (Soft Rock)

8.5.5 Ventilation system

The tunnel requires ventilation system to discharge the exhaust from the vehicles and to keep the air quality inside tunnel within allowable limit. In Nepal, the heavy vehicles are not in good condition and produce relatively large amounts of exhaust gas. Ventilation is usually not required in short tunnel. A natural wind is developed by the difference in pressure between the two portals and also due to the traffic movement. Ordinarily tunnel which have a length longer than 500 m – 1000 m, requires ventilation system according to Japanese Standard. Mechanical ventilation system is required when the combination of the length of tunnel (L) and traffic volume (N) exceeds the limit as calculated by the following formula;

$L \times N > 600$ for two-way traffic operation
$L \times N > 2000$ for one-way traffic operation

Where, L is the length of tunnel in km and N is the hourly traffic volume (veh/h).

In this Study, two tunnel alternatives, of which length are 500 m and 2000 m respectively, are studied. The short tunnel will not need any mechanical ventilation system, whereas the long tunnel option will be designed with some ventilation system. As a rough estimate, seven jet fans of 1000 mm diameter should be enough for long tunnel option, when the traffic has reached traffic capacity.

8.5.6 Lighting system

When the vehicle travels from outside brighter place to the inside dark section of tunnel, the pupil of the driver's eye needs adjustment time for this sudden change in brightness. The portals of tunnel design with the adaptation lighting to make the change in brightness gradual. Required length of this adoption zone depends on the design speed. After the adaptation zone, the basic lighting with minimum brightness for visibility is applied.

8.5.7 Emergency and other incidental facilities

Proper emergency facilities corresponding alternative lengths of tunnel are proposed to be applied.

In some tunnel, lining surface is designed to improve visibility and to provide better delineation. However, this system is not proposed in this Study in consideration to high cost and relatively low volume of traffic.