7.4 Population and Employment Distribution Plan

7.4.1 Population

For existing urban areas, future population density by Traffic Zone is assumed considering the population density in 1990 and the recent trend. The average population density will be 93.5 persons/ha. and 2,361 thousand persons will live there in future.

Then, based on the location plan of new residential areas in the land use plan, 639 thousand persons are distributed to each Traffic Zone.

In Table 7.4.1, the assumed population density of East Guatemala for the existing urban area is very high, reflecting the fact that the population density of Traffic Zone 33 in Zona 18 is as high as 224.5 persons/ha. in 1990. On the contrary, the reason why the population densities of Villa Nueva, Petapa, and Sta. Catarina Pinula are comparatively low is because they all, each include a future rural area.

Comparing the future population distribution with the present one, Central Guatemala's share will drop from 46% in 1990 to 31% in 2010, although experiencing an increase of 106 thousand in absolute terms.

As for the zonal distribution of the increased population during the 20-year period of 1990-2010, Central Guatemala and Sta. Catarina Pinula will gain around 10% respectively, and the other zone groups about 20% respectively. In the new residential area, Villa Nueva will register a remarkable increase.

Table 7.4.1 Planned Population and Average Population Density

Zone Group	Existing urban area		New residential area		Planned Population Total
	Population (1,000 persons)	Population Density (persons /ha.)	Population (1,000 persons)	Population Density (persons /ha.)	(1,000 persons)
Central Guatemala	873	116.9	63	150.0	936
East Guatemala	324.5	128.7	120	120.0	444.5
Mixco	512	112.8	79	92.9	591
Villa Nueva	355	76.7	184.5	94.5	539.5
Petapa	208	60.5	100	100.0	308
Sta. Catarina Pinula	88.5	33.3	92.5	80.4	181
Total	2,361	93.5	639	100.2	3,000

Note: Zone grouping is the same as Table 7.2.2

Table 7.4.2 Change in Population Distribution, 1990-2010

Zone Group	1990	2010	Increase (1990-2010)	
			Total	Of which in new residential area
Population (Unit: 1,000 persons)				
Central Guatemala	830	936	106	63
East Guatemala	225	444.5	219.5	120
Mixco	364.5	591	226.5	79
Villa Nueva	273.5	539.5	266	184.5
Petapa	55	308	253	100
Sta.C.Pinula	52	181	129	92.5
Total	1,800	3,000	1,200	639
Percentage (Unit: %)				
Central Guatemala	46.1	31.2	8.8	9.8
East Guatemala	12.5	14.8	18.3	18.8
Mixco	20.2	19.7	18.9	12.4
Villa Nueva	15.2	18.0	22.2	28.9
Petapa	3.1	10.3	21.1	15.6
Sta.C.Pinula	2.9	6.0	10.7	14.5
Total	100.0	100.0	100.0	100.0

Note: Zone grouping is the same as Table 7.2.2

7.4.2 Employment

The number of employed persons in the primary sector is small and its future value is not used for the traffic demand projection. Therefore, no special planning considerations are taken for its distribution and future zonal values are obtained by applying the decrease rate of the whole Study Area to the existing zonal employment.

The following three types of location can be recognized for the secondary and tertiary sector activities:

Type a): Location on the planned development sites
Type b): Location in pursuit of benefits of agglomeration
Type c): Location for meeting demand created by the population increase

Type a) will be the location of the planned industrial estates and planned commercial/institutional cores accepting the induction policy and incentives of the developer.

Type b) will make much of business linkages and locate inside or near the existing industrial zone or the established commercial district. In the secondary sector, for example, medium-and small-scale companies associated with or serving as subcontractors for bigger manufacturers tend toward such behavior, while, in the tertiary sector, no much central management functions and business services.

The local consumer market, such as construction field team in the secondary sector and neighborhood commercial services in the tertiary sector, will be located in Type c).

The number of employed persons on the new planned development sites is assumed to be 93,500 for the secondary sector and 156,000 for the tertiary sector, and distributed to every zone based on the land use plan.

Then, subtracting the number of employed persons on the planned development sites from the whole increased number of employment between 1990 and 2010 in the secondary and tertiary sector respectively, one half of the remainder as Type b) is distributed proportionally to the 1990 employment distribution and the other half as Type c) proportionally to the population increase 1990-2010.

Table 7.4.3 Planned Number of Employed Persons by Sector on Work Place Basis

Unit: 1,000 persons

Zone group	Primary	Secondary		Tertiary		Whole sector total
		Total	Of which on new industrial estate	Total	Of which on new commercial /institutional core	
Central Guatemala	2.8	139.2	-	532.5	16	674.5
East Guatemala	1.7	34.9	16.7	74.5	28	111.1
Mixco	0.1	30.7	6.7	93.5	24	124.3
Villa Nueva	3.4	58.6	33.4	94	32	156
Petapa	0.9	29.9	20	51.3	20	82.1
Sta. Catarina Pinula	1.1	22.7	16.7	53.2	36	77
Total	10	316	93.5	899	156	1,225

Note: Zone grouping is the same as Table 7.2.2

Comparing the future employment distribution with the present one, Central Guatemala's share will drop from 78% in 1990 to 55% in 2010, although increase by 190 thousand in absolute terms.

Nearly one third of the total increased employment during the period of 1990-2010 will be distributed to Central Guatemala, followed by Villa Nueva with nearly 20%. The other zone groups will gain around 12% each. On the new planned development sites, Villa Nueva and Sta. Catarina Pinula will register a remarkable increase.

Table 7.4.4 Change in Employment Distribution, 1990-2010

Zone Group	1990	2010	Increase (1990-2010)	
			Total	Of which on new development site
Employment (Unit : 1,000 persons)				
Central Guatemala	484.6	674.5	189.9	16
East Guatemala	33.1	111.1	78	44.7
Mixco	47.1	124.3	77.2	30.7
Villa Nueva	42.7	156.0	113.3	65.4
Petapa	9.9	82.1	72.2	40
Sta.C.Pinula	7.6	77	69.4	52.7
Total	625	1,225	600	249.5
Percentage (Unit : %)				
Central Guatemala	77.6	55.1	31.6	6.4
East Guatemala	5.3	9.1	13.0	17.9
Mixco	7.5	10.1	12.9	12.3
Villa Nueva	6.8	12.7	18.9	26.2
Petapa	1.6	6.7	12.0	16.1
Sta.C.Pinula	1.2	6.3	11.6	21.1
Total	100.0	100.0	100.0	100.0

Note: Zone grouping is the same as Table 7.2.2

8. FUTURE TRAFFIC DEMAND FORECAST

8.1 Forecast Procedure

8.1.1 Development of Models

The future traffic demand forecast model is developed by analyzing the quantitative relationship, between person trip behavior such as Origin-Destination (hereinafter called "OD") table, and the regional (zonal) socioeconomic activities, which should be expected to remain stable in the future.

The forecast model consists of the following four basic models so that the procedure is called the four step methods.

a) Trip generation and attraction model
b) Trip distribution model
c) Modal split model
d) Traffic assignment model

A flow chart in Figure 8.1.1 shows the development process and the models.

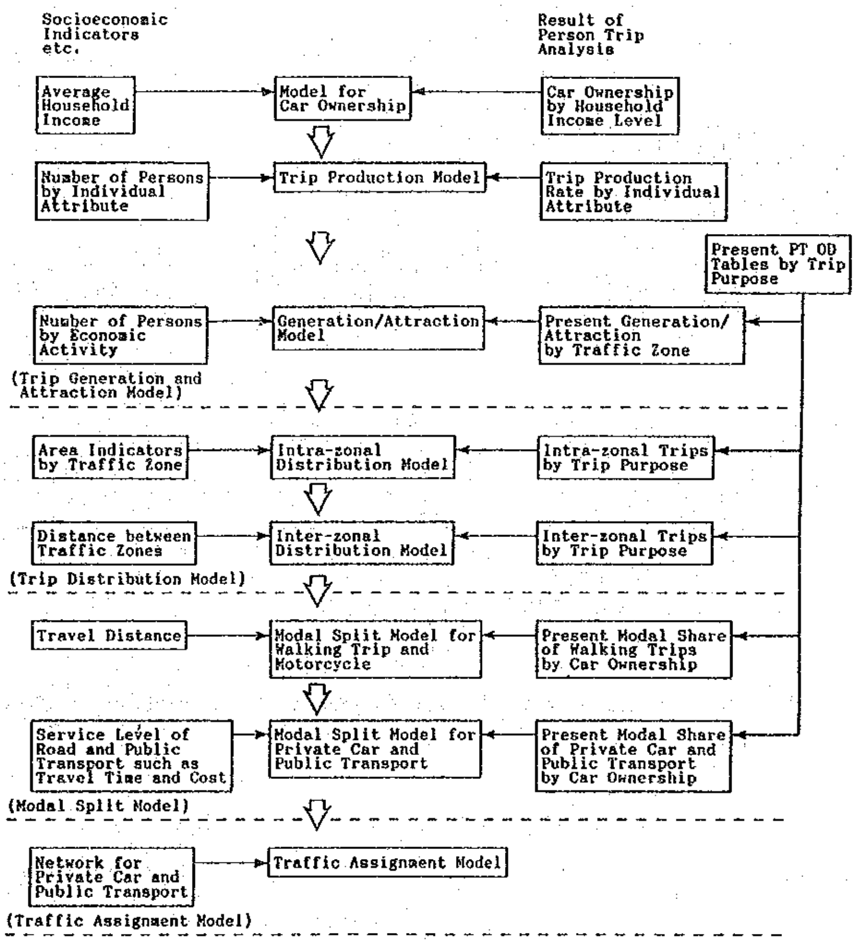


Figure 8.1.1 Model Development Process

The person trip survey conducted in the first stage of the Study focused on person trip behavior of residents in the study area only. Therefore, trips traveled by residents outside the study area are forecast based on the simple growth rate method.

8.1.2 Traffic Demand Forecast Procedure

Future demand can be estimated by inputting data one by one according to the steps exhibited in the following figure.

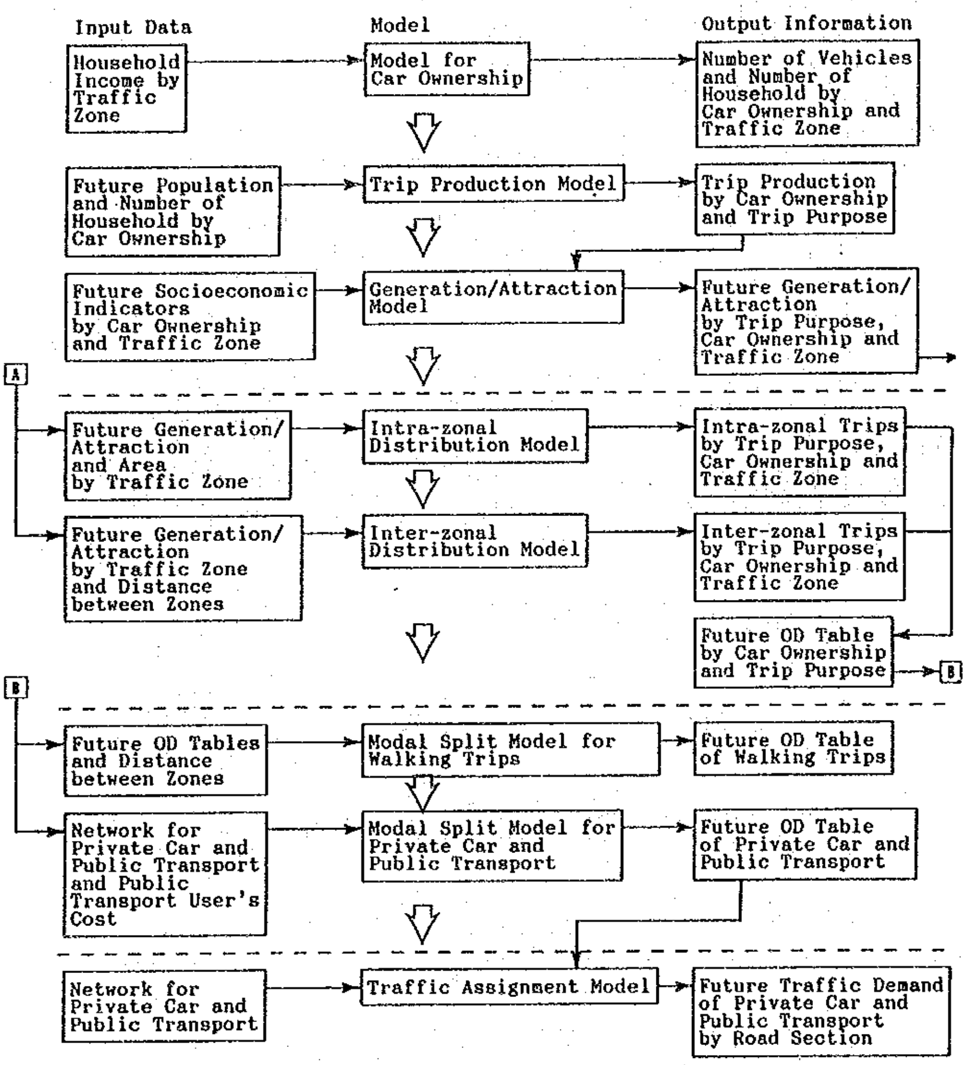


Figure 8.1.2 Traffic Demand Forecast Procedure

8.2 Total Number of Trips

8.2.1 Models

The total number of trips produced in the whole Study area (trip production) is forecast at first. Using this total number as the control total, the generation and attraction of person trips mentioned in the later section, are then forecast for each zone. The total number of person trips, however, should be calculated according to car ownership. Therefore, the following model for car ownership is required.

(1) Model for Car Ownership

By analyzing the relationship between the share of car ownership and the average household income level, the following models were obtained.

$$Sk = a \times HI^2 + b \times HI + c$$

where, Sk: Share of household by car ownership
HI: Average household income (Q1,000)
a,b,c: Parameters

Table 8.2.1 Model for Car Ownership

Car Ownership	Parameters			Correlation Coefficient
	a	b	c	
Non-car own	0.01506	-0.22957	0.91043	0.98
1 veh. own	-0.01020	0.11342	0.13396	0.85
2 veh. own	-0.00590	0.10109	-0.03759	0.98
3 veh. own	0.00105	0.01507	-0.06797	0.99

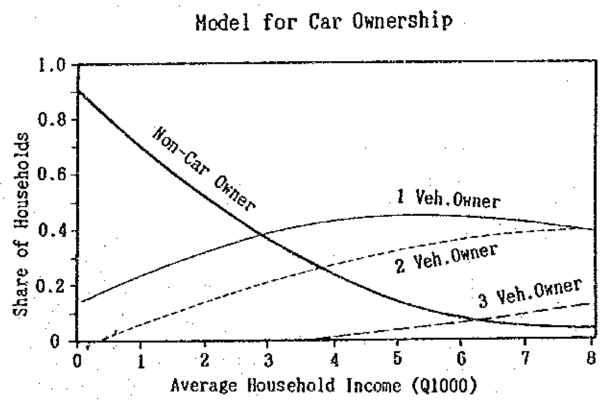


Figure 8.2.1 Model for Car Ownership

(2) Trip Production Model

The number of trip production is estimated by using the production rate method.

Consideration of various individual attributes such as age, occupation and car ownership, car ownership was adopted as an individual attribute to be used for the estimation of future production.

Table 8.2.2 Trip Production Rate

Trip Purpose	Trip Production Rate	
	Car Owner	Non-car Owner
to work	0.627	0.431
to school	0.364	0.298
shopping	0.112	0.092
business	0.154	0.059
others	0.184	0.130
to home	1.262	0.942
total	2.703	1.952

8.2.2 Total Number of Trips

(1) Car Ownership in 2010

The figures estimated concerning to car ownership are described in Table 8.2.3.

In the year 2010, the ratio of car owning household increases to 46.6%, while the number of household increases to 625,000. Besides, the number of vehicles can be estimated to be 2.6 times of the present figure. Therefore, the traffic congestion must worsen.

Table 8.2.3 Comparison of Car Ownership

Car Ownership	1990		2010	
	Number of Households	Number of Vehicles	Number of Households	Number of Vehicles
Non-car owner	248,594	-	340,026	-
1 veh. owner	84,139	84,139	210,485	210,500
2 veh. owner	21,984	43,968	62,375	124,800
3 veh. and over	4,900	16,590	12,114	41,000
Total	359,617	144,697	625,000	376,300

(2) Trip Production in 2010

Table 8.2.4 shows the result of the calculation for the trip production in 2010 by car ownership.

The number of persons who belong to car owning households, estimated by using the model mentioned above, is 1,219,567 in 2010. On the other hand, the number of non-car owning persons is 1,444,433.

The trip production traveled by car owners can be calculated as 3,296,500 (53.9%) person trips in 2010, and that of non-car owner is 2,819,600. The total of both trips is 6,116,100 that is 1.8 times of present number of person trips.

Table 8.2.4 Trip Production in 2010

Trip Purpose	Production Rate		Trip Production in 2010		
	Car Owner	Non-car Owner	Car Owner	Non-car Owner	Total
to work	0.627	0.431	764,700	622,600	1,387,300
to school	0.364	0.298	443,900	430,400	874,300
shopping	0.112	0.092	136,600	132,900	269,500
business	0.154	0.059	187,800	85,200	273,000
others	0.184	0.130	224,400	187,800	412,200
to home	1.262	0.942	1,539,100	1,360,700	2,899,800
Total	2.703	1.952	3,296,500	2,819,600	6,116,100
Population Estimated to be over 4 years old in 2010			1,219,567	1,444,433	2,664,000

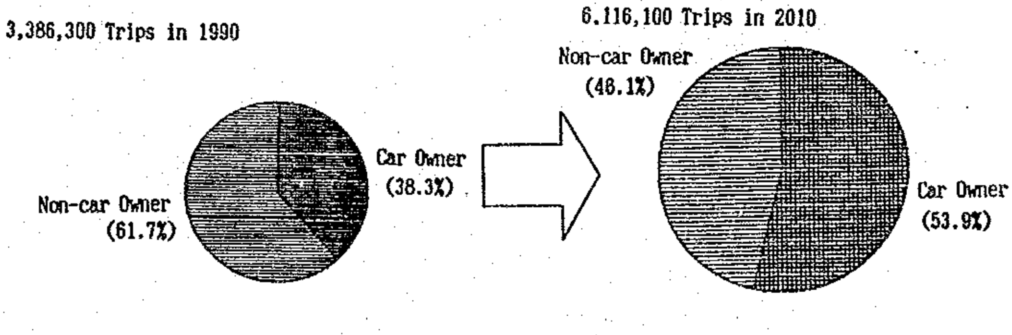


Figure 8.2.2 Comparison of Person Trips by car Ownership

8.3 Trip Generation and Attraction

8.3.1 Trip Generation and Attraction Model

The number of trips in terms of generation and attraction by traffic zone is calculated by car ownership and trip purpose. The following formula was employed based on the idea that socioeconomic characteristics by zone can describe the number of person trips that generate from or attract to certain zone.

$$G_i = K_i + a_i X_1 + b_i X_2 + c_i X_3 + \cdots$$
$$A_j = K_j + a_j X_1 + b_j X_2 + c_j X_3 + \cdots$$

Where, G_i: Trip generation in zone i
A_j: Trip attraction in zone j
X_n: Socioeconomic indices by zone
K_i, a_i, b_i, c_i: Parameters of Generation Model
K_j, a_j, b_j, c_j: Parameters of Attraction Model

Explanatory variables and parameters were calculated as shown in Table 8.3.1.

Table 8.3.1 Generation and Attraction Model

Trip Purpose	Formula	Correlation Coefficient
(Car Owner)		
to work	Gi = 1.702 x W2c + 1.214 x W3c + 3289.8 x D + 389.1	0.96
	Aj = 0.693 x E2 + 0.593 x E3 - 1452.9	0.95
to school	Gi = 1.082 x Sc + 447.3	0.96
	Aj = 0.486 x Ss + 5975.4 x D - 590.8	0.92
shopping	Gi = 0.059 x Pc + 0.031 x Et + 109.5	0.85
	Aj = 0.106 x Et - 217.0	0.89
business	Gi = 0.267 x Nc + 0.052 x Et + 1715.6 x D + 2.0	0.88
	Aj = 0.113 x E2 + 0.143 x E3 - 215.5	0.95
others	Gi = 0.386 x Wtc + 2004.1 x D + 75.6	0.91
	Aj = 0.171 x Et + 2319.7 x D - 364.3	0.92
to home	Gi = 1.544 x E2 + 0.941 x E3 + 0.243 x Ss - 3099.1	0.95
	Aj = 0.424 x Pc + 1.738 x Wtc + 443.85	0.97
(Non-car Owner)		
to work	Gi = -0.289 x Pn + 1.779 x Wtn + 389.5	0.94
	Aj = 0.886 x Et - 1705.9	0.98
to school	Gi = 0.909 x Sn + 702.7	0.97
	Aj = 0.815 x Ss - 726.9	0.99
shopping	Gi = 0.067 x Pn + 2128.8 x D + 403.6	0.90
	Aj = 0.225 x E3 + 3189.1 x D - 157.9	0.92
business	Gi = 0.026 x Pn + 0.051 x Et + 48.3	0.88
	Aj = 0.124 x Wt - 297.4	0.95
others	Gi = -0.094 x Pn + 0.445 x Wtn + 3081.4 x D + 632.2	0.90
	Aj = -0.224 x E2 + 0.432 x E3 - 502.8	0.96
to home	Gi = 1.382 x Et + 0.842 x Ss - 4096.4	0.98
	Aj = -0.465 x Pn + 2.569 x Wtn + 1.120 x Sn + 1448.6	0.97

Where, Pc,Pn : Number of persons by car ownership
W2c,W2n: Number of secondary industrial workers by car ownership
W3c,W3n: Number of tertiary industrial workers by car ownership
Wtc,Wtn: Total number of workers by car ownership
E2 : Number of secondary industrial employee by place of work
E3 : Number of tertiary industrial employee by place of work
Et : Total number of employee by place of work
Sc,Sn : Number of students and pupils by car ownership
Ss : Total number of students and pupils by place of school
D : Dummy variable (which is 1 or 0)

8.3.2 Trip Generation and Attraction in 2010

Figure 8.3.1 illustrates the growth of person trip generation and attraction between 1990 and 2010 by postal zone, and Table 8.3.2 shows the trip generation and attraction by postal zone and municipality in the study area.

As can be seen in the illustration, the large volume of person trips is generated in the central district in he Municipality of Guatemala, especially in zone 1. Increase of generation in suburban areas such as Mixco, Villa Nueva and zone 18, is obviously great.

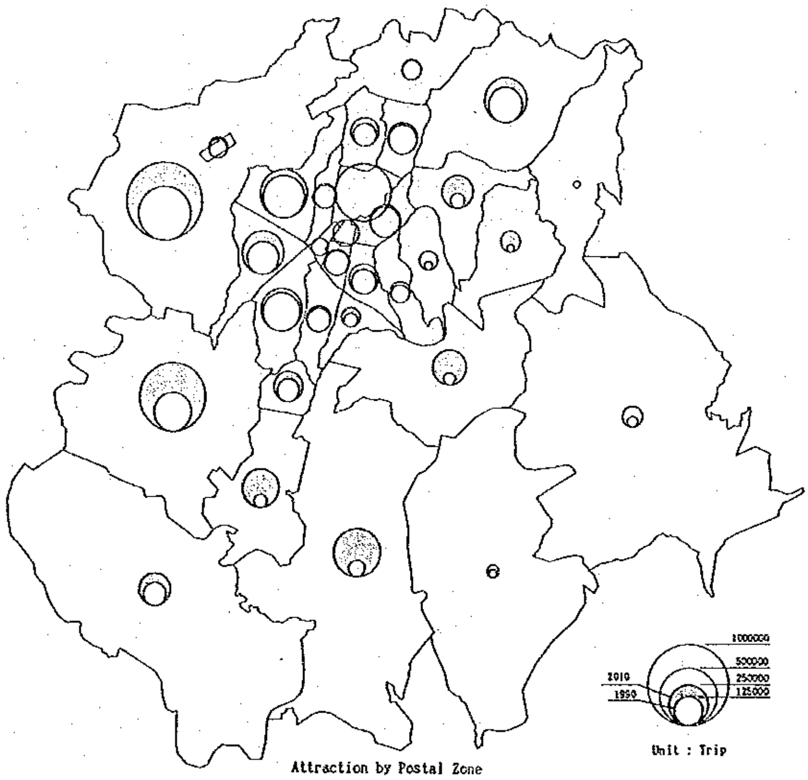


Figure 8.3.1 Growth of Generation by Postal Zone

Table 8.3.2 Comparison of Generation and Attraction by Postal Zone and Municipality

Zona/ Municipality	Generation+Attraction by Trip Purpose														Growth Rate
	1990							2010							
	to work	to school	shopping	business	others	to home	Total	to work	to school	shopping	business	others	to home	Total	(2020/1990)
1	237,653	119,972	54,051	53,481	97,228	473,689	1,036,074	241,310	91,897	53,578	63,641	102,012	472,815	1,025,253	0.99
2	33,147	26,566	6,333	6,069	10,095	71,782	153,992	55,955	41,673	9,339	11,070	19,032	120,054	257,123	1.67
3	38,327	16,044	7,576	8,661	12,240	76,834	159,682	44,200	18,623	9,046	8,747	15,225	90,725	186,566	1.17
4	62,256	4,762	20,468	13,295	11,379	95,175	207,335	68,275	3,581	19,681	16,817	12,296	111,776	232,426	1.12
5	51,835	36,916	15,546	9,419	29,186	133,676	276,578	62,048	39,701	18,079	11,376	37,380	156,579	325,163	1.18
6	54,507	30,017	13,366	10,174	22,291	121,121	251,476	65,087	33,193	14,172	13,865	29,734	143,457	299,518	1.19
7	112,121	87,545	21,744	19,517	41,945	263,934	546,806	157,051	97,128	29,009	31,808	64,472	343,974	723,442	1.32
8	22,953	8,920	3,602	6,393	6,697	40,764	89,329	23,329	6,895	3,937	8,036	7,638	43,176	93,011	1.04
9	65,798	8,990	6,957	13,052	10,333	77,538	182,668	76,246	6,024	9,061	16,579	12,852	99,911	220,673	1.21
10	51,175	19,013	6,416	11,678	12,674	82,700	183,656	76,688	19,555	10,964	22,706	25,503	133,330	288,846	1.57
11	74,760	38,495	14,772	16,956	25,905	146,980	317,868	132,531	72,644	24,418	30,095	47,686	260,149	567,523	1.79
12	87,774	101,899	7,730	12,597	14,763	211,602	436,365	120,286	112,740	11,713	23,183	31,053	266,657	565,632	1.30
13	47,340	16,748	4,722	9,961	10,082	78,507	167,360	56,864	19,339	6,394	13,192	13,073	99,029	207,891	1.24
14	13,599	6,357	2,140	2,754	4,265	25,964	65,079	30,306	12,646	3,804	5,176	9,153	57,522	118,609	2.15
15	23,455	13,541	4,147	3,755	5,659	46,487	97,044	33,064	19,881	6,285	5,693	8,821	67,183	140,907	1.45
16	1,972	7,144	432	535	933	10,215	21,231	10,409	32,712	3,081	3,742	7,012	41,110	98,046	4.62
17	14,909	9,010	1,970	1,879	5,733	32,249	65,750	69,036	45,359	8,849	10,574	34,409	151,170	319,396	4.86
18	65,640	77,803	16,536	9,139	22,700	179,819	371,636	125,983	110,751	26,264	24,266	49,934	294,421	631,619	1.70
19	17,817	14,077	6,867	5,914	8,421	48,632	101,728	24,208	10,204	9,964	11,039	12,603	63,062	131,080	1.29
22	36,504	26,622	3,925	1,890	7,860	75,278	152,079	66,788	48,790	7,137	5,343	16,728	149,436	294,222	1.93
24	2,865	2,419	2,123	518	1,036	8,181	17,142	20,816	37,720	11,047	6,167	5,429	27,341	108,320	6.32
25	2,148	1,389	1,352	669	549	5,863	11,970	2,282	1,774	1,746	840	899	6,929	14,470	1.21
Mixco	198,398	144,365	29,356	18,865	45,483	428,074	862,541	420,544	303,486	54,453	49,637	112,725	862,011	1,802,856	2.09
Villa Nueva	89,969	87,957	22,548	14,795	14,105	227,787	457,161	333,550	225,731	69,693	51,332	58,916	602,900	1,342,122	2.94
Petapa	11,680	7,753	4,353	192	1,422	24,655	50,055	100,253	70,632	28,353	11,931	16,825	247,891	475,935	9.51
Amatitlan	34,482	22,376	8,938	7,302	8,889	76,173	158,160	74,889	38,629	16,713	22,109	19,573	180,350	352,263	2.23
Villa Canales	15,622	14,414	5,720	2,361	3,136	40,391	81,644	177,781	83,134	44,495	31,048	16,541	371,194	724,193	8.87
Sta.C.Pinula	9,346	8,942	1,641	1,249	1,480	22,492	45,150	43,865	108,297	10,002	12,659	10,294	185,349	370,466	8.21
San Jose Pinula	4,760	6,429	2,721	925	2,526	16,525	33,906	27,720	10,136	9,107	8,078	13,635	71,933	140,609	4.15
Fraijanes	2,655	2,510	304	717	3,068	9,371	18,625	3,866	10,282	1,174	10,655	2,958	15,219	44,154	2.37
Chinautla	24,836	15,513	5,012	3,662	7,415	54,875	111,113	29,787	15,582	6,691	4,767	9,845	62,607	129,479	1.17
Total	1,510,323	986,508	303,368	266,373	449,498	3,205,133	6,721,203	2,775,019	1,748,719	538,229	546,221	824,255	5,799,470	12,231,913	1.82

8.4 Trip Distribution

8.4.1 Trip Distribution Model

The model for distribution of OD trips is itself divided into two models: an Intra-zonal distribution model and Inter-zonal distribution model. The former model calculates the number of trips that are traveled within a zone, and the latter model calculates the number of person trips between zones.

(1) Intra-zonal Distribution Model

The following equation was used as the Intra-zonal trip model by purpose.

$$T_{ii} = K \times (G_i^{a}) \times (A_i^{b}) \times (R_i^{c})$$

Where, T_{ii}: Intra-zonal trips in zone i
G_i : Trip generation in zone i
A_i : Trip attraction in zone i
R_i : Area of zone i (ha)
K,a,b,c: Parameters

Table 8.4.1 Intra-zonal Distribution Model

Trip Purpose	Parameters a	b	c	K	Correlation Coefficient
(Car Owner)					
to work	0.6633	0.5267	0.4488	1.090E-3	0.85
to school	0.8248	0.3673	0.6622	6.969E-4	0.91
shopping	0.4274	0.4885	0.2794	9.599E-2	0.80
business	0.4145	0.5447	0.4487	1.333E-2	0.82
others	0.7078	0.3931	0.4263	5.893E-3	0.82
to home	0.3049	0.8199	0.4306	3.373E-3	0.94
(Non-car Owner)					
to work	0.6267	0.2857	0.3838	2.738E-2	0.86
to school	0.9511	0.2474	0.3756	6.486E-3	0.95
shopping	0.4597	0.5589	0.3410	3.187E-2	0.86
business	0.3737	0.5105	0.3592	4.930E-2	0.83
others	0.5140	0.5657	0.4761	5.190E-3	0.89
to home	0.2745	0.8456	0.3376	3.374E-3	0.97

(2) Inter-zonal Distribution Model

The voorhees type gravity model shown in the following formula was adopted as the model to calculate inter-zonal trip distribution.

$$T_{ij} = G_i \times \frac{A_j \times D_{ij}^{a}}{A_j \times D_{ij}^{a}}$$

Where, T_{ij}: Trip distribution between i and j zone
G_i : Trip generation from i zone
A_j : Trip attraction to j zone
D_{ij}: Distance between i and j zone
a: Parameter

The parameter is 1.62 calculated by multiple regression analysis of present data.

8.4.2 Distribution of Trips by Purpose in 2010

(1) Outline of OD Flow

Figure 8.4.1 exhibits a principal person trip flow between integrated traffic zones.

The number of person trips between Central Guatemala and Mixco is the largest, and that between East Guatemala and central Guatemala is next. The person trip flow from Sta. C. Pinula is not so large. Therefore, it can be pointed out that there are four major trip axes of transit relating different parts of the Study Area.

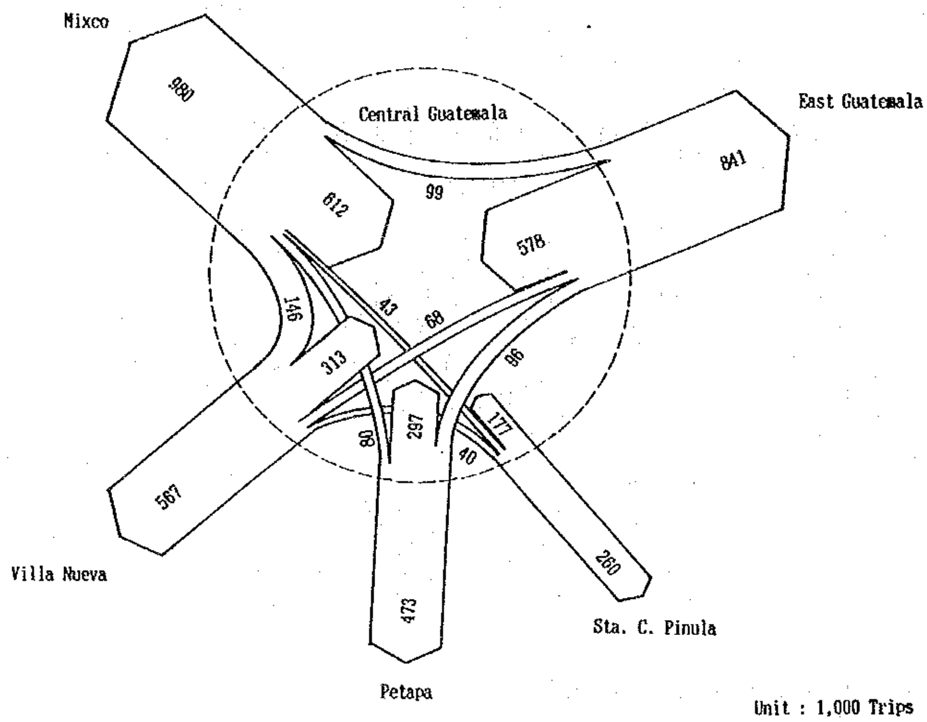


Figure 8.4.1 Principal Person Trip Flow

(2) Distribution of Trips by Purpose

Figure 8.4.2 and 8.4.5 display the desire line of person trips which were estimated by the distribution model by trip purpose.

The following findings can be obtained from these figures.

("to work" purpose)

Many workers concentrate in the central area of Guatemala City coming from suburban areas such as Mixco and zone 18. However, the relation between Mixco and Villa Nueva, which are supposed to be large city cores outside Guatemala City, becomes stronger.

("to school" purpose)

There are two major centers of person trip attraction in the figure. One is zone 1 and the other is zone 12 where the national university is located.

("to home" purpose)

"To home" purpose trips also have the tendency mentioned above. Compared with the present tendency, the number of trips between adjacent zones becomes larger outside of Guatemala City.

(other purposes)

The center of other purposes' attraction is still zone 1. The attraction area spreads to east side of Guatemala City along the arterial road such as zone 7, zone 11 and zone 12, as well.

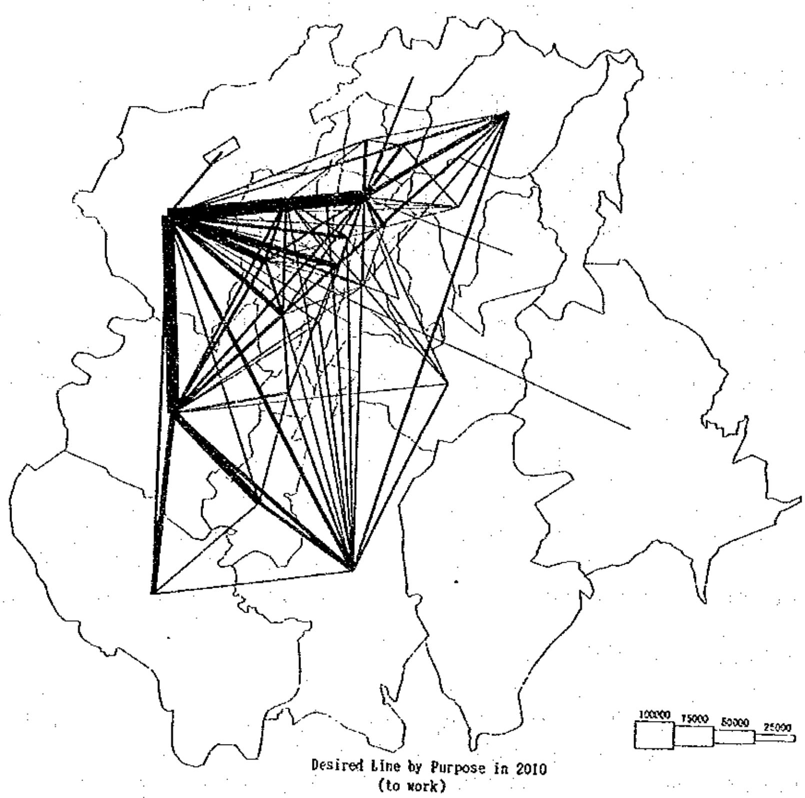


Figure 8.4.2 Desire Line of "to work" Trip in 2010

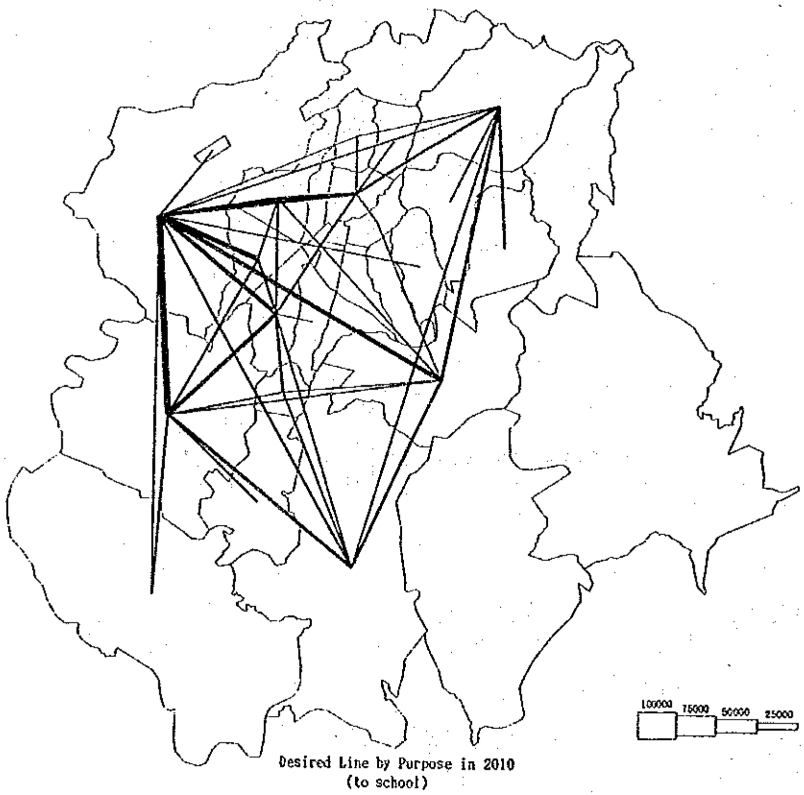


Figure 8.4.3 Desire Line of "to school" Trip in 2010

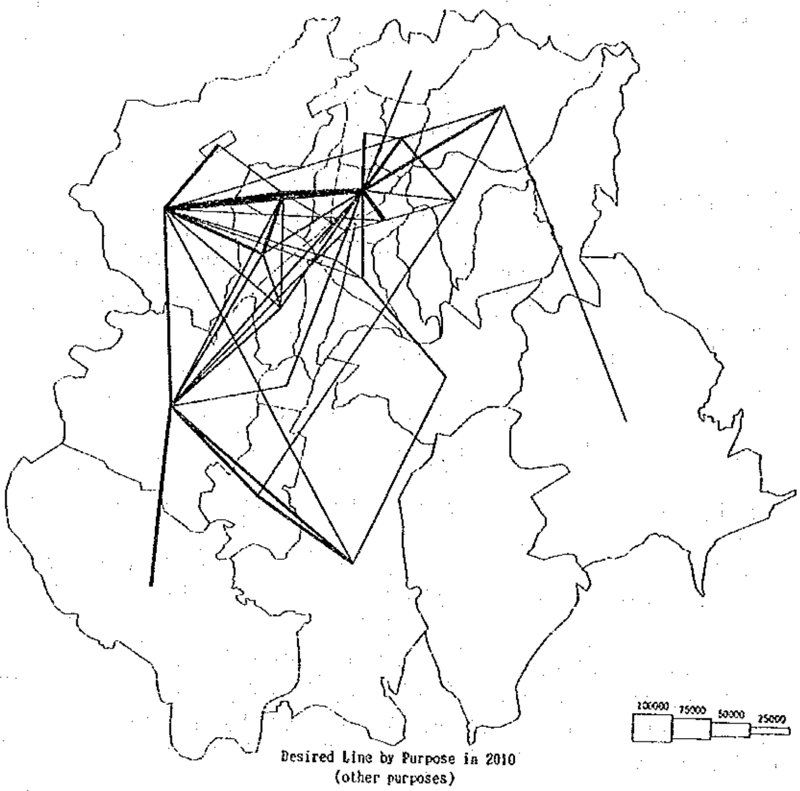


Figure 8.4.4 Desire Line of Other Purposes' Trip in 2010

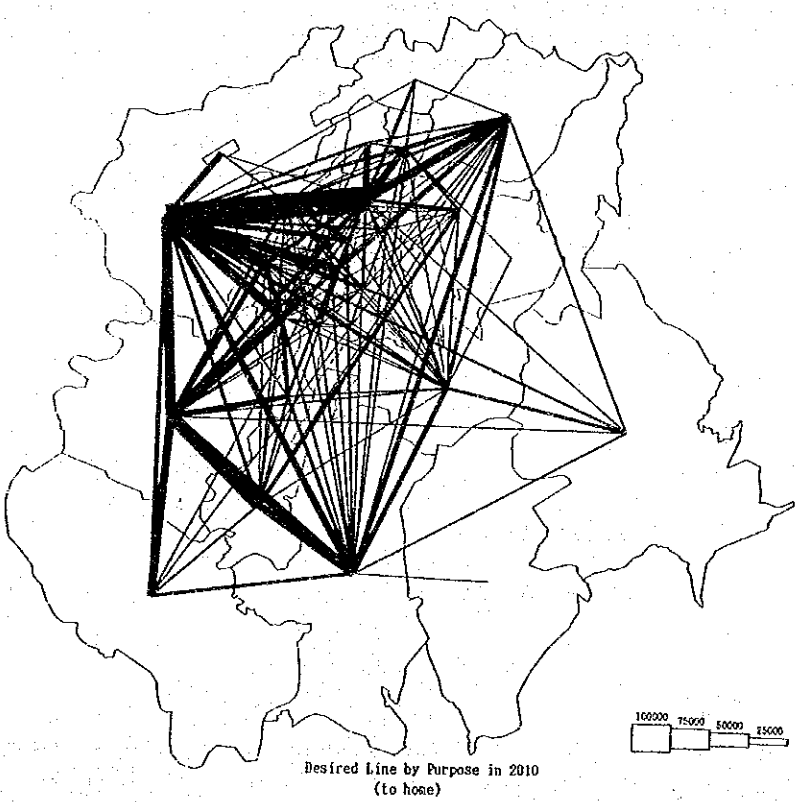


Figure 8.4.5 Desire Line of "to home" Trip in 2010

8.5 Modal Split

8.5.1 Modal Split Models

(1) Basic Consideration

1) Type of Model

Methods of forecasting the modal split can be roughly divided into the following two types.

- Trip end model

  Modal shares are determined before the estimation of trip distribution in this model.

- Trip interchange model

  Modal shares are determined after the estimation of trip distribution in this model.

The trip interchange model is employed in this study so that strategy of planning such as improvement of public transportation system and upgrading and construction of arterial roads, could be reflected to the demand of each mode.

2) Modes to be Chosen

In the person trip survey conducted in the first stage of the Study, nine modes were employed. In this section, however, the modes are simplified to three modes as follows.

Person Trip Survey	Modal Split Model
a. Walking	a. Walking and motorcycle
b. Motorcycle	
c. Passenger car	b. Private car
d. Pick-up	
e. Small truck	
f. Large truck	
g. Taxi	
h. Others	
i. Small microbus	c. Public transport
j. Microbus	
k. Bus	
(railway)	

Figure 8.5.1 Reference of Modes

3) Modal Choice Structure

A modal split model can be generally distinguished as a binary method and a share method. The former method separates each two mode step by step, and the later one simultaneously shares plural modes.

A binary choice method was applied and the assumed binary choice structure is shown in Figure 8.5.2.

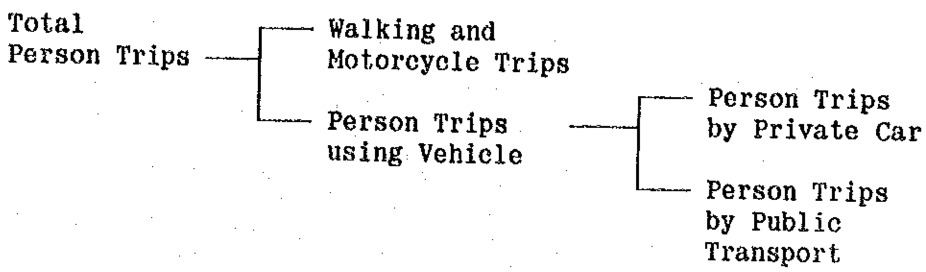


Figure 8.5.2 Binary Choice Structure

Therefore, the following two modal split models are required.

a) Model for walking trips
Modal shares are determined before the estimation of trip distribution in this model.

b) Model for private car and public transport
Modal shares are determined after the estimation of trip distribution in this model.

(2) Modal Split Models

1) Modal Split Model for Walking Trips

The present modal share of walking trips (including motorcycle trips) is shown by travel distance and car ownership in Figure 8.5.3. According to the figure, the share of walking trips by car owners is lower than that of non-car owners. Besides, the longest distance is approximately 8km. Therefore, the modal split model for walking trips is developed by using the travel distance as an explanatory factor in each car owner and non-car owner.

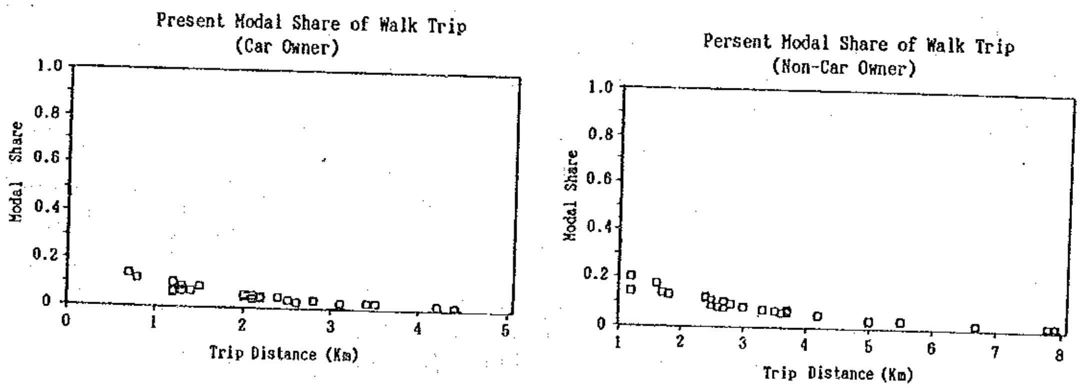


Figure 8.5.3 Present Modal Share of Walking Trips

The following equation which has sufficient correlation coefficient, was employed after examination of several formulas. This formula will be applied to origin and destination pair up to an 8km distance.

$$P^{W}_{ij} = \frac{1.0}{1.0 + EXP(\ a \times D_{ij} + b\ )}$$

Where, P^{W}_{ij}: Modal share of walking trips between i and j zone

D_{ij} : Distance between i and j zone (km)

a: Parameters (See the following number)

Table 8.5.1 Modal Split Model for Walking Trips

Model	Parameters		Correlation Coefficient
	a	b	
Car Owner	0.57708	1.57737	0.921
Non-car Owner	0.49559	0.97955	0.897

The modal split curve is displayed in Figure 8.5.4.

After the OD table of walking trips is separated from the OD table which is estimated by the distribution model, the rest of OD is the OD table of the person trips using vehicles. This person trip OD table using vehicles will be divided into OD tables of trips by private car, and by public transport, by using the modal split model which is discussed in the following section.

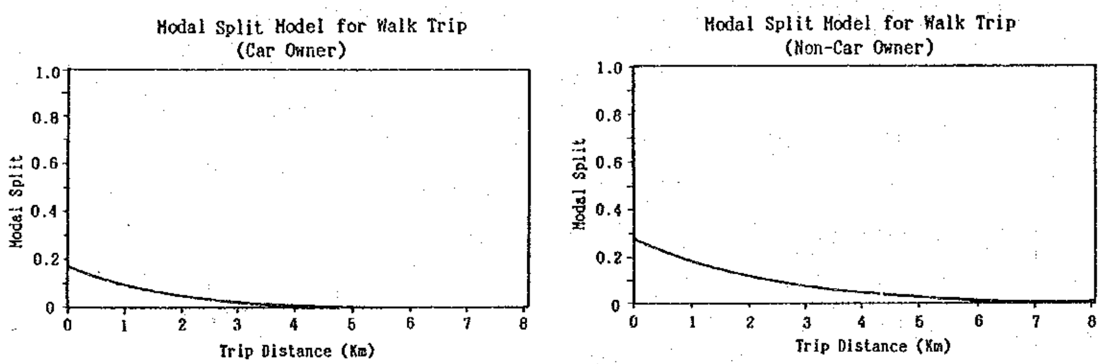


Figure 8.5.4 Modal Split Curve for Walking Trips

2) Modal Split Model for Private Car and Public Transport

(a) Assumption

The vehicle trips will be divided into trips by private car and public transportation.

The modal split is developed based on the idea that travelers using vehicles choose a more convenient mode considering the time and cost difference between private car and public transport. Therefore, the above two factors are included in the modal split model and the planning condition will be converted to travel time and travel cost.

When the model is structured according to this idea, the following points are assumed in this study.

- Travel Time and Travel Cost

  It is impossible to obtain the actual travel time and travel cost data by each zone pair. Therefore, travel time and travel cost are calculated by searching the shortest time route on a network modeled reflecting actual and planning conditions.

  This calculation will be done by private car and public transport on each network.

- Modal Split Curve

  The modal split curve separating trips by private car and public transport is assumed to be logit curve. The parameters will be calculated by analyzing the relationship between actual modal share and the travel time and cost difference by each zone pair.

(b) Modal Split Model Description

On the basis of the above assumption, the following formula was obtained.

$$P^{p}_{ij} = \frac{1.0}{1.0 + \mathrm{EXP}(a \times (T^{c}_{ij} - T^{p}_{ij}) + b \times (C^{c}_{ij} - C^{p}_{ij}) + c)}$$

Where, P^{p}_{ij}: Modal share of public transport trips between i and j zone
T^{c}_{ij}: Travel time by private car between i and j zone (hours)
T^{p}_{ij}: Travel time by public transport between i and j zone (hours)
C^{c}_{ij}: Travel cost by private car between i and j zone (Q)
C^{p}_{ij}: Travel cost by public transport between i and j zone (Q)
a,b,c: Parameters (See the following number)

Table 8.5.2 Modal Split Model for Private Car and Public Transport

Model	Parameters a	Parameters b	Parameters c	Correlation Coefficient
Car Owner	-3.74474	-0.15058	0.48514	0.893
Non-car Owner	-2.85496	-0.25026	-2.23008	0.983

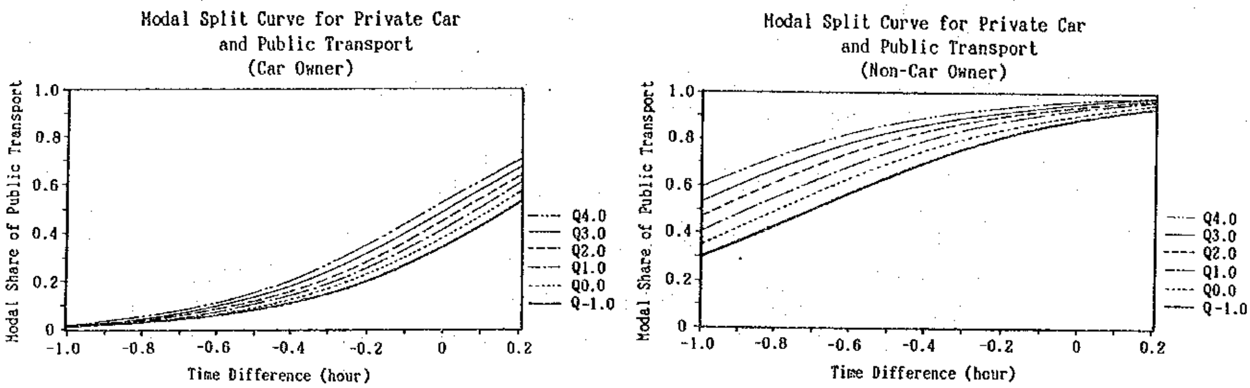


Figure 8.5.5 Modal Split Curve for Private Car and Public Transport

(3) Modal Split in 2010

1) Traffic Analysis of "Do-nothing" Case

A case in which the present road network remains without realization of any new projects in 2010, is traced out in order to be one of the materials when a plan will be formulated. This case is called the "Do-nothing" case.

The future person trip OD table by purpose and car ownership was obtained in the former section. Therefore, based on these OD tables, modal share of person trips and traffic situation in the "Do-nothing" case, are estimated.

The estimation of modal split in case of "Do-nothing" is discussed in this section. Namely, how travelers choose vehicle is estimated if the present transport service remains as it is in 2010. The OD tables using vehicles are obtained in case of "Do-nothing".

2) Modal Split

Table 8.5.3 describes the comparison of modal share between the "Do-nothing" case and the present figure.

In the "Do-nothing" case, the number of private car trips reaches 2 million person trips (42% of the total number of person trips using vehicles). This number amounts to twice the present figure, thus massive congestion will occur if none of the road projects are realized.

Table 8.5.3 Modal Share of "Do-nothing" Case

Year	Public Transport			Private Car		
	Car Owner	Non-car Owner	Total	Car Owner	Non-car Owner	Total
Do Nothing in 2010	883	1,933	2,816 (58.0%)	1,868	172	2,040 (42.0%)
1990	382	1,412	1,794 (64.3%)	798	199	997 (35.7%)

Note: Unit of above number is 1,000 person trips per day
This number does not include intra-zonal trips

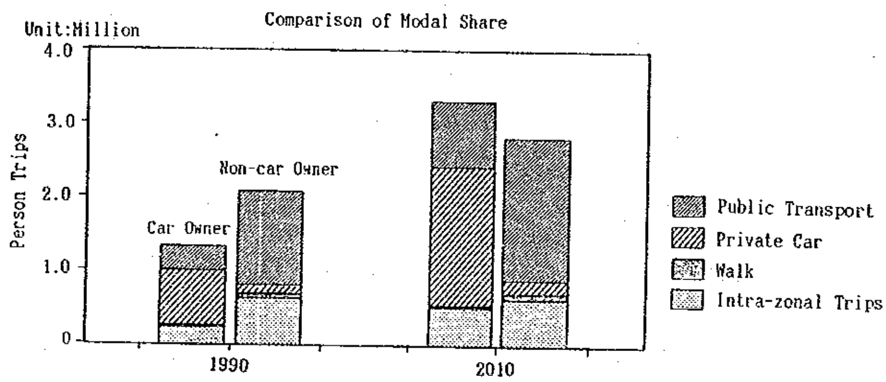


Figure 8.5.6 Comparison of Modal Share

On the other hand, Figure 8.5.7 describes the modal split between private cars and public transport by direction in the same manner as Figure 8.4.1.

The percentage of private cars between Mixco and Central Guatemala, and Villa Nueva and Central Guatemala is almost 50%. Namely, it is supposed that traffic of private cars is congested in both directions. The percentage of private cars between Sta. C. Pinula and Central Guatemala is also high though it's volume is not so high.

On the other hand, in the person trip flow between Central Guatemala and East Guatemala, the percentage of private car is low.

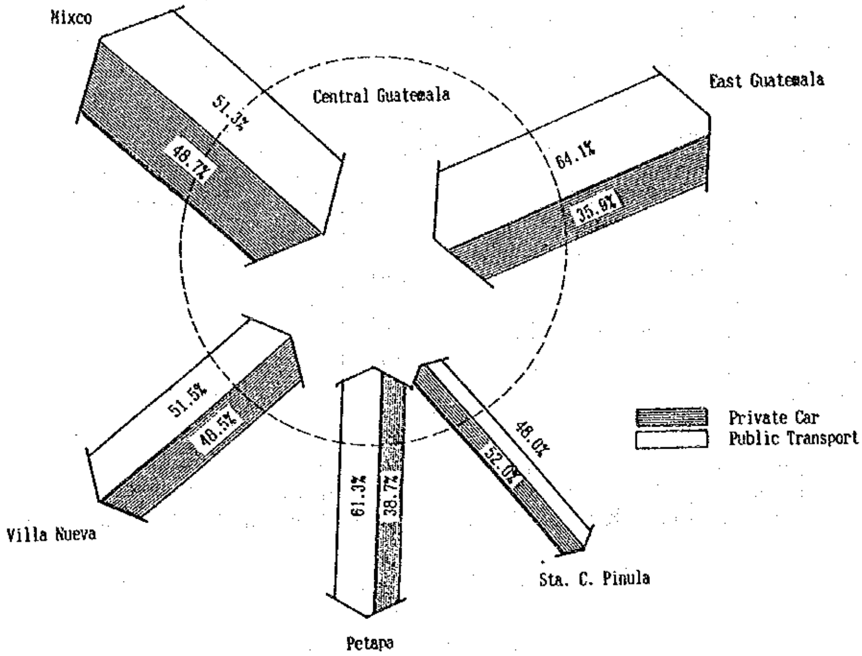


Figure 8.5.7 Modal Share by Direction

8.6 Traffic Assignment

8.6.1 Traffic Assignment Model

(1) Procedure of Traffic Assignment

The traffic assignment simulation is repeatedly executed to assign the divided OD trips on the shortest time route several times. For example, trip volume between i zone to j zone is 1,000 trips, each 200 trip will be assigned by five times, if repeating time is five.

The shortest time route is searched for on the road network from i origin node to all destination nodes. The divided OD trips which generate from i zone, will be assigned on the shortest route previously discovered.

Every time the divided OD trips of all OD pairs are assigned on the shortest route, the travel speed on each road section will be re-calculated by using the QV curve which the road section has.

These steps are repeated a certain number of times which is decided in advance.

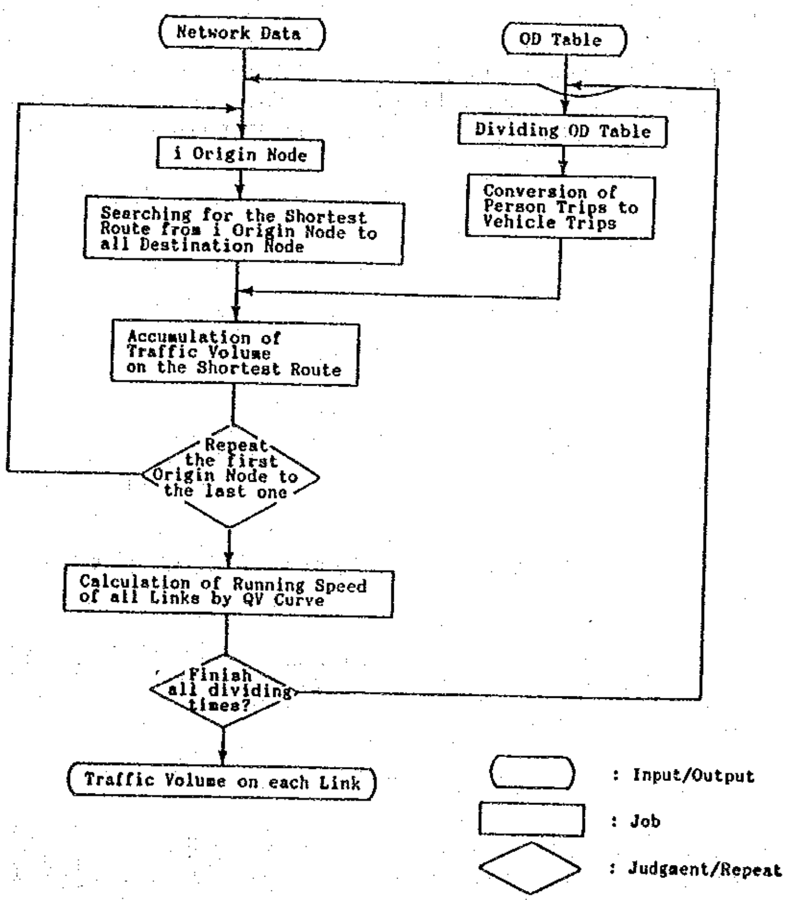


Figure 8.6.1 Traffic Assignment Procedure

(2) Model Components

1) Network Data

Network data is a way to express the linkage of actual or planned roads in a computer and it consists of two components. One is called a "node", the other one called a "link".

A node is a point which symbolizes an intersection, and a link is a road section which is explained by the linkage of two nodes at the both ends. In order to search the shortest route in time by computer, each link should have the following information according to the actual or planned condition.

- Length of road section
- QV condition (relationship between capacity and velocity)
- Direction of traveling (one way or two ways)

Length of each road section was measured on the map of 1/15,000 scale by using a measure tool. Moreover, certain QV curve was set on each link according to actual observation.

2) QV Curve

A QV curve is the equation which indicates the relationship between road capacity and velocity of a vehicle. Namely, it explains the condition that the velocity of a certain road decreases according to the increase of traffic volume as illustrated in Figure 8.6.2.

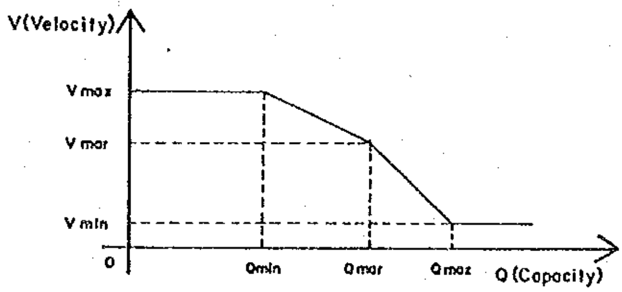


Figure 8.6.2 Basic Idea of QV Curve

Furthermore, based on the methodology in the "Highway Capacity Manual", 84 formulas were set for the car network, and 20 formulas for the bus network.

3) Passenger Car Unit (PCU) Conversion

The element of the OD table calculated by the modal split model is the number of person trips by each zone pair. Therefore, the number of person trips should be converted into the number of vehicle trips, before the traffic assignment simulation is done. This conversion is made based on the average number of passengers per vehicle and the PCU estimated from the size and shape of each mode of transport and the load placed on the road facilities. The conversion coefficient for each mode of transport is shown in Table 8.6.1, and the number of vehicles traveled (TV) for traffic assignment is calculated from the number of trips (T) by the following equation:

$$TV^{k}_{ij} = \frac{Tk_{ij}}{AOR^{k} \times PCU^{k}}$$

where, TV^{k}_{ij}: Traffic volume of k mode between i and j zone

T^{k}_{ij} : Person trips of k mode between i and j zone

AOR^{k}: Average occupancy ratio of k mode

PCU^{k}: Passenger car unit of k mode

Table 8.6.1 Passenger Car Unit Conversion (PCU)

Transport Mode	Average Occupancy Ratio	PCU
Private Car	1.6	1.0
Public Transport	20.0	2.0

8.6.2 Traffic Volume Assigned

(1) Assignment on Spider Network

A spider network is an imaginary linkage in which adjacent traffic zones are connected by a straight line. Traffic assignment on a spider network is made in order to find out importance of the connection between traffic zones.

The result of the traffic assignment in the "Do-nothing" case OD table which was obtained in the former section, is displayed in Figure 8.6.3. This assignment was not made by traffic zones (67 zones) but by integrated zones. In the Figure, a black belt indicates the person trip flow using private cars and a white belt indicates the flow using public transport.

The main flow of person trips using private cars can be seen on the following belts:

- from Mixco to zone 1
- from Petapa to zone 1
- from Villa Nueva to zone 4

On the other hand, the main flow of person trips using public transport can be seen on the following belts:

- from Mixco to zone 1
- from zone 18 to zone 4 and zone 8
- from zone 21 to zone 1

Figure 8.6.3 Traffic Assignment on Spider Network

(2) Assignment on "Do-nothing" Network

The traffic assignment result of the "Do-nothing" case is shown in Figure 8.6.4. Every arterial road is congested by a massive volume of traffic.

In particular, terrible congestion occur on the major roads such as CA9, CA1, and San Juan Sacatepequez, and their traffic volume exceeds 150,000 PCU per day.

The congestion rate of the roads in CBD area is also higher than 1.0. Much traffic concentrates on Bolivar, 6a Av. and 7a Av.

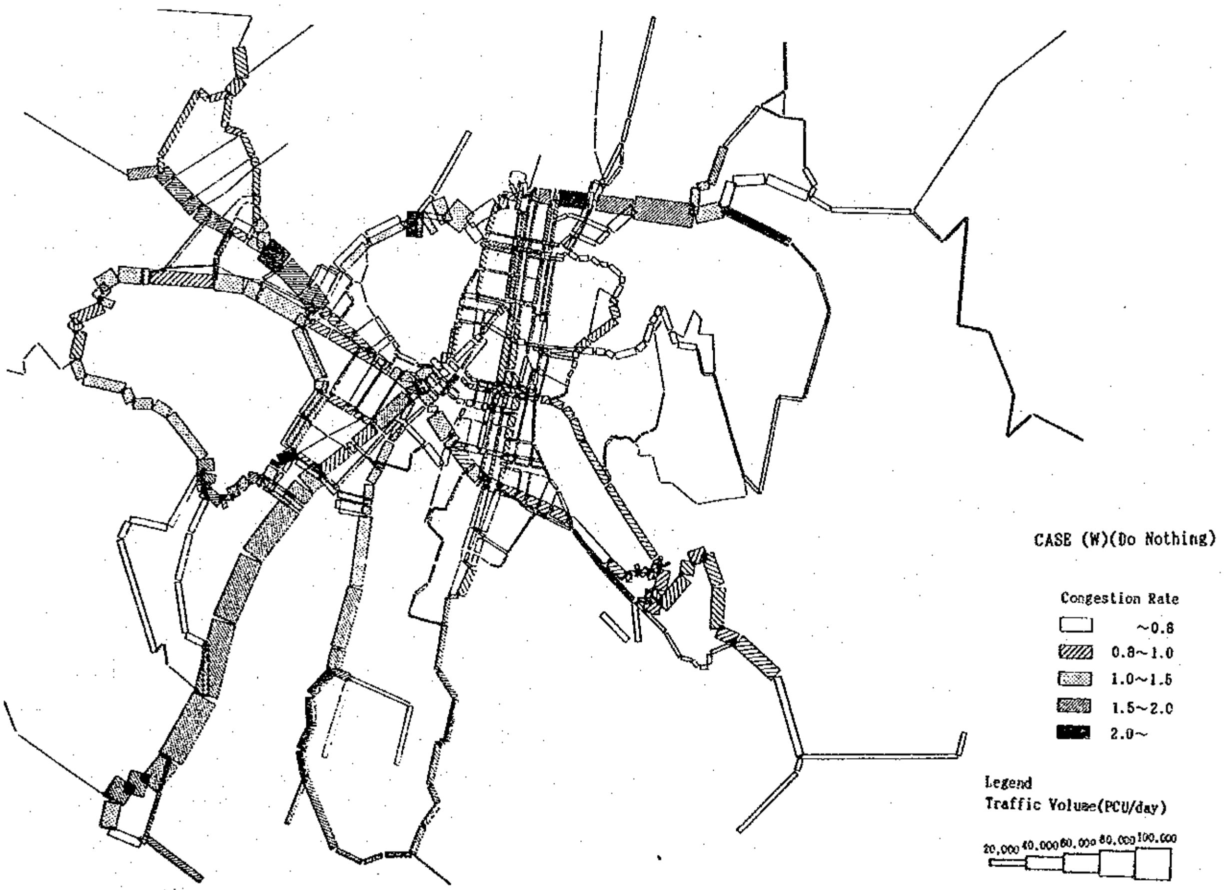


Figure 8.6.4 Traffic Assignment of "Do-Nothing" Case

9. FUTURE TRANSPORT NETWORK PATTERN

9.1 Planning Conditions and Basic Strategy

9.1.1 Background of Environment Planning Conditions

(1) Socio-Economy

The growth rate for the GDP will continue its increase from 4.0% in 1990 to 4.5% in 1995, and expand at an average annual growth rate of 4.5% after 1995. The national economy will be driven by the growth of the secondary and tertiary sectors in the Study area.

(2) Land Use

Of the total area of 93,725 ha in the Study Area, an area of 47,326 ha (50.5%) lies on a gradient of over 30%. The greatest parts of this land are currently forest and deep valley, for which urbanization is deemed impossible, due to the difficulty of contracting infrastructure, such as roads and railways.

The future transport network pattern is examined based on the selected future land use pattern in the previous section.

(3) Traffic Demand

In chapter 3, the traffic demand was forecast, then, the projected traffic volume was assigned on the existing road network.

According to this traffic assignment, many congested roads such as the CA-1, CA-9, San Juan Sacatepéquez, and Petapa road are observed as shown in Figure 9.1.1. These roads should be improved.

(4) Road Facilities

The existing road network pattern of urban and suburban areas are formed as grid and radial patterns, respectively. The road facilities problems are mainly as follows:

a) Inadequacy of the road network
b) Concentration of trunk road
c) Traffic congestion on road and at major intersections.

(5) Public Transport Facilities

At present, about 70% of total person trips in the Study use the public transport, especially urban bus and extra- urban bus systems. In the future, it is expected that the percentage of bus users will decrease, due to increasing car ownership. The main public transport problems are as follows:

a) Unreliable operation
b) Overcrowding in buses
c) Low speed of buses
d) Financial problems

(6) Traffic Management

One way system, car parking restrictions on streets, and signal control system are present in the urban area. However, traffic congestion occurs on specific roads and intersections. The main traffic management problems are as follows:

a) Traffic congestion on specific roads and intersections.
b) Many traffic accidents on these roads and intersections.

(7) Construction Organization

Basic infrastructure development projects such as construction of roads and bridges have been implemented by the Guatemala Municipality and Ministry of Transport and Public Works.

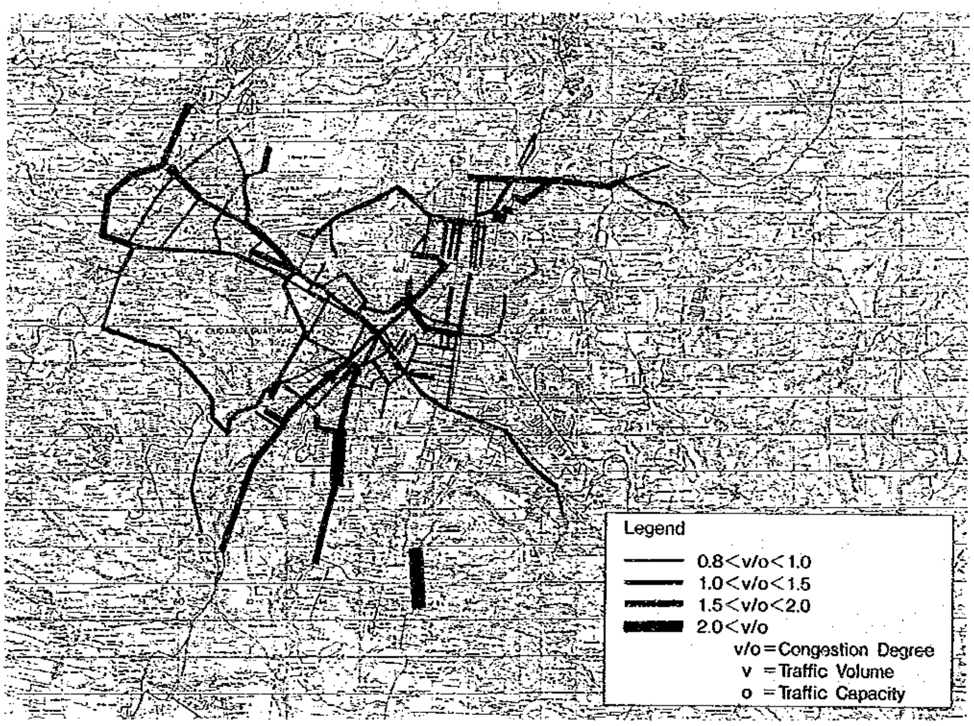


Figure 9.1.1 Congestion Degree on the Road Network

9.1.2 Planning Policy and Strategies

(1) Planning Policy for the Improvement of the Transport System

By the year 2010, the population of the Study Area will increase to about 3.0 million and about 33,000 hectares of land will have been developed for urban activities.

At present, traffic volume on major trunk roads has overreached capacity. It is easily expected that many roads will overflow by the year 2010 by passenger cars and buses as previous mentioned.

Taking into account the existing transport situation and future expected transport conditions, the study team identified the following goals for the future transport system.

a) To reduce the traffic congestion
b) To maintain a good urban environment
c) To identify a functional and effective transport system.

In order to achieve these planning goals, the following planning policies are identified.

a) To emphasize a public transport network
b) To maintain a high service level

(2) Planning Strategies

The Master Plan consists of the following sector plans in order to satisfy the planning goals and planning policies.

a) Road plan
b) Public transport plan
c) Traffic management plan

The Master Plan is also divided into two plans: these are the Short Term Plan and the Long Term Plan. A Short Term Plan, for which the target year is 1995, will be derived from the Master Plan, for which the target year is 2010, and which is positioned as a Long Term Plan.

Taking into account the objectives of the Short Term Plan, the following planning concepts or strategies are identified.

a) Coordination and consistency with existing projects.
b) No, or minimum necessity for land acquisition.
c) Keeping construction costs down through avoidance of large scale construction works.
d) Effective utilization of existing facilities.

On the other hand, the Long Term Master plan is identified based on planning goals and policies. In particular, the following factors are given greater importance in the Long Term Plan.

1) Strengthening of Transport Axes

According to the existing transport network and future land use, the main transport axes are formed as following four axes.

a) Centro Area	<--->	Mixco	(West Axis)
b) Centro Area	<--->	Villa Nueva	(South Axis)
c) Centro Area	<--->	Chinautla	(North Axis)
d) Centro Area	<--->	San José Pinula	(East Axis)

The future transport system should be planned based on the abovementioned four transport axes.

2) Strengthening of Public Transport

The future transport demand is expected double the existing volume. In addition, the space of road construction is limited along each above-mentioned transport axis.

Therefore, the public transport system should be reinforced as a traffic volume control plan. The public transport systems to be considered is as follows:

a) Introducing a bus-exclusive lane
b) Introducing a busway
c) Introducing a railway

9.2 Concept of Transport Network Alternative Plan

9.2.1 Basic Consideration

Basically, there are two traffic congestion mitigation methods; one is traffic demand control, and the other is increasing capacity. The control of traffic demand is maintained by strengthening of the public transport system and capacity increase is attained by new road construction and widening of existing roads.

Taking into account the characteristics and function of each transport system, future demand and the existing transport situation, the following transport systems are to be considered for preparing an alternative transport network plan.

1) Strengthening of public transport system

   a) To introduce a bus-exclusive lane system
   b) To introduce a bus rout system
   c) To introduce railway system

2) Improvement of road network system

   a) To construct new roads
   b) To improve existing roads

9.2.2 Concepts of Alternative Master Plans

As mentioned previously, the alternative plans are prepared to select the optimum transport network system in the Study Area.

When alternative plans are prepared, the following factors should be examined as basic considerations:

a) To develop the transport axis
b) To balance the capacity with demand for transport
c) To formulate the realistic system plan
d) To utilize the existing transport facilities

(1) West Axis (Center <---> Mixco)

Future traffic volume on the section between Center to Mixco is forecasted as 260,000 pcu/day. However, only three roads exist. The traffic capacity on these three roads is estimated as 170,000 pcu/day. In this transport axis (West Axis), at least 90,000 pcu/day of traffic capacity is in short supply and improvement of the existing roads is very difficult due to dense housing on both sides of the road.

For mitigation of this traffic situation, the following alternative transport networks are prepared taking into account the capacity and characteristics of each transport system.

a) Introduce alternative bus-exclusive lane system
b) Introduce alternative busway system

c) Introduce alternative railway system
d) Construct alternative new radial road
e) Construct alternative new ring road

(2) South Axis (Center <---> Villa Nueva, Petapa)

Future traffic volume on the section between Center to Villa Nueva, Petapa is expected as 397,000 ^{pcu}/day and only three roads, (CA-9), Av. Petapa, and Av. Hincapié, exist.

The traffic capacity of these roads is estimated to be 170,000 ^{pcu}/day. So, shortage of traffic capacity is about 230,000 ^{pcu}/day.

For mitigation of this traffic situation, the following alternative transport networks are prepared taking into account the capacity of each transport system.

a) Introduce alternative bus-exclusive lane system
b) Introduce alternative busway system
c) Introduce alternative railway system
d) Improve alternative radial roads
e) Construct alternative new ring road

(3) North Axis (Center <---> Zona 18)

Future traffic volume on the section from the Center to the direction of Zona 18 is expected to be 90,000 ^{pcu}/day, and only one road,(CA-9), exists.

The traffic capacity of this road is estimated as 60,000 ^{pcu}/day. So, shortage of traffic capacity is calculated to be 30,000 ^{pcu}/day. For mitigation measurement of this traffic situation, the following alternative transport networks are prepared taking into account the capacity and characteristics of each transport system.

a) Introduce alternative bus-exclusive lane system
b) Construction of new alternative ring road

Widening the existing Calle Martí is very difficult, due to dense construction along both sides of it.

Taking into account future traffic volume on this section, it seems that neither the introduction of busway system nor a railway system will be necessary.

(4) East Axis (Center <---> Sta. Catarina Pinula)

The future traffic volume on the section between the Center to Sta. Catarina Pinula is expected to be 100,000 ^{pcu}/day, and three roads, CA-9, 20 calle and 2a. calle exist.

Future traffic volume may not exceed the traffic capacity of these roads. Therefore, it seems that the introduction of an improved transport system will not be necessary.

(5) Centro Area

The future traffic volume on major roads in the Centro Area is expected to exceed the capacity based on the traffic assignment of the Base Case in 2010.

It is very difficult to acquire land in the Centro Area, due to dense building located on both road sides. The improvement of traffic problems in Centro Area should be carried out mainly by Traffic Management Plan. In addition, taking into account the existing public transport situation, the following alternative transport networks are prepared.

a) Introduce alternative bus-exclusive lane system
b) Introduce alternative busway system
c) Introduce alternative railway system

9.3 Transport Network Alternative Plan

As mentioned previously, there are two different modes of transport system to be considered: that is, the road network system and the public transport system in the Study Area.

9.3.1 Road Network Strengthen Plan

Taking into account future land use, traffic characteristics, the existing road network, and future traffic demand, the following two road network improvement plans can be prepared;

1) Radial Road Network Improvement Plan

   This road network improvement plan is basically formulated based on the development of the following factors.

   a) To utilize the existing road network
   b) To improve the most congested transport axes
   c) To minimize road construction costs

2) Radial and Ring Road Improvement Plan

   This road network improvement plan is basically formulated on the development of the following factors.

   a) To utilize the existing road network
   b) To improve the most congested transport axes
   c) To form the comprehensive road network pattern
   d) To complete the unlinked road

9.3.2 Public Transport Improvement Plan

Taking into account the functions and characteristics of the public transport systems, future transport demand, and the existing public transport system, three public transport plans, that is, 1) introducing a bus-exclusive lane, 2) introducing a busway, and 3) introducing railway plans are identified.

However, considering the importance of strengthening public transport for the solution of urban transport problems and the function of each public transport system, three public transport plans are prepared as a combination of the public transport plans described below.

a) Introduced Bus Exclusive Lane Plan
b) Introduced Bus Exclusive Lane and Busway Plan
c) Introduced Bus Exclusive Lane and Railway Plan

9.3.3 Formation of Alternative Plan

As mentioned above, two road network plans are identified for the road network improvement plan, and three public transport network improvement plans are identified for the public transport improvement plan.

Considering the effectiveness among the above-mentioned improvement plans, six alternative plans are prepared as the combination plan of each improvement plan.

The above-mentioned matters are summarized in Figure 9.3.1 and the combination among the six alternative plans is also summarized in Figure 9.3.2.

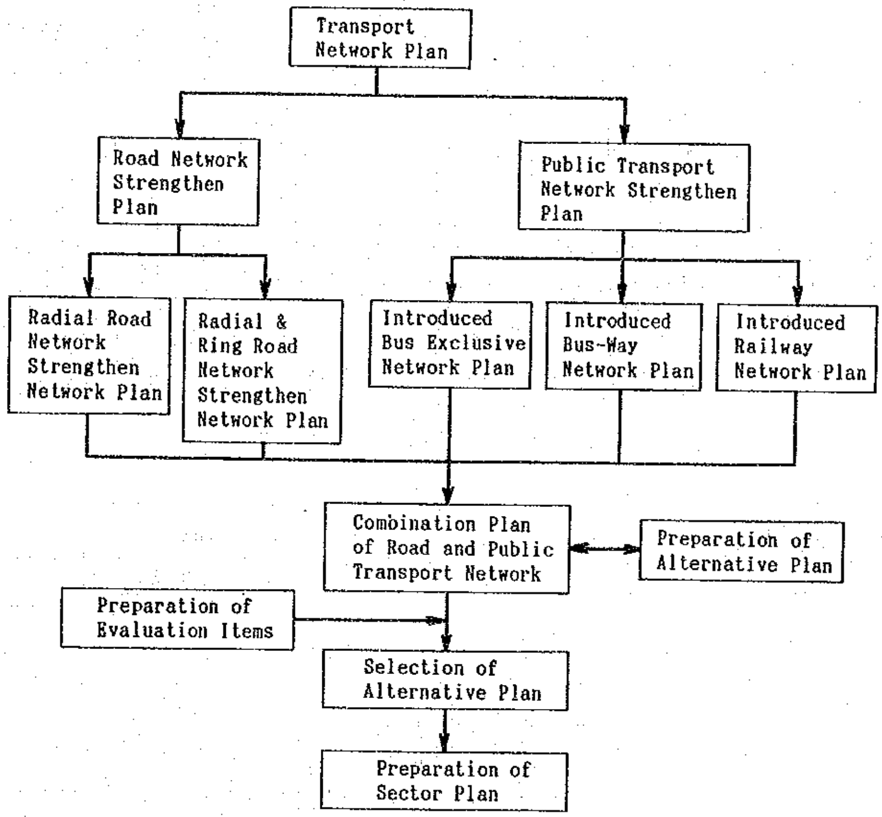


Figure 9.3.1 Formation of Alternative Plan

1) Alternative Plan-A

The Alternative Plan-A consists of the radial road network improvement plan and the introduced bus-exclusive lane plan. The conceptual plan is illustrated in Figure 9.3.3.

2) Alternative Plan-B

The Alternative Plan-B consists of the radial road network improvement plan, and introduced bus-exclusive lane and busway plan. The conceptual plan is illustrated in Figure 9.3.4.

3) Alternative Plan-C

The Alternative Plan-C consists of the radial road network improvement plan, and introduced bus-exclusive lane and railway plan. The conceptual plan is illustrated in Figure 9.3.5.

4) Alternative Plan-D

The Alternative Plan-D consists of the radial and ring road network improvement plan, and the bus-exclusive lane plan. The conceptual plan is illustrated in Figure 9.3.6.

5) Alternative Plan-E

The Alternative Plan-E consists of the radial and ring road network improvement plan, and the bus-exclusive lane and busway plan. The conceptual plan is illustrated in Figure 9.3.7.

6) Alternative Plan-F

The Alternative Plan-F consists of the radial and ring road network improvement plan, and the bus-exclusive lane and railway plan. The conceptual plan is illustrated in Figure 9.3.8.

The outline of the above-mentioned Alternative Plans is summarized in Table 9.3.1, and the project cost is shown in Table 9.3.2.

Public Transport Strengthen Plans / Road Network strengthen Plans	Existing Situation	Introduced Bus Exclusive Lane Plan	Introduced Bus Exclusive Lane & Bus Way Plan	Introduced Bus Exclusive Lane & Railway Plan
Existing Road Network	Base Case	—	—	—
Radial Road Network Plan-1	—	Alternative Plan-A	Alternative Plan-B	Alternative Plan-C
Radial & Ring Network Plan-2	—	Alternative Plan-D	Alternative Plan-E	Alternative Plan-F

Figure 9.3.2 Combination of Six Alternative Plans

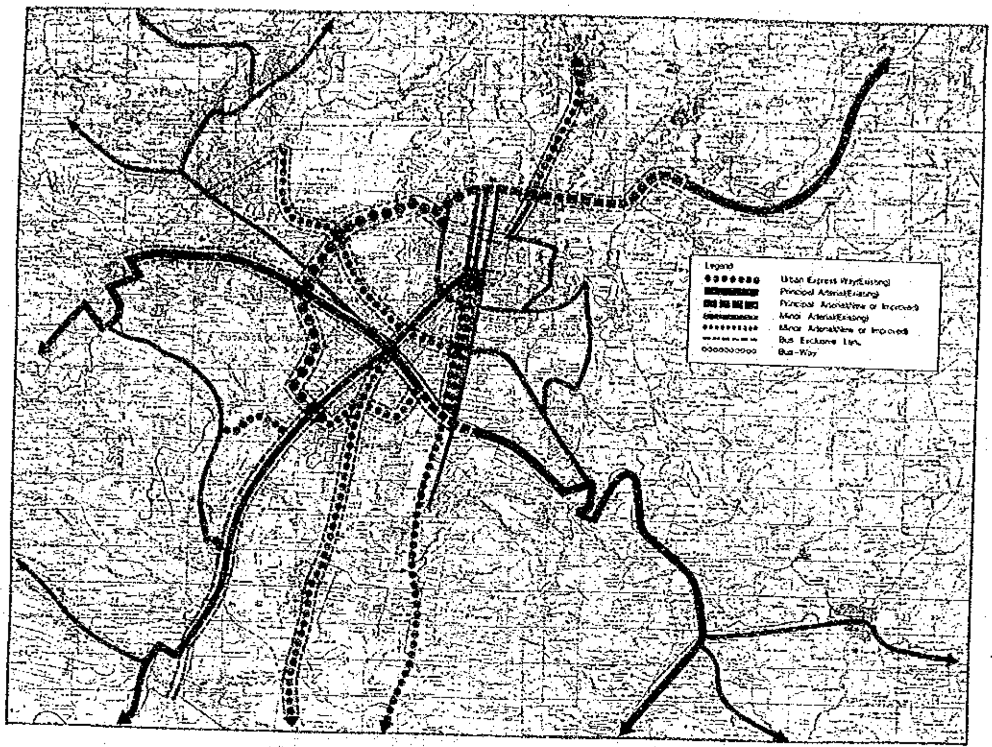


Figure 9.3.3 Alternative Plan A

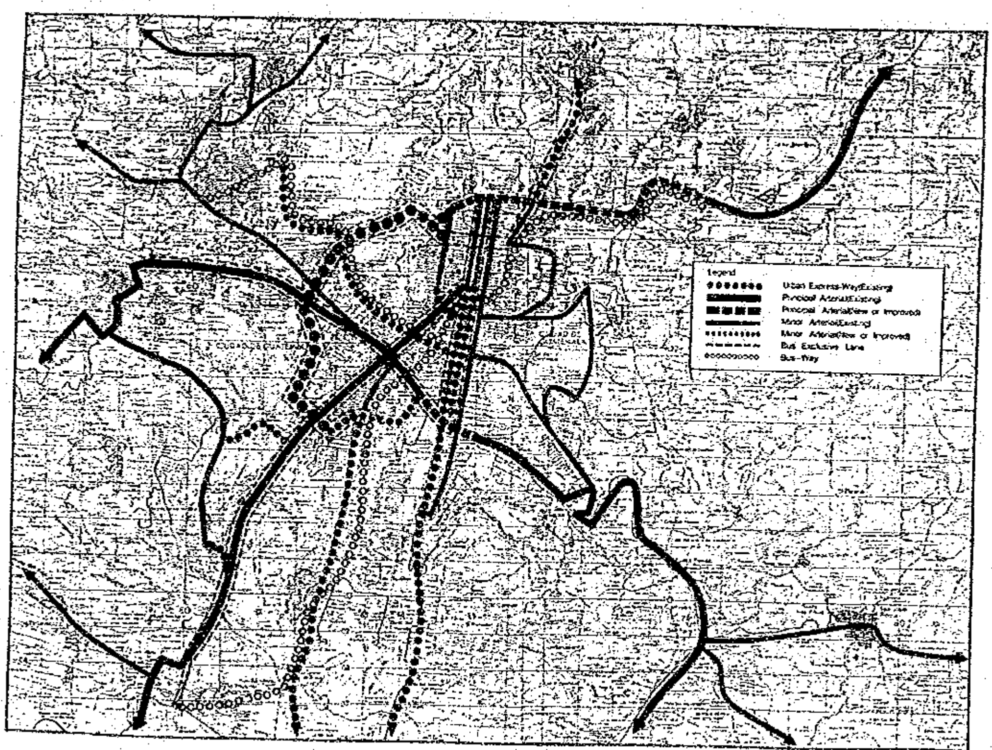


Figure 9.3.4 Alternative Plan B

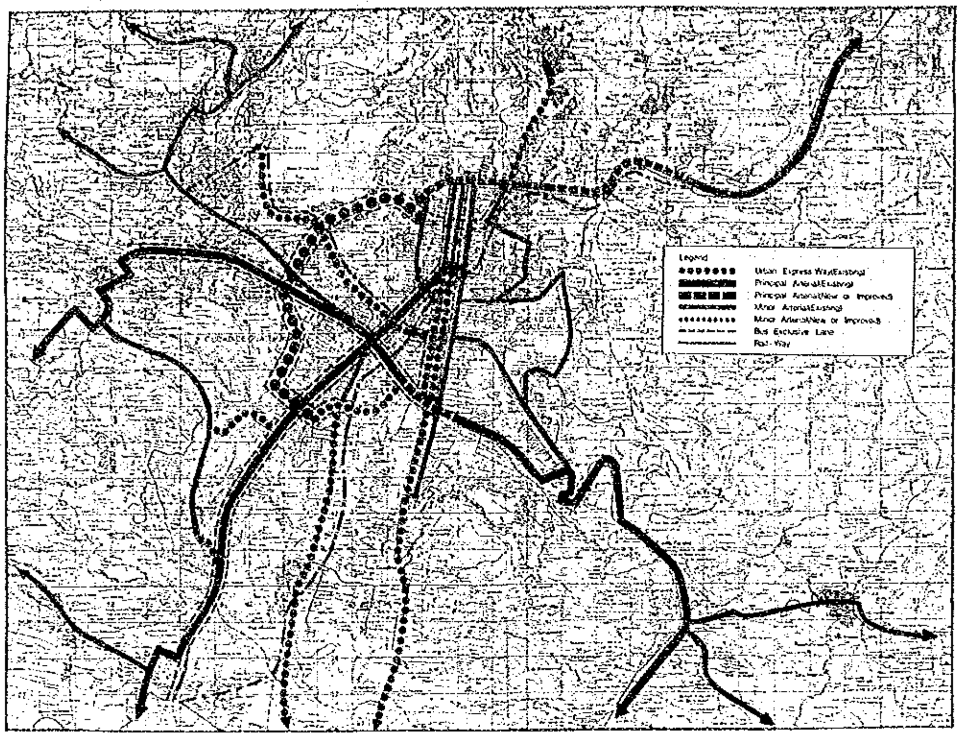


Figure 9.3.5 Alternative Plan C

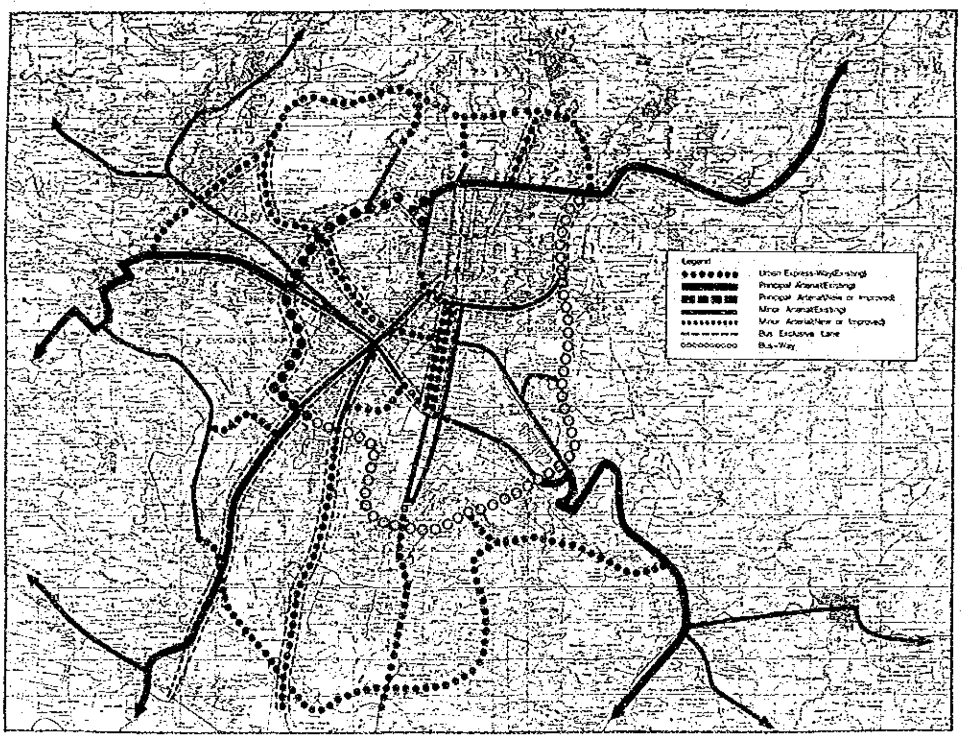


Figure 9.3.6 Alternative Plan D

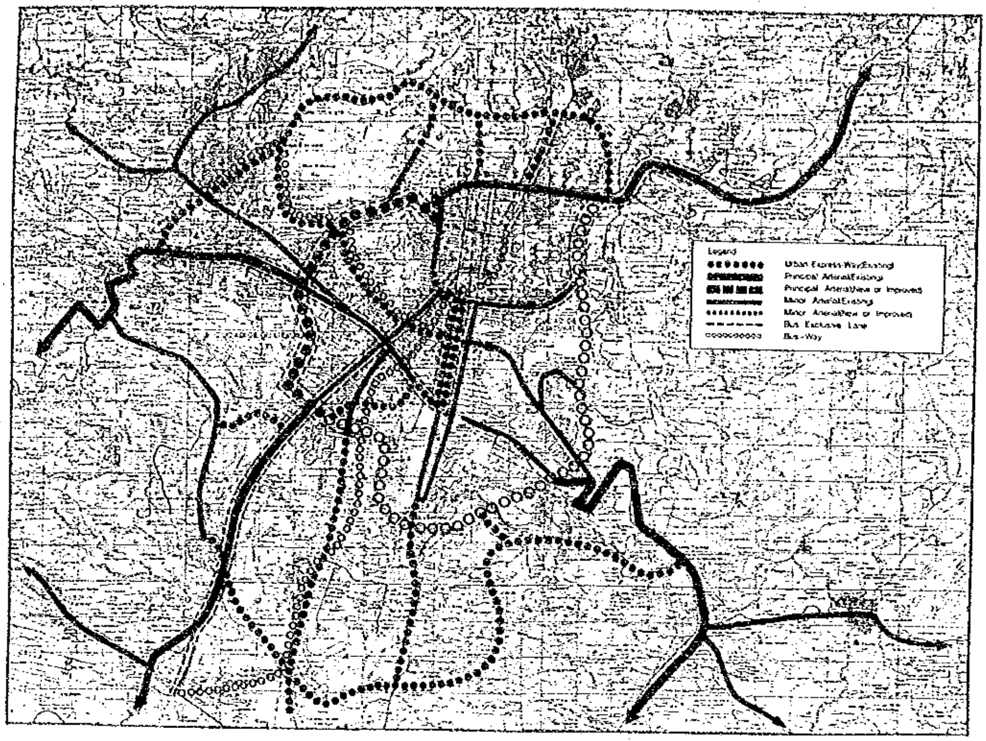


Figure 9.3.7 Alternative Plan E

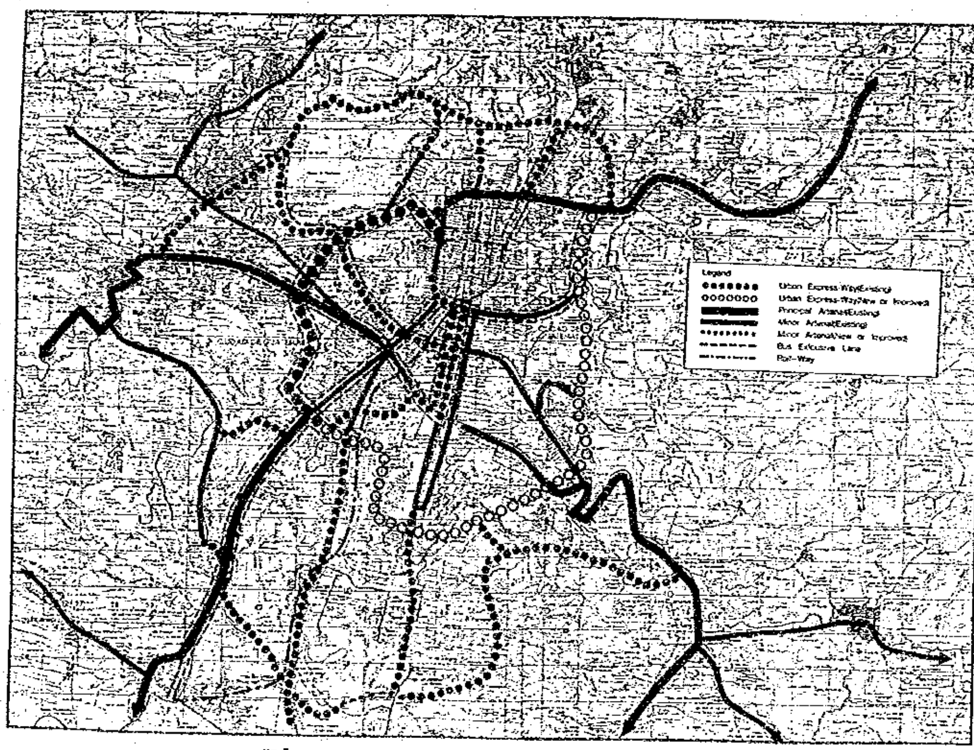


Figure 9.3.8 Alternative Plan F

Table 9.3.1 Outline of Alternative Plans

	Alternative Plans					
	A	B	C	D	E	F
1. Road Length (m)	76,250	76,250	76,250	122,330	118,330	118,330
1.1 Urban Expressway (Improved)	----	----	----	----	----	----
1.2 Urban Expressway (New)	----	----	----	20,400	20,400	20,400
1.3 Principal Arterial (Improved)	24,000	24,000	24,000	17,500	17,500	17,500
1.4 Principal Arterial (New)	----	----	----	----	----	----
1.5 Minor Arterial (Improved)	33,370	33,370	33,370	29,540	25,540	25,540
1.6 Minor Arterial (New)	18,880	18,880	18,880	54,890	54,890	54,890
2. Bridge Length (m)						
2.1 Road Way Bridge	2,380	2,380	2,380	6,115	6,115	6,115
2.2 Busway Bridge	----	13,000	----	----	13,000	----
2.3 Railway Bridge	----	----	33,000	----	----	26,000
3. Bus Exclusive Lane Length (m)	100,000	85,000	85,000	100,000	85,000	85,000
4. Busway Length (m)	----	33,000	----	----	26,000	----
4.1 At Grade Section	----	20,000	----	----	13,000	----
4.2 Viaduct Section	----	13,000	----	----	13,000	----
5. Railway Length (m)	----	----	33,000	----	----	26,000
5.1 At Grade Section	----	----	0	----	----	0
5.2 Viaduct Section	----	----	33,000	----	----	26,000
6. Projected Cost (Q Million)	1,696	2,186	4,918	2,316	2,502	4,803

Table 9.3.2 Projected Cost of Each Alternative

(Unit: Q1,000)

	Alternative Plan					
	A	B	C	D	E	F
1. Road Traffic						
1- 1 ORR (N)	----	----	----	174,395	174,395	174,395
1- 2 ORR (S)	71,324	71,324	71,324	175,441	175,441	175,441
1- 3 HRR	----	----	----	470,002	470,002	470,002
1- 4 IRR	81,029	81,029	81,029	81,029	81,029	81,029
1- 5 EWC	265,216	221,014	221,014	221,014	221,014	221,014
1- 6 Periférico	38,278	38,278	38,278	25,519	25,519	25,519
1- 7 Av. 13	----	----	----	2,642	2,642	2,642
1- 8 Av. 6	----	----	----	21,062	21,062	21,062
1- 9 Av. 15	15,215	15,215	15,215	15,215	15,215	15,215
1-10 35 Calle	35,782	35,782	35,782	35,782	35,782	35,782
1-11 Blvd. Sur	11,729	11,729	11,729	11,729	11,729	11,729
1-12 CA-9 (S)	122,096	122,096	61,048	122,096	61,048	61,048
1-13 Av. Petapa	103,844	59,358	59,358	103,844	59,358	59,358
1-14 Av. Hincapié	206,050	206,050	124,670	206,050	124,670	124,670
1-15 Calle Martí	169,481	124,735	124,735	124,735	----	----
1-16 CA-9 (E)	84,741	84,741	84,741	84,741	84,741	84,741
1-17 Av. Américas	7,085	7,085	7,085	----	----	----
1-18 2a. Calle	43,303	43,303	43,303	----	----	----
Sub-Total	1,255,173	1,121,739	979,308	1,875,296	1,563,647	1,563,647
2. Public Traffic						
2- 1 Bus Stop	3,305	3,305	3,305	3,305	3,305	3,305
2- 2 Bus Exclusive	4,450	3,900	3,900	4,450	3,900	3,900
2- 3 Busway	----	624,130	----	----	498,550	----
2- 4 Railway	----	----	3,498,854	----	----	2,799,083
2- 5 Bus Terminal (R)	12,459	12,459	12,459	12,459	12,459	12,459
2- 6 Bus Terminal (U)	243,500	243,500	243,500	243,500	243,500	243,500
Sub-Total	263,714	885,294	3,762,018	263,714	761,714	3,062,247
3. Traffic Management						
3- 1 Management	128,323	128,323	128,323	128,323	128,323	128,323
3- 2 Centro	49,000	49,000	49,000	49,000	49,000	49,000
Sub-Total	177,323	177,323	177,323	177,323	177,323	177,323
Grand Total	1,696,210	2,186,356	4,918.650	2,316,333	2,502,684	4,803,219

9.4 Traffic Analysis of Alternative Plans

9.4.1 Modal Split

(1) Master Plan Alternative Network

The detailed definition of the master plan alternative network was discussed in the former section. However, it is presented in brief in order to clarify the result of modal split and traffic assignment estimation.

Figure 9.4.1 shows a road network within the limits of the area which should be estimated by this simulation. The road network includes the whole road plan.

The road sections indicated a certain project ID, are shown in Figure 9.4.2. The master plan alternative network can be described with the combination of the road sections as shown in Table 9.4.1.

The car network of alternative A, B and C is the same as input data of the traffic assignment simulation. and alternative D, E and F is also the same.

Figure 9.4.3 and Table 9.4.2 show the master plan alternative public transport network in the same manner as the car network.

As can be seen in Table 9.4.2, the main public transport project is a bus-exclusive lane in alternative A and D. A busway is emphasized in alternative B and E, and a railway transit system in alternative C and F.

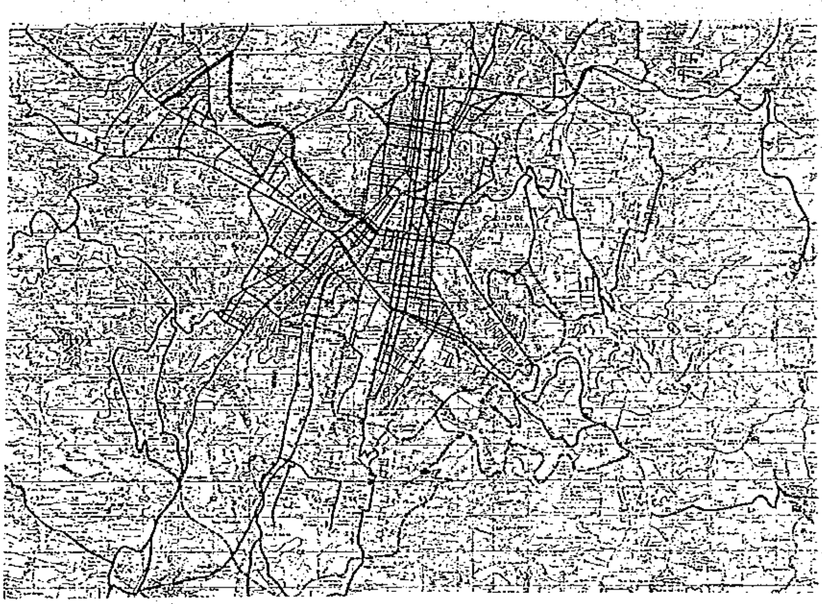


Figure 9.4.1 Road Network for Traffic Assignment

Table 9.4.1 Road Project Components by Alternative

Project Number	Project Name		Project ID	Project Components					
				Case (A)	Case (B)	Case (C)	Case (D)	Case (E)	Case (F)
1	Inner Ring Road		IRR	○	○	○	○	○	○
2	Middle Ring Road	Section 1	MRR-1				○	○	○
3		Section 2	MRR-2				○	○	○
4		Section 3	MRR-3				○	○	○
5		Section 4	MRR-4				○	○	○
6		Section 5	MRR-5				○	○	○
7	Periferico Extension		MRR-6	○	○	○	○	○	○
8	Outer Ring Road (North)	Section 1	ORN-1				○	○	○
9		Section 2	ORN-2				○	○	○
10		Section 3	ORN-3				○	○	○
11	Access road 1		13 Av.				○	○	○
12	Access road 2		6a Av.				○	○	○
13	Access road 3		15 Av.				○	○	○
14	Outer Ring Road (South)	Section 1	ORS-1	○	○	○	○	○	○
15		Section 2	ORS-2				○	○	○
16			Blv. Sur	○	○	○	○	○	○
17	East-West Corridor	Section 1	EWC-1	○	○	○	○	○	○
18		Section 2	EWC-2	○	○	○	○	○	○
19			1 & 2 Clle	○	○	○	○	○	○
20	35 Calle		35 Clle	○	○	○	○	○	○
21	Av. Petapa		Petapa	○	○	○	○	○	○
22	Av. Hincapie		Hincapie	○	○	○	○	○	○
23	Underpass Obelisco		UPO	○	○	○	○	○	○

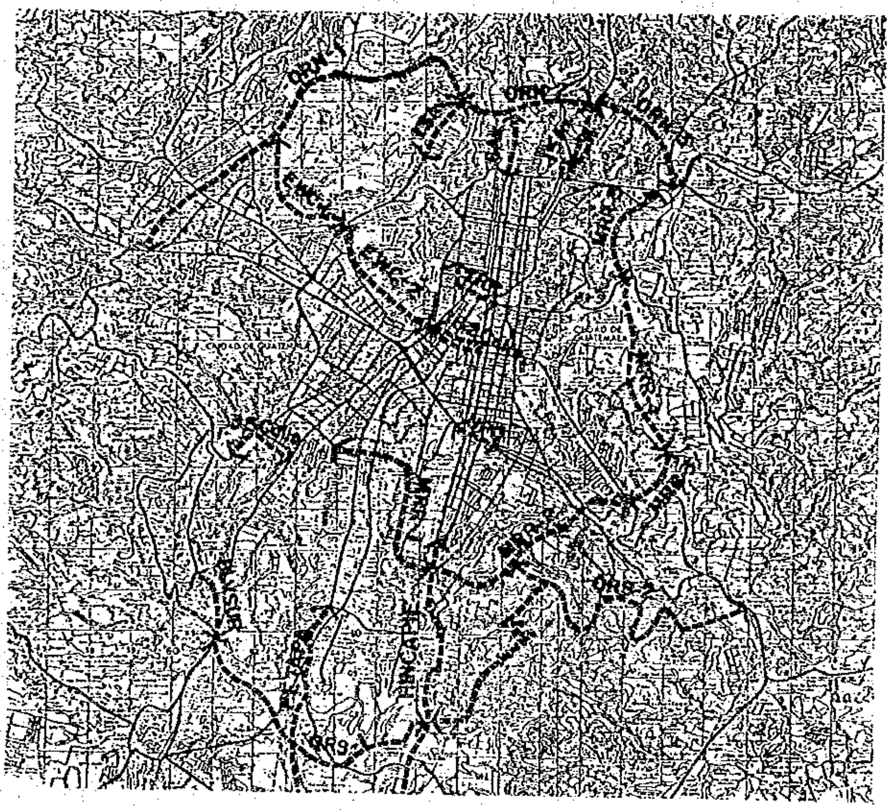


Figure 9.4.2 Road Section of Project

Table 9.4.2 Public Transport Project Components by Alternative

Project Number	Project Name		Project ID	Type of Public Survice	Project Components					
					Case (A)	Case (B)	Case (C)	Case (D)	Case (E)	Case (F)
1	E-W Corridor		EWC-R	Railway			O			O
2			EWC-B	Bus Way		O			O	
3			EWC-E	Exclusive Lane	O			O		
4	South Railway	Section 1	SR1-R	Railway			O			O
5			SR1-E	Bus Way		O			O	
6		Section 2	SR2-R	Railway			O			O
7			SR2-E	Bus Way		O			O	
8	North Railway	Section 1	NR1-R	Railway			O			O
9			NR1-E	Bus Way		O			O	
10		Section 2	NR2-R	Railway			O			
11			NR2-E	Bus Way		O				
12		Section 3	NR3-R	Railway			O			
13			NR3-E	Bus Way		O				
14	CA 1	Section 1	C11-E	Exclusive Lane	O	O	O	O	O	O
15		Section 2	C12-E	Exclusive Lane	O	O	O	O	O	O
16	CA 9	Section 1	C91-E	Exclusive Lane	O	O	O	O	O	O
17		Section 2	C92-E	Exclusive Lane	O					
18		Section 3	C93-E	Exclusive Lane	O			O	O	O
19	Inner Ring Road		IRR-E	Exclusive Lane				O	O	O
20	Middle Ring Road		MR1-E	Exclusive Lane	O	O	O	O	O	O
21			MR2-E	Exclusive Lane				O	O	O
22	San Juan Sacatepequez		San Fuan	Exclusive Lane						
23	6a Av. & 7a Av.		6 & 7 AV.	Exclusive Lane	O	O	O	O	O	O
24	8 Calle & 9 Calle		8 & 9 Clle	Exclusive Lane	O	O	O	O	O	O
25	18 Calle		18 Calle	Exclusive Lane	O	O	O	O	O	O
26	1a Calle & 2a Calle		1 & 2 Clle	Exclusive Lane	O	O	O	O	O	O
27	Av. Bolivar		Bolivar	Exclusive Lane	O	O	O	O	O	O
28	Petapa	Section 1	PT1-E	Exclusive Lane	O			O		
29		Section 2	PT2-E	Exclusive Lane	O			O		
30	15 Av.		15 Av.	Exclusive Lane	O	O	O	O	O	O

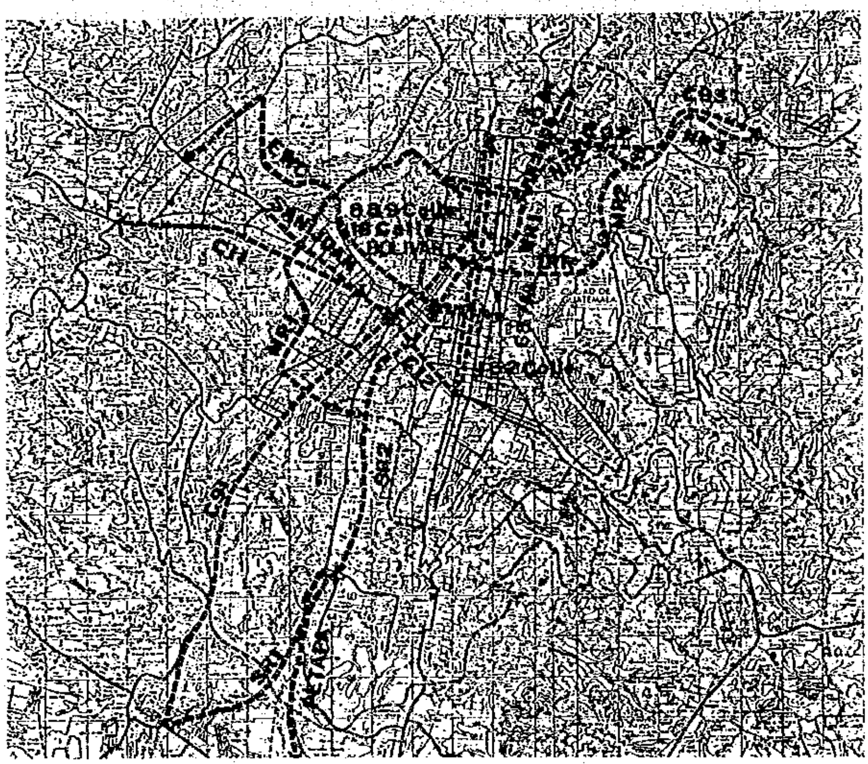


Figure 9.4.3 Project Section of Public Transport

(2) Modal Split by Alternative Plan

Table 9.4.3 describes the modal share by the master plan alternative.

In case of alternative A and C, the share of private car trips which is higher than that of the other alternatives, approximately reaches 40%. Travelers gradually divert to use public transport from private car according as the introduction of better public transport system.

If railway transit system is introduced (in case of alternative C and F), many travelers will use public transport and the share of private car will largely decrease comparing with "Do-nothing" case. However, the number of person trips using public transport approximately indicates 1.7 times of the present value (including alternative B and C). Therefore, it is required to consider introduction of efficient public transport system carrying these passengers.

Table 9.4.3 Modal Share by Master Plan Alternative

Alternative	Public Transport			Private Car		
	Car Owner	Non-car Owner	Total	Car Owner	Non-car Owner	Total
A	952	1,954	2,906 (59.8%)	1,799	151	1,950 (40.2%)
B	1,008	1,963	2,971 (61.2%)	1,743	142	1,885 (38.8%)
C	1,104	1,972	3,077 (63.3%)	1,647	133	1,780 (36.7%)
D	965	1,954	2,919 (60.1%)	1,786	151	1,937 (39.9%)
E	1,001	1,959	2,960 (61.0%)	1,750	148	1,896 (39.0%)
F	1,082	1,967	3,049 (62.8%)	1,669	138	1,807 (37.2%)
Do Nothing	883	1,933	2,816 (58.0%)	1,868	172	2,040 (42.0%)
1990	382	1,412	1,794 (64.3%)	798	199	997 (35.7%)

Note: Unit of above number is 1,000 person trips per day.
This number does not include intra-zonal trips.

9.4.2 Traffic Assignment

(1) Traffic Volume Assigned

Table 9.4.4 shows the traffic volume assigned on main roads as shown in Figure 9.4.4. The traffic flow with a graphic presentation of road congestion is exhibited in Figure 9.4.5 to Figure 9.4.7.

Seeing these figures, the following findings can be pointed out.

1) Alternative A

In every road in alternative A, B, C and D, the congestion rate exceeds 1.0. Namely, it can be said that road facilities are insufficient.

2) Alternative B

The congestion on the roads for Mixco, Villa Nueva and Zona 18, where bus ways are introduced, disappears. On the other hand, the bus way which was introduced along the road for Villa Nueva, has twice the number of passengers indicated as it's capacity. This indicates only potential demand because the traffic assignment of bus was done only as a one time division of the OD table. Traffic demand of bus passengers on parallel roads is small. In the sector plan stage, therefore, this imbalance will be cleared.

3) Alternative C

The congestion rate of almost all of the roads falls lower then 1.0 because of the introduction of a railway transit. However, demand of passengers on the south railway is 0.8 million, and that on the East-West railway is 0.5 million. These figures will be reviewed and examined for planning in the sector plan stage.

4) Alternative D

Comparing with the alternative A, the congestion rate is wholly lower, because more road projects are constructed than alternative A. However, the congestion of roads for Villa Nueva City still remains.

5) Alternative E

The congestion on CA-9 and Ave. Petapa disappears compared with alternative D. However, so much demand on the busway was estimated that it is necessary to study introducing a large capacity bus and converting the bus demand to a normal bus system.

6) Alternative F

The congestion of all roads is lower than 0.8. Therefore, it can be said that the good service is maintained.

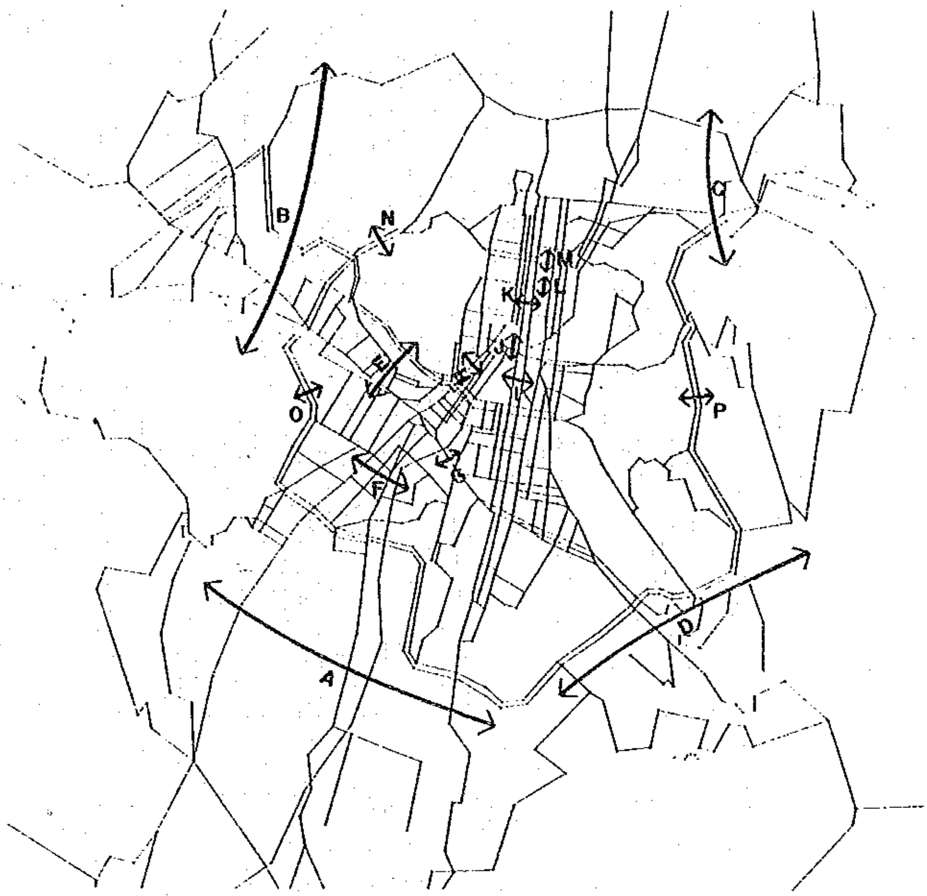
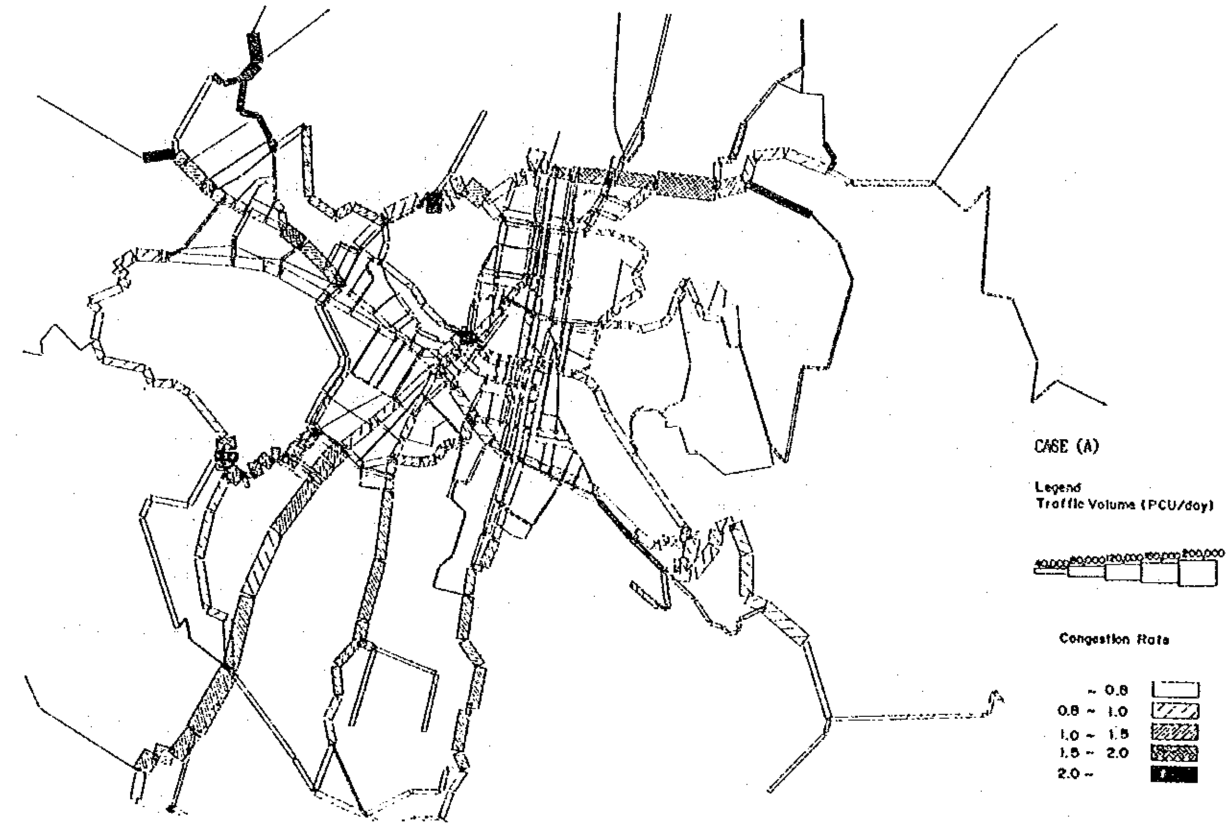


Figure 9.4.4 Road Section for Traffic Volume Analysis

Table 9.4.4 Traffic Volume Assigned on Principal Road

Check Point	Road Name	Capacity (PCU)	Link Number	Case (A) Traffic Volume (Veh.) Bus	Case (A) Pass.Car	Case (A) Total	Case (A) Congestion Rate	Case (A) Railway Passenger (PT)	Case (B) Traffic Volume (Veh.) Bus	Case (B) Pass.Car	Case (B) Total	Case (B) Congestion Rate	Case (B) Railway Passenger (PT)	Case (C) Traffic Volume (Veh.) Bus	Case (C) Pass.Car	Case (C) Total	Case (C) Congestion Rate	Case (C) Railway Passenger (PT)
A	CA9	109,400	215	15,000	67,300	82,300	0.83	-	5,300	67,400	72,700	0.71	-	800	60,700	61,500	0.57	-
	Avenida de Petapa	62,800	511	18,200	45,700	63,900	1.31	-	0	60,100	60,100	0.96	-	0	48,000	48,000	0.76	-
	Avenida Hincapie	53,300	1023	1,100	71,600	72,700	1.38	-	300	54,800	55,100	1.04	-	0	45,800	45,800	0.86	-
	South Railway/Busway	30,800	806	-	-	-	-	-	31,400	-	31,400	2.04	-	-	-	-	-	800,300
B	Outer Ring Road	53,300	909	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	E-W Corridor	59,800	706	19,600	23,100	42,700	1.04	-	0	59,300	59,300	0.99	-	0	49,000	49,000	0.82	-
	E-W Railway/Busway	30,800	756	-	-	-	-	-	20,300	-	20,300	1.32	-	-	-	-	-	612,700
	Calle de San Juan	79,700	609	4,800	79,400	84,200	1.12	-	3,700	61,900	65,600	0.87	-	900	59,200	60,100	0.77	-
	2a Calle	18,200	3601	0	2,200	2,200	0.12	-	0	600	600	0.03	-	0	0	0	0.00	-
	CA1	97,200	118	3,900	70,300	74,200	0.80	-	3,900	70,500	74,400	0.81	-	4,300	55,000	59,300	0.65	-
C	Outer Ring Road	53,300	903	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	CA9	98,500	256	22,500	110,200	132,700	1.58	-	3,200	89,900	93,100	0.98	-	0	84,700	84,700	0.86	-
	Periferico	104,000	340	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	North Railway/Busway	37,800	829	-	-	-	-	-	22,100	-	22,100	1.17	-	-	-	-	-	521,700
D	CA1	109,400	153	100	89,300	89,400	0.82	-	100	89,000	89,100	0.82	-	100	84,100	84,200	0.77	-
	20 Calle	16,100	2411	10,700	14,300	25,000	2.22	-	9,600	9,300	18,900	1.77	-	9,800	9,400	19,200	1.80	-
	Outer Ring Road	53,300	997	-	-	-	-	-	0	0	0	0.00	-	-	-	-	-	-
E	E-W Corridor	59,800	713	12,700	24,000	36,700	0.83	-	0	35,600	35,600	0.60	-	0	28,000	28,000	0.47	-
	E-W Railway/Busway	15,400	763	-	-	-	-	-	15,800	-	15,800	2.05	-	29,500	0	29,500	3.83	589,800
	Calle de San Juan	79,700	602	0	45,400	45,400	0.57	-	0	43,100	43,100	0.54	-	0	41,800	41,800	0.52	-
	CA1	97,200	122	3,600	47,400	51,000	0.56	-	3,700	41,600	45,300	0.50	-	3,100	33,000	36,100	0.40	-
F	CA9	79,700	222	16,000	33,200	49,200	0.82	-	6,000	50,100	56,100	0.78	-	800	51,800	52,600	0.67	-
	Avenida de Petapa	59,300	504	15,100	19,800	34,900	0.86	-	1,500	38,600	40,100	0.71	-	100	26,200	26,300	0.45	-
	South Railway/Busway	30,600	809	-	-	-	0.00	-	30,700	-	30,700	1.99	-	-	-	-	-	915,200
G	CA1	97,200	131	10,700	58,400	69,100	0.82	-	12,600	53,300	65,900	0.81	-	14,100	48,000	62,100	0.78	-
H	Avenida Bolivar	56,300	231	24,300	4,600	28,900	0.91	-	7,300	34,900	42,200	0.85	-	2,200	45,400	47,600	0.85	-
I	6a Avenida	62,600	1011	3,500	43,500	47,000	0.81	-	3,100	32,100	35,200	0.61	-	3,600	27,200	30,800	0.55	-
	7a Avenida	62,600	1109	6,100	35,200	41,300	0.76	-	4,000	27,400	31,400	0.57	-	4,000	20,500	24,500	0.45	-
J	24 Calle	51,400	2104	1,800	13,200	15,000	0.33	-	0	15,600	15,600	0.31	-	0	9,500	9,500	0.18	-
	Under Pass	96,000	2106	2,300	41,900	44,200	0.48	-	1,300	41,200	42,500	0.46	-	600	36,900	37,500	0.40	-
	North Railway/Busway	30,800	817	-	-	-	0.00	-	0	-	0	0.00	-	-	-	-	-	715,700
K	6a Avenida	10,800	1008	12,600	0	12,600	2.33	-	4,500	0	4,500	0.83	-	2,600	2,400	5,000	0.70	-
	7a Avenida	10,800	1105	14,200	0	14,200	2.63	-	4,600	2,800	7,400	1.11	-	1,700	6,000	7,700	0.87	-
L	13 Calle	23,300	2205	0	6,600	6,600	0.37	-	0	7,900	7,900	0.34	-	0	6,800	6,800	0.29	-
M	8a Calle	27,400	2014	9,400	7,500	16,900	0.96	-	3,600	11,300	14,900	0.68	-	6,000	10,000	16,000	0.80	-
	9a Calle	27,400	2023	14,900	0	14,900	1.09	-	5,200	12,800	18,000	0.85	-	5,300	11,600	16,900	0.81	-
N	Periferico	129,600	301	12,000	87,300	99,300	0.86	-	11,700	70,900	82,600	0.73	-	7,600	74,500	82,100	0.69	-
		51,400	408	0	22,000	22,000	0.43	-	0	24,900	24,900	0.49	-	0	11,000	11,000	0.21	-
O	Periferico	79,200	305	8,200	29,100	37,300	0.57	-	5,400	34,000	39,400	0.57	-	1,700	37,700	39,400	0.52	-
		51,400	415	0	29,900	29,900	0.58	-	0	25,300	25,300	0.49	-	0	19,400	19,400	0.36	-
P	Periferico	116,400	335	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		51,400	444	0	6,800	6,800	0.13	-	0	6,900	6,900	0.13	-	0	6,400	6,400	0.12	-

Check Point	Road Name	Capacity (PCU)	Link Number	Case (D) Traffic Volume (Veh.) Bus	Case (D) Pass.Car	Case (D) Total	Case (D) Congestion Rate	Case (D) Railway Passenger (PT)	Case (E) Traffic Volume (Veh.) Bus	Case (E) Pass.Car	Case (E) Total	Case (E) Congestion Rate	Case (E) Railway Passenger (PT)	Case (F) Traffic Volume (Veh.) Bus	Case (F) Pass.Car	Case (F) Total	Case (F) Congestion Rate	Case (F) Railway Passenger (PT)
A	CA9	109,400	215	14,900	72,300	87,200	0.93	-	5,300	62,200	67,500	0.67	-	800	59,200	60,000	0.56	-
	Avenida de Petapa	62,800	511	18,300	37,100	55,400	1.17	-	0	60,500	60,500	0.95	-	0	46,000	46,000	0.73	-
	Avenida Hincapie	53,300	1023	1,000	53,300	54,300	1.04	-	600	50,000	50,600	0.95	-	0	46,800	46,800	0.92	-
	South Railway/Busway	30,800	806	-	-	-	-	-	29,900	-	29,900	1.94	-	-	-	-	-	774,700
B	Outer Ring Road	53,300	909	0	16,600	16,600	0.31	-	0	6,900	6,900	0.13	-	0	4,200	4,200	0.08	-
	E-W Corridor	59,800	706	19,600	17,200	36,600	0.94	-	0	46,500	46,500	0.78	-	0	39,600	39,600	0.66	-
	E-W Railway/Busway	30,800	758	-	-	-	-	-	20,600	-	20,600	1.35	-	-	-	-	-	506,700
	Calle de San Juan	79,700	609	4,800	60,000	64,800	0.87	-	3,700	55,000	58,700	0.78	-	900	57,200	58,100	0.74	-
	2a Calle	18,200	3601	0	6,400	6,400	0.35	-	0	0	0	0.00	-	0	0	0	0.00	-
	CA1	97,200	118	3,900	71,000	74,900	0.81	-	3,700	67,200	70,900	0.77	-	4,200	60,300	64,500	0.71	-
C	Outer Ring Road	53,300	903	1,500	19,200	20,700	0.42	-	1,500	17,900	19,400	0.39	-	1,500	17,700	19,200	0.39	-
	CA9	99,500	256	8,000	46,700	54,700	0.64	-	8,700	46,100	54,800	0.64	-	12,300	40,200	52,500	0.66	-
	Periferico	104,000	340	12,900	50,100	63,000	0.73	-	12,300	48,100	60,400	0.70	-	9,700	48,300	58,000	0.65	-
	North Railway/Busway	37,800	829	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
D	CA1	109,400	153	0	77,000	77,000	0.70	-	0	75,400	75,400	0.69	-	0	71,900	71,900	0.66	-
	20 Calle	16,100	2411	5,200	0	5,200	0.65	-	5,300	0	5,300	0.66	-	5,500	0	5,500	0.68	-
	Outer Ring Road	53,300	997	0	3,400	3,400	0.06	-	0	3,200	3,200	0.06	-	0	2,400	2,400	0.05	-
E	E-W Corridor	59,800	713	13,400	15,300	28,700	0.70	-	0	28,800	28,800	0.48	-	0	23,800	23,800	0.40	-
	E-W Railway/Busway	15,400	763	-	-	-	-	-	16,500	-	16,500	2.14	-	-	-	-	-	570,100
	Calle de San Juan	79,700	602	0	45,900	45,900	0.58	-	0	41,100	41,100	0.52	-	0	39,700	39,700	0.50	-
	CA1	97,200	122	3,900	46,500	50,400	0.56	-	3,900	40,000	43,900	0.49	-	3,200	36,600	39,800	0.44	-
F	CA9	72,700	222	15,500	39,700	55,200	0.89	-	5,800	50,200	56,000	0.78	-	800	52,800	53,600	0.68	-
	Avenida de Petapa	58,300	504	14,600	17,500	32,100	0.80	-	1,500	36,200	37,700	0.67	-	100	22,300	22,400	0.39	-
	South Railway/Busway	30,800	809	-	-	-	-	-	28,500	-	28,500	1.85	-	-	-	-	-	885,500
G	CA1	97,200	131	9,900	58,400	68,300	0.80	-	12,600	61,100	73,700	0.89	-	14,500	45,600	60,100	0.77	-
H	Avenida Bolivar	58,300	231	27,000	0	27,000	0.93	-	12,100	22,700	34,800	0.80	-	1,600	39,900	41,500	0.74	-
I	6a Avenida	62,600	1011	3,000	32,800	35,800	0.62	-	2,700	29,500	32,200	0.56	-	2,800	22,300	25,100	0.45	-
	7a Avenida	62,600	1109	3,100	37,900	41,000	0.70	-	2,900	29,600	32,500	0.57	-	2,900	20,000	22,900	0.41	-
J	24 Calle	51,400	2104	13,700	7,200	20,900	0.67	-	6,000	11,300	17,300	0.45	-	900	18,500	19,400	0.39	-
	Under Pass	98,000	2106	400	34,800	35,200	0.37	-	400	29,000	29,400	0.31	-	400	28,400	28,800	0.30	-
	North Railway/Busway	30,800	817	-	-	-	-	-	16,700	-	16,700	1.08	-	-	-	-	-	678,800
K	6a Avenida	10,800	1008	7,000	0	7,000	1.30	-	6,900	0	6,900	1.28	-	3,700	0	3,700	0.69	-
	7a Avenida	10,800	1105	8,000	0	8,000	1.49	-	5,600	0	5,600	1.04	-	4,900	0	4,900	0.91	-
L	13 Calle	23,300	2205	0	2,000	2,000	0.09	-	0	1,300	1,300	0.06	-	0	2,000	2,000	0.09	-
M	8a Calle	27,400	2014	2,900	14,800	17,700	0.75	-	2,700	12,800	15,500	0.66	-	2,800	10,500	13,300	0.59	-
	9a Calle	27,400	2023	6,000	10,600	16,600	0.97	-	5,400	11,900	17,300	0.83	-	5,900	12,200	18,100	0.68	-
N	Periferico	129,600	301	11,200	69,700	80,900	0.71	-	11,100	68,300	79,400	0.70	-	8,200	74,200	82,400	0.70	-
		51,400	408	0	19,100	19,100	0.37	-	0	20,400	20,400	0.40	-	0	9,600	9,600	0.19	-
O	Periferico	79,200	306	8,200	27,300	35,500	0.55	-	5,300	33,500	38,800	0.56	-	1,500	38,000	39,500	0.52	-
		51,400	415	0	26,800	26,800	0.52	-	0	23,300	23,300	0.45	-	0	18,900	18,900	0.37	-
P	Periferico	116,400	335	1,500	31,000	32,500	0.29	-	1,500	28,300	29,800	0.27	-	1,500	24,000	25,500	0.23	-
		51,400	444	200	1,800	2,000	0.04	-	200	1,700	1,900	0.04	-	200	1,800	2,000	0.04	-



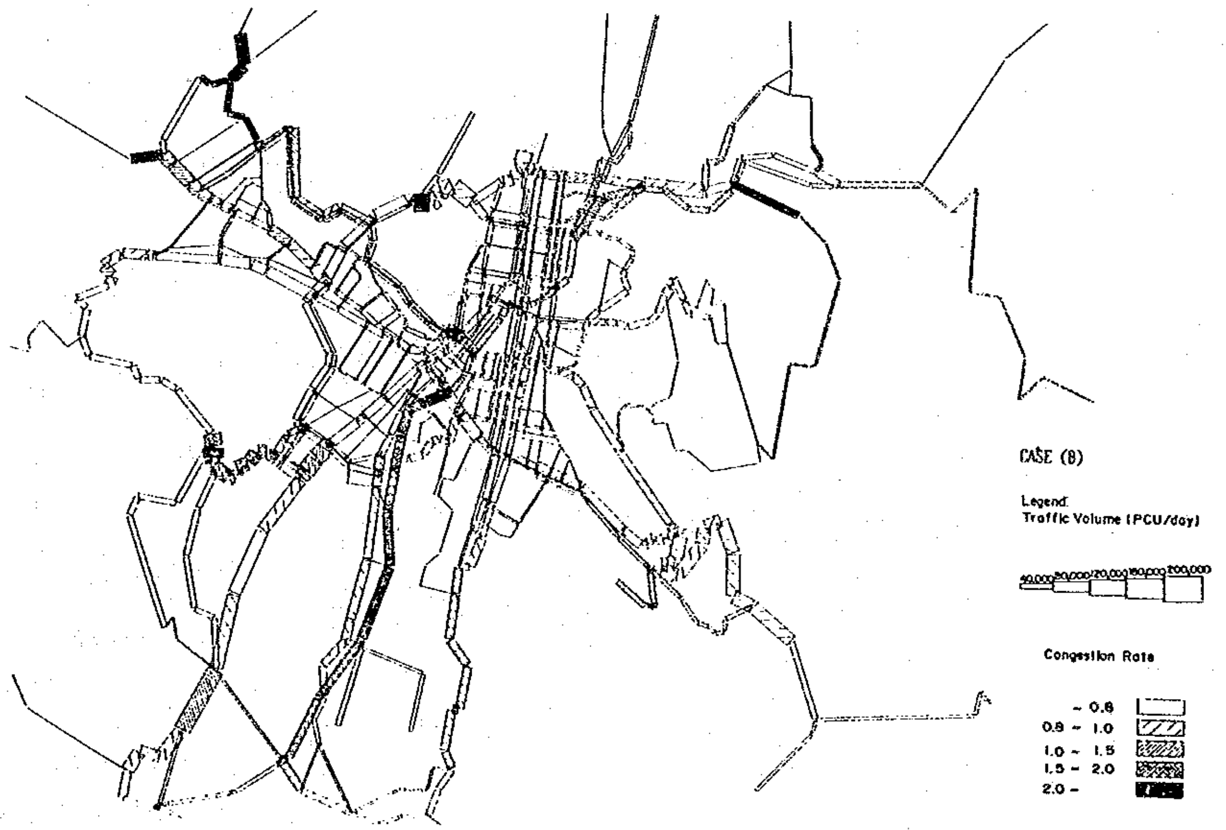
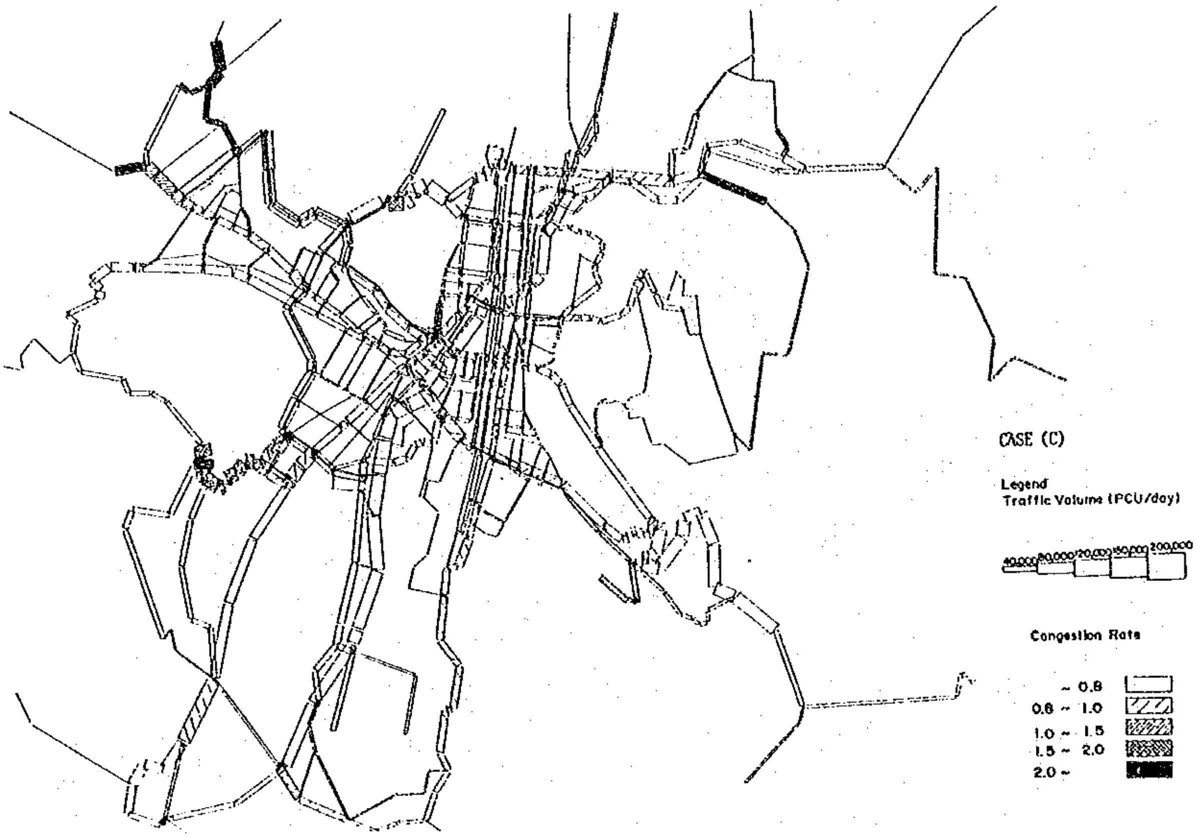


Figure 9.4.5 Traffic Flow (Traffic Assignment Result) (1)



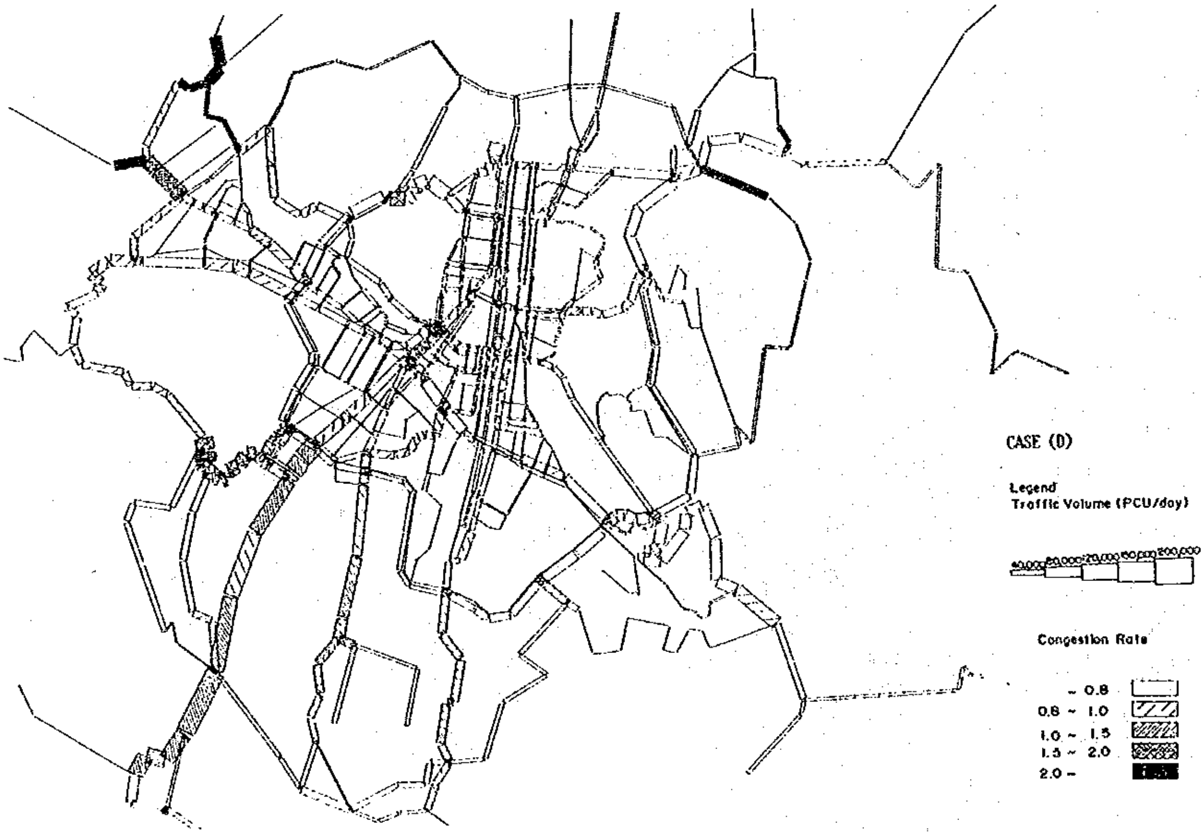


Figure 9.4.6 Traffic Flow (Traffic Assignment Result) (2)

Figure 9.4.7 Traffic Flow (Traffic Assignment Result) (3)

(2) Traffic Analysis of Master Plan Alternative

Table 9.4.5 indicates the comparison of alternatives in terms of traffic demand. The following findings are easily obtained in this table.

a) Average trip length extends to approximate 1.2 times of the present value.

b) Average congestion rate of alternative A, B and D exceeds 1.0. That of the others is less than 1.0. From the point of view of average congestion rate, case F where the railway transit is introduced, is the best.

c) The figures of average travel speed have the same tendency as the average congestion. Namely, introduction of railway transit system effects disappearance of the road congestion.

d) Vehicle travel distance and vehicle travel time become shorter as a better public transport system is introduced.

e) Therefore, it can be derived from these figures that alternative F is the best.

Table 9.4.5 Comparison of Alternatives

Evaluation Items		Master Plan Alternative in 2010						Do Nothing in 2010	Base Case in 1990
		Case (A)	Case (B)	Case (C)	Case (D)	Case (E)	Case (F)	Case (W)	Case (P)
Average Trip Length (km/trip)	Public Transport	9.5	10.0	10.8	9.3	9.6	10.3	9.3	8.0
	Passenger Car	9.2	9.0	8.6	9.0	8.9	8.5	9.6	7.9
	Total	9.4	9.6	10.0	9.2	9.3	9.7	9.4	8.0
Average Congestion Rate (Vol./Cap.)	Public Transport	1.75	1.16	0.48	1.59	1.20	0.67	1.74	1.15
	Passenger Car	1.28	1.24	1.08	0.99	0.92	0.82	1.52	0.54
	Total	1.38	1.22	0.94	1.11	0.98	0.78	1.56	0.69
Average Travel Speed (km/h)	Public Transport	11.1	14.5	34.7	11.7	13.4	29.2	8.0	9.8
	Passenger Car	21.0	24.1	26.7	26.0	27.8	29.8	17.5	34.9
	Total	19.0	22.0	28.6	23.0	24.8	29.6	15.8	28.8
Vehicle Travel Distance (1,000 Veh.*km/day)	Public Transport	1,712.3	1,854.3	2,073.3	1,691.8	1,775.7	1,967.5	1,635.8	663.2
	Passenger Car	13,150.7	12,166.5	10,876.5	12,723.9	12,072.3	11,008.2	14,811.5	4,135.4
	Total	14,863.0	14,020.8	12,949.8	14,415.6	13,848.0	12,975.7	16,447.4	4,798.7
Vehicle Travel Time (1,000 Veh.*h/day)	Public Transport	199.1	178.6	147.3	184.3	179.4	158.9	263.1	91.3
	Passenger Car	932.0	753.6	591.3	722.9	626.6	527.4	1,351.6	152.2
	Total	1,131.1	932.1	738.6	907.2	806.0	686.2	1,614.7	243.5

Note: Average congestion rate does not consider railway in Alternative (C) and (F)

9.5 Evaluation of Alternative Plans

Based on the six alternative plans identified in the previous section, a comparison study is carried out to select the optimum future transport network systems.

9.5.1 Procedure for Evaluation of Alternative Plans

The evaluation of alternative plans is made by the following procedures:

a) Estimation of the following indications relating to the traffic conditions in each alternative plan

- Total vehicle running-kms.
- Total vehicle running-hours
- Average congestion degree
- Average travel speed

b) Estimation of time value and reduction in vehicle operation cost (VOC) by type of vehicle

c) Estimation of traffic benefits of each alternative plan

d) Comparison of each alternative plan

In addition to the above-mentioned aspect, technical and social aspects are examined for overall evaluation of alternative plans. The indications relating to traffic conditions are shown in Section 9.4.

9.5.2 Economic Analysis

The above alternative plans were proposed with the intention of improving transportation conditions in Guatemala City and its surrounding area. In order to identify which alternative is most viable, a project evaluation was performed in this section.

Alternative plans were evaluated through the comparison of their costs and benefits. The internal rate of return (IRR), benefit and cost ratio (B/C) and net present value (NPV) were adopted as the economic indicators of economic evaluation. As the economic evaluation in this section is provisional, the shadow price was not applied, since even if the shadow price were applied, the order of project priority would not be affected. The more detailed evaluation with the shadow price is performed in Chapter 14.

(1) Estimation of Benefit

Savings in the cost of operating vehicles (vehicle operating cost saving) and decreased travel time (travel time saving) were estimated as major benefit items obtained from the above proposed plans. The estimation method of these two benefits are as follows:

1) Benefit of vehicle operating cost saving

The benefit of vehicle operating cost (VOC) saving is defined in the following equation:

$$BVOC = \Sigma\ {}_kVOC^{without} - \Sigma\ {}_kVOC^{with}$$
$$= \Sigma\ \Sigma\ \Sigma\ (c_k \times db^{ij}) - \Sigma\ \Sigma\ \Sigma\ (c_k \times da^{ij})$$

where,

BVOC	:Vehicle operating saving benefit
${}_kVOC^{without}$	:VOC without plan case
${}_kVOC^{with}$	:VOC with plan case
c_k	:Unit cost of VOC (Q/km) (Variable for vehicle running speed)
db^{ij}	:Link distance between i node and j node without plan case
da^{ij}	:Link distance between i node and j node with plan case
k	:Type of vehicle

From the above equation BVOC can be calculated if the c_k, da^{ij} and db^{ij} are available. The latter two data, da^{ij} and db^{ij}, are set in Section 3.1. The data of c_k was determined in the following procedures:

a) Determination of VOC

VOC is set to five type of vehicles, that is, passenger cars, mini buses, large buses, light trucks, medium trucks and heavy trucks, considering the characteristics of transportation in the Study area. VOC is composed of the following eight items: fuel cost, engine oil cost, repair cost, depreciation, interest cost, crew cost, general administration cost and insurance cost. The former three items are variable costs and the remainder are fixed costs. The followings are the calculation method of each VOC item:

<u>FUEL COST</u>

$$FC_i = FEP_i \times FCQ_i$$

FC : Fuel cost
FEP : Economic price of fuel (DATA-5)
FCQ : Fuel consumption quantity (DATA-6)
i : Type of Vehicle

<u>ENGINE OIL COST</u>

$$EOC_i = EEP_i \times ECQ_i$$

EOC : Engine oil cost
EEP : Economic price of engine oil (DATA-7)

ECQ : Engine oil consumption quantity (DATA-8)
i : Type of vehicle

REPLACEMENT/REPAIR COST

Since the repair cost data is not available in the interview survey, only replacement cost of tire is counted.

$$RRC_i = \frac{(EPT_i \times NTR_i \times NOT_i)}{LSV_i \times AVR_i}$$

RRC : Replacement/repair cost
EPT : Economic price of tires (DATA-9)
NTR : Number of tires replaced (DATA-10)
NOT : Number of tires per vehicles (DATA-10)
LSV : Life Span of Vehicle (DATA-4)
AVR : Annual vehicle running distance (DATA-1)
i : Type of vehicle

DEPRECIATION

$$DPi = \frac{PPV_i - SVV_i}{LSV_i \times AVR_i}$$

DP : Depreciation cost
PPV : Economic price of vehicle purchase (DATA-3)
SSV : Salvage value of vehicle (DATA-4)
LSV : Life span of Vehicle (DATA-2)
AVR : Annual vehicle running Distance (DATA-1)
i :Type of vehicle

INTEREST COST

The customers are assumed to borrow half of the purchase price from financial agents with 24% of annual interest and a repayment period of five years.

$$IC_i = \frac{TIC_i}{LSV_i \times AVR_i}$$

IC : Interest cost
TIC : Total interest payment (DATA-13)
LSV : Life span of vehicle (DATA-2)
AVR : Annual vehicle running distance (DATA-1)
i : Type of vehicle

CREW COST

$$CR_i = \frac{ACW_i}{AVR_i}$$

CR : Crew cost (Q/km)
ACW : Total crew wage (DATA-11)
AVR : Annual vehicle running distance (DATA-1)
i : Type of vehicle

INSURANCE COST

$$IC_i = \frac{PPV_i \times VIR_i}{AVR_i}$$

IC : Insurance Cost
PPV : Purchase price of a new vehicle (DATA-3)
VIR : Vehicle insurance rate (DATA-12)
AVR : Annual vehicle running distance (DATA-1)
i : Type of vehicle

GENERAL ADMINISTRATION COST

The general administration cost was determined on the basis of the data obtained through the interview survey to transportation companies.

Based on the above method, VOC was calculated as summarized in Table 9.5.1 with the data obtained by the interview survey to car owners, which are shown from DATA-1 to DATA-13 followed Table 9.5.1.

Table 9.5.1 Vehicle Operating Cost (VOC)
- Economic Price -

Unit: Q/km at 1991 price

	Passenger Car	Mini Bus	Large Bus	Truck		
				Small	Medium	Heavy
Variable Cost						
Fuel	0.218	0.275	0.432	0.137	0.204	0.735
Engine Oil	0.025	0.042	0.042	0.025	0.050	0.067
Repair	0.034	0.078	0.117	0.039	0.069	0.152
Sub-total	0.277	0.395	0.591	0.201	0.323	0.954
Fixed Cost						
Depreciation	0.121	0.166	0.102	0.089	0.068	0.147
Interest	0.092	0.087	0.066	0.047	0.036	0.077
Crews Cost	0.000	0.323	0.184	0.107	0.063	0.450
Insurance	0.113	0.106	0.081	0.057	0.044	0.141
Administration	0.000	0.326	0.682	0.433	0.300	0.211
Sub-total	0.326	1.008	1.115	0.733	0.511	1.026
Total	0.603	1.403	1.706	0.934	0.834	1.980

DATA-1 Average Annual Vehicle Running Km

(Unit: km/Year)

Passenger Car	Mini Bus	Large Bus	Truck		
			Light	Medium	Heavy
20,000	40,000	70,000	70,000	120,000	100,000

DATA-2 Life span of Vehicle

(Unit: Year)

Passenger Car	Mini Bus	Large Bus	Truck		
			Light	Medium	Heavy
10	10	10	10	10	10

DATA-3 Purchase Price of New Vehicle

	Passenger Car	Mini Bus	Large Bus	Truck		
				Light	Medium	Heavy
A	45,000	85,000	113,000	80,000	105,000	188,000
B	30%	15%	30%	15%	15%	15%
C	7%	7%	7%	7%	7%	7%
D	28,350	66,300	71,190	62,400	81,900	146,640

Note: A Market Price (Q/Vehicle)
B Import duty (%)
C Sales Tax (%)
D Economic Price (Q/Vehicle)

DATA-4 Salvage Value

(Unit: Q/Vehicle)

Passenger Car	Mini Bus	Large Bus	Truck		
			Light	Medium	Heavy
4,185	0	0	0	0	0

Passenger Car 45,000 x 0.1 x (1-0.07)

DATA-5 Fuel Economic Price

(Unit: Q/liter)

	Petroleum	Diesel
Market Price	2.36	1.57
Tax	20%	20%
Economic Price	1.888	1.256

Tax
- Consumption tax 7%
- Import tax 11%
- Municipal tax 2%

DATA-6 Fuel Consumption Quantity

	Passenger Car	Mini Bus	Large Bus	Truck		
				Light	Medium	Heavy
A	Petrol	Diesel	Diesel	Diesel	Diesel	Diesel
B	1/8.67	1/4.57	1/2.91	1/9.14	1/6.16	1/1.71

Note: A Kind of Fuel Used
B Consumption (liter/km)

DATA-7 Economic Price of Engine Oil

(Unit: Q/Liter)

	Engine Oil
Market Price	12.53
Tax	20%
Economic Price	10.024

DATA-8 Engine Oil Consumption

(Unit: Liter/km)

Passenger Car	Mini Bus	Large Bus	Truck		
			Light	Medium	Heavy
1/400	1/236	1/236	1/400	1/200	1/150

DATA-9 Economic Price of Tire

	Passenger Car	Mini Bus	Large Bus	Truck		
				Light	Medium	Heavy
A	350	750	1000	500	750	1000
B	20%	20%	20%	20%	20%	20%
C	280	600	800	400	600	800

A : Tire Price (Q/Tire)
B : Tax rate (%)
C : Economic Price of Tires (Q/Tire)

DATA-10 Number of Tires Replaced

	Passenger Car	Mini Bus	Large Bus	Truck		
				Light	Medium	Heavy
A	200,000	400,000	700,000	700,000	1,200,000	1,000,000
B	30,000	30,000	40,000	40,000	50,000	50,000
C	6	13	17	17	23	19
D	4	4	6	4	6	10

A : Total Vehicle Running Distance (km)
(Life Span x Annual Vehicle Running km)
B : Maximum Tire Running km per tire (km)
C : Number of Tires Replaced
D : Number of Tires per Vehicle

DATA-11 Wage of Crews

	Passenger Car	Mini Bus	Large Bus	Truck		
				Light	Medium	Heavy
A		Driv. 1 Asst. 1	Driv. 1 Asst. 1	Driv. 1	driv. 1	driv. 1 asst. 1
B	0	12,900	12,900	7,500	7,500	45,000

Note 1: A Number of crews per vehicle (Person/Vehicle)
B Annual crew wage per vehicle (Q/Year)
Note 2: Wage of crew

	Driver	Assistant	(Unit)
Mini Bus	23	20	Q/day
Large Bus	23	20	Q/day
Light Truck	25		Q/day
Medium Truck	25		Q/day
Large Truck	100	50	Q/day

300 working days per year

DATA-12 Vehicle Insurance Rate

(Unit: %)

Passenger Car	Mini Bus	Large Bus	Truck		
			Light	Medium	Heavy
5	5	5	5	5	7.5

DATA-13 Total Interest Repayment

(Unit: Q)

Passenger Car	Mini Bus	Large Bus	Truck		
			Light	Medium	Heavy
18,478	34,903	46,400	32,850	43,115	77,196

Note: Total interest payment is calculated by the compound interest method.

b) VOC depending on vehicle running speed

VOC calculated in subsection a) was estimated under the condition of the existing vehicle running speed on the road within the Study area. However, the fuel consumption varies depending on the vehicle running speed. Using the relationship between vehicle running speed and fuel consumption as shown in Table 9.5.2, the fuel cost indicated in Table 9.5.1 was modified according to that of Table 9.5.2. This result is shown in Table 9.5.3.

Table 9.5.2 Fuel Consumption by Vehicle Running Speed

(Unit: Liter/km)

km/h	Passen.	M.Bus	L.BUS	S.Truck	M.Truck	H.Truck
5	0.451	0.463	0.527	0.408	0.463	0.519
10	0.393	0.433	0.503	0.374	0.433	0.492
15	0.340	0.400	0.463	0.336	0.400	0.463
20	0.302	0.355	0.426	0.307	0.355	0.404
25	0.277	0.329	0.397	0.282	0.329	0.375
30	0.255	0.307	0.372	0.262	0.307	0.352
35	0.236	0.285	0.351	0.243	0.285	0.326
40	0.219	0.268	0.329	0.228	0.268	0.308
45	0.207	0.254	0.313	0.216	0.254	0.293
50	0.198	0.244	0.299	0.208	0.244	0.280
55	0.190	0.238	0.291	0.202	0.238	0.273
60	0.185	0.234	0.285	0.202	0.234	0.265
65	0.182	0.236	0.291	0.205	0.236	0.268
70	0.179	0.241	0.298	0.208	0.241	0.275
75	0.177	0.251	0.307	0.216	0.251	0.286
80	0.176	0.262	0.318	0.225	0.262	0.298

Table 9.5.3 VOC Depending on Vehicle Running Speed

(Unit: Q/km)

km/h	Passen.	M.Bus	L.BUS	S.Truck	M.Truck	H.Truck
5	0.807	1.568	1.869	1.088	0.999	2.157
10	0.748	1.538	1.845	1.053	0.969	2.130
15	0.696	1.505	1.805	1.016	0.936	2.101
20	0.658	1.460	1.769	0.987	0.891	2.042
25	0.632	1.433	1.740	0.961	0.864	2.014
30	0.611	1.412	1.715	0.941	0.843	1.990
35	0.592	1.390	1.693	0.923	0.821	1.965
40	0.575	1.373	1.672	0.907	0.804	1.946
45	0.562	1.359	1.655	0.895	0.790	1.931
50	0.554	1.349	1.642	0.887	0.780	1.919
55	0.545	1.343	1.633	0.882	0.774	1.911
60	0.541	1.339	1.628	0.882	0.770	1.904
65	0.538	1.341	1.633	0.885	0.772	1.906
70	0.535	1.346	1.640	0.887	0.777	1.914
75	0.533	1.356	1.650	0.895	0.787	1.924
80	0.531	1.367	1.660	0.905	0.798	1.936

In the traffic assignment, the assignment is done by only two types of vehicle. One is "bus", which includes mini bus and large bus, the other is "car", which includes passenger car and trucks. Therefore, the vehicle operating costs of these two types of vehicle were obtained by the weighted average of the existing volume of each cars. The weight is as follows:

"Bus"	Mini Bus	0.3225
	Large Bus	0.6775
"Car"	Passenger Car	0.6706
	Small Truck	0.2529
	Middle Truck	0.0765
	Large Truck	0.0000

Consequently, the vehicle operating cost using for the traffic assignment is obtained as shown in Table 9.5.4.

Table 9.5.4 Vehicle Operating Cost for Traffic Assignment

(Q/km)

km/h	BUS	CAR
5	1.772	0.893
10	1.746	0.842
15	1.708	0.795
20	1.669	0.759
25	1.641	0.733
30	1.617	0.712
35	1.595	0.693
40	1.575	0.676
45	1.560	0.664
50	1.547	0.655
55	1.539	0.648
60	1.535	0.645
65	1.539	0.644
70	1.546	0.643
75	1.555	0.644
80	1.566	0.646

c) Operating cost of light rail transit

Judging from the increase of transportation demand within the Study Area in the future, the necessity of introducing the light rail transit is considered to be very high. In order to estimate the operating cost of light rail transit in the case of its introduction, the unit cost was tentatively calculated, based on "Urban Transit Systems Guidelines for Examining Options" published by the World Bank.

Estimation Premise:

Route length	33 km
Spacing of stations	500 m
Operating hours/day	18 hours
Operating days/Year	350 days
Average trips	9 km
Length of peak period	3 hours
Capacity per train	900 passenger
Cars per train	4 cars
Passengers (average working day)	500,000 persons

Based on the above premise, operating cost of light rail transit is estimated according to the method listed in the above World Bank report. The result is as follows:

Operating Cost of Light Rail Transit
0.299 Q/passenger·km

2) Benefit of travel time saving

The benefit of travel time saving is defined in the following equation:

$$BTTS = \Sigma \{ {}_k v \times ({}_k TRT^{without} - {}_k TRT^{with}) \}$$

where, BTTS : Travel time saving benefit
$TRT^{without}$: Travel time without plan case
TRT^{with} : Travel time with plan case
v : Time value (Q/hour)
k : k=1 Private car user
k=2 Public transportation user

In the above equation TRT can be obtained by assigning traffic on the network. Therefore, BTTS can be calculated if v, time value, is set. The time value was estimated in the following procedures, using the data shown in Table 9.5.5

Table 9.5.5 Household and Car ownership by Income Class

Income class (median)	-300 (150)	301-600 (450)	601-1000 (750)	1001-1500 (1250)	1501-3000 (1750)	3001- (4000)	Total
Household	35539	59693	76275	60508	56911	21230	310156
(weight)	0.116	0.192	0.246	0.195	0.183	0.069	1.000
Ownership	4230	9712	20757	27004	41400	29069	132172
(weight)	0.032	0.073	0.157	0.204	0.313	0.221	1.000
Non-Owner	31390	49981	55518	33504	15511	-	185823
(weight)	0.168	0.269	0.299	0.180	0.084	-	

Note: Income level is monthly income.

a) Income of car owner

The income of the car owner is estimated to be the weighted average of the median of each income class with the number of car-owning households by income class.

$$IPC = \Sigma (IM_j \times wO_j)$$

IPC : Income of car owner
IM : Median of income class
wO : Weight by the number of car owners in each income class
j : Income class

Using data in Table 9.5.4, the income of the car owner is obtained 1842.3 Quetzales per month.

b) Income of non-car owner

The income of the non-car owner is estimated to be the weighted average of the median in each income class with the number of non-car owning households by income class.

$$INC = \Sigma (IM_j \times wN_j)$$

INC : Income of non-car owner
IM : Median of income class
wN : Weight by the number of non-car owners in each income class
j : income class

Using data listed in Table 9.5.4, the income of the non-car owner was 742.6 Quetzales per month.

Assuming 25 working days per month and 8 working hours per day, the hourly income of the car owner and the non-car owner are obtained by dividing the above income by (25 x 8). Therefore, each income level per hour is estimated as follows:

Car owner	9.212 Quetzales/hour
Non-car owner	3.713 Quetzales/hour

It also must be considered that trips are made for varying purposes. Generally, in the transportation study, time value is attached only to trips relating to business. According to the Study Team's survey, the ratio of business related trips and that of non-business related trips were 0.49 to 0.51. Therefore, the above income level should be discounted by 0.49 for the time value of business related trips. In conclusion, the time value was determined as follows if car owners use private cars and non-car owners use public transport:

Time Value of Private Car User	4.514 (Q/hour)
Time Value of Public Transport User	1.819 (Q/hour)

As is the case of the vehicle operating cost, the above time value is also set for the categories of "Bus" and "Car" for the traffic assignment. The time value of each bus or car is obtained by multiplying the above time value per person by the average number of passengers of "Bus" or "Car". The average number of passengers is 20 persons for "Bus" and 1.8 persons for "Car", respectively. Therefore, the time value of "Bus" is 36.38 Quetzales per hour and the time value of "Car" is 8.125 Quetzales per hour.

Time Value of "Car"	8.125 Quetzales/hour
Time Value of "Bus"	36.38 Quetzales/hour

(2) Estimated Benefit

Based on the previously mentioned procedures, vehicle operating running cost saving benefit (VOC Benefit) and travel time saving benefit (Time Value Benefit) were estimated for six alternative plans and "Do Nothing Case". The result of this estimation is summarized in Table 9.5.6.

Table 9.5.6 Summary of Estimated Benefit

(Unit: Million Q/Year)

Items Of Evaluation	Mode	Master Plan Alternatives						Do Nothing Case Case(w)	Base Case (1990)
		Alt. A	Alt. B	Alt. C	Alt. D	Alt. E	Alt. F		
Running Cost	Public	888.7	951.7	1012.6	875.8	913.9	972.3	857.4	344.1
	Private	3381.0	3052.8	2681.4	3163.0	2957.0	2665.9	3938.2	966.9
	Total	4269.7	4004.5	3694.0	4038.8	3870.9	3638.2	4795.6	1311.0
Time Cost	Public	2172.5	1948.7	1608.1	2011.9	1957.7	1733.8	2872.0	996.2
	Private	2271.8	1836.9	1441.3	1762.1	1527.4	1285.5	3294.6	371.1
	Total	4444.4	3785.7	3049.4	3773.9	3485.1	3019.2	6166.5	1367.3
Running Cost	Public	-31.3	-94.3	-155.2	-18.4	-56.5	-114.9		
	Private	557.2	885.4	1256.8	775.2	981.2	1272.3		
	Total	525.9	791.1	1101.6	756.8	924.7	1157.4		
Time Cost	Public	699.4	923.2	1263.9	860.1	914.3	1138.2		
	Private	1022.7	1457.6	1853.2	1532.5	1767.2	2009.1		
	Total	1722.2	2380.9	3117.2	2392.6	2681.4	3147.3		
Total Benefit	Public	668.1	828.9	1108.7	841.7	857.8	1023.3		
	Private	1579.9	2343.0	3110.0	2307.7	2748.4	3281.4		
	Total	2248.1	3172.0	4218.8	3149.4	3606.1	4304.7		

According to this result, the vehicle running cost of public transport for each plan is estimated to be higher than that of the "Do Nothing Case". The reason is as follows: in the "Do Nothing Case" the public transport is assumed to pass through the shortest route among zones as much as possible, while in alternative plans the public transport is planned to pass through the trunk roads as much as possible. Consequently, the route distance in the alternative plan shows a tendency to be longer than that of the "Do Nothing Case", which leads to the higher vehicle operating cost of the public transport. As another reason, it is considered that the number of buses increases in alternative plans, compared with the "Do Nothing Case" because of the introduction of bus priority lanes and bus exclusive lanes.

Looking at the travel time cost saving, both public transport and private cars obtain much more benefit, compared with vehicle operating cost saving. In the total benefit, a private car acquires three to five times more benefit than public transport for each alternative. The alternative F shows the most benefit, almost 3.8 billion Quetzales per year, followed by the alternative C of 3.5 billion Quetzales per year. The least benefit is shown in alternative A, 1.9 billion Quetzales per year.

(3) Cost estimation

The construction cost of each plan was tentatively estimated as shown in Table 4.2.2. This cost is the financial cost, not the economic cost. Since data of tax, was not available in this stage of the Study, 7% of the financial cost was subtracted from the financial cost for the purpose of obtaining the economic cost. Table 9.5.7 shows the financial cost and economic cost of each alternative plan.

Table 9.5.7 Cost Estimation

(Unit: Q1,000)

Alternative Plans	Financial Cost	Economic Cos
Alternative A	1,696,210	1,577,475
Alternative B	2,186,356	2,033,311
Alternative C	4,918,650	4,574,345
Alternative D	2,316,333	2,154,190
Alternative E	2,502,634	3,257,450
Alternative F	4,803,217	4,466,992

(4) Economic Analysis

Using the benefits and costs estimated above, economic indicators were calculated in order to compare the viability of each alternative plan. The following three indicators are adopted in this analysis:

1) Benefit Cost Ratio (B/C)

B/C is a ratio of the total present value of economic benefit to the total present value of economic cost. For project viability B/C of more than 1.0 is required.

$$B/C = \Sigma B_t /(1+i)^t / \Sigma C_t/(1+i)^t$$

Here, B : Present value of benefit
C : Present Value of cost
i : Discount rate (12%)
t : Year
T : Calculation period

2) Net Present Value (NPV)

NPV is the difference between the total present value of benefit and the total present value of cost. A positive value of NPV is required for project viability.

$$NPV = \Sigma B_t/(1+i)^t - \Sigma C_t/(1+i)^t$$

3) Internal Rate of Return (IRR)

IRR is a discount rate such that the net present value equals zero. The higher the value of IRR, the more desirable the project, however, the value must be higher than the interest rate of the IDB (12%).

$$IRR = \Sigma (B_t-C_t)/(1+i)^t = 0$$

Table 9.5.8 summarizes the value of the above three economic indicators by alternative plan. The values of B/C and NPV were calculated under the discount rate of 12%. The benefit and cost stream for each alternative are shown in Table 9.5.9.

Table 9.5.8 Value of Economic Indicators by Alternative

Alternative	B/C	NPV (Million Q)	IRR (%)
Alternative A	3.183	2781	29.0
Alternative B	3.537	4166	30.9
Alternative C	2.230	4436	23.1
Alternative D	3.315	4026	29.8
Alternative E	3.540	4773	31.0
Alternative F	2.131	4179	22.4

Table 9.5.9 Benefit and Cost Stream by Alternative

(Unit: Million Q)

Year	Alternative A		Alternative B		Alternative C		Alternative D		Alternative E		Alternative F	
	Benefit	Cost	Benefit	Cost	Benefit	Cost	Benefit	Cost	Benefit	Cost	Benefit	Cost
1995	0.0	339.2	0.0	437.3	0.0	983.7	0.0	463.3	0.0	500.5	0.0	960.6
1996	0.0	339.2	0.0	437.3	0.0	983.7	0.0	463.3	0.0	500.5	0.0	960.6
1997	0.0	339.2	0.0	437.3	0.0	983.7	0.0	463.3	0.0	500.5	0.0	960.6
1998	0.0	339.2	0.0	437.3	0.0	983.7	0.0	463.3	0.0	500.5	0.0	960.6
1999	0.0	339.2	0.0	437.3	0.0	983.7	0.0	463.3	0.0	500.5	0.0	960.6
2000	580.1	0.0	844.7	0.0	1168.5	0.0	838.4	0.0	975.5	0.0	1195.3	0.0
2001	664.3	0.0	964.2	0.0	1328.6	0.0	957.0	0.0	1111.8	0.0	1358.7	0.0
2002	760.6	0.0	1100.6	0.0	1510.6	0.0	1092.5	0.0	1267.0	0.0	1544.4	0.0
2003	871.0	0.0	1256.3	0.0	1717.5	0.0	1247.1	0.0	1444.0	0.0	1755.6	0.0
2004	997.3	0.0	1434.0	0.0	1952.8	0.0	1423.5	0.0	1645.7	0.0	1995.6	0.0
2005	1142.0	0.0	1636.9	0.0	2220.3	0.0	1624.9	0.0	1875.6	0.0	2268.4	0.0
2006	1307.7	0.0	1866.4	0.0	2524.4	0.0	1854.9	0.0	2137.6	0.0	2578.5	0.0
2007	1497.4	0.0	2132.7	0.0	2870.2	0.0	2117.4	0.0	2436.1	0.0	2931.0	0.0
2008	1714.6	0.0	2434.4	0.0	3263.4	0.0	2417.0	0.0	2776.4	0.0	3331.6	0.0
2009	1963.4	0.0	2778.8	0.0	3710.4	0.0	2759.0	0.0	3164.2	0.0	3787.1	0.0
2010	2248.2	0.0	3171.9	0.0	4218.7	0.0	3149.4	0.0	3606.2	0.0	4304.6	0.0

As a result of economic analysis, all six alternative plans were confirmed to be viable. Among these, alternative E shows the highest viability from the viewpoint of three economic indicators, that is, IRR is 31.0%, B/C is 3.540, and NPV is 4774 million Quetzales. Alternative B ranked second, however, its economic viability is almost the same as that of alternative E.

Considering the estimation errors of cost and benefit and/or future uncertainty, the sensitivity analysis was performed under the cost increase of 5%,10%, 15%, and 20% and the benefit decrease of 5%, 10%, 15%, and 20%, respectively. Even in the worst case of 20% cost increase and 20% benefit decrease, all alternative plans were viable as shown in Table 9.5.10.

Table 9.5.10 Results of Sensitivity Analysis (Worst Case: 20% Cost up and 20% Benefit Down)

Alternative	B/C	NPV (Million Q)	IRR (%)
Alternative A	1.698	1333	18.8
Alternative B	1.886	2183	20.4
Alternative C	1.189	1024	13.7
Alternative D	1.768	2003	19.4
Alternative E	1.881	2603	20.5
Alternative F	1.137	757	13.1

(5) Other benefits

In addition to the above-mentioned benefits, the proposed plans bring about other benefits, although they are not quantified in terms of money.

1) Employment demand effect

Construction projects require a lot of workers, both skilled and unskilled. Considering that the unemployment problem is much more severe for unskilled workers than for skilled workers, the number of unskilled workers required in the projects in the proposed plan was estimated, based on project cost estimation. Table 9.5.11 shows the demand for unskilled workers expected.

Table 9.5.11 Expected Unskilled Workers

Alternative Plans	Amount of Investment (Thousand Q)	Necessary Unskilled Workers (Person)
Alternative A	1,696,210	15,700
Alternative B	2,186,356	20,200
Alternative C	4,918,650	45,500
Alternative D	2,316,333	21,400
Alternative E	2,502,634	23,100
Alternative F	4,803,217	44,500

2) GDP increment effect

With the past five years data of GDP and public road improvement investment, the following relationship was obtained through the regression analysis:

$$GDP = 852.145 + 1.085 \times GDP_{-1} + 2.630 \times RINV$$

GDP : Gross domestic product
GDP_{-1} : GDP in the previous year
RINV : Road improvement investment

From the above equation, it is understood that one Quetzal of road improvement investment makes GDP increase 2.63 Quetzales. Consequently, the following GDP increment as shown in Table 9.5.12 will be expected if the proposed project is executed.

Table 9.5.12 Expected GDP Increment through the Proposed Projects
(Unit: Q1,000)

Plans of Alternatives	Amount of Investment	Expected GDP Increment
Alternative A	1,696,210	4,461,032
Alternative B	2,186,356	5,750,116
Alternative C	4,918,650	12,936,049
Alternative D	2,316,333	6,091,996
Alternative E	2,502,634	6,581,927
Alternative F	4,803,217	12,632,460

3) Saving Energy

As shown in Table 9.4.5, each alternative plan reduces the vehicle travel distance or increase the average travel speed. These two factors contribute the saving of energy consumption. In this part firstly the energy consumption is estimated for each alternative plan, then the energy saving is estimated.

From Table 9.5.2, gasoline and diesel consumption in terms of liter/km is calculated as shown in Table 9.5.13. In the Table, Car(P) shows gasoline consumption of passenger cars. Car(D) and Bus show diesel consumption of trucks and buses, respectively. Therefore, Car(D) and Bus is calculated with the following weight, based on the existing vehicle composition.