CHAPTER 8
Technical Analysis for Conceptual Plan

8. TECHNICAL ANALYSIS FOR CONCEPTUAL PLAN

8.1. GENERAL

Evaluation of the alternative plans for the trunk and feeder bus system, which are proposed in the conceptual plan in Chapter 7 are conducted in this Chapter 8. The evaluation of each alternative is conducted by tangible items. This Chapter covers only the evaluation from the viewpoint of engineering aspects exclusive of economic and financial evaluation of these projects, which are conducted in another chapter.

The major beneficiaries of the busway system are the public transport users. Busways can result in improvement in the quality of bus travel. The fully segregated bus priority lanes are constructed on the existing right-of-way and private car users will be limited in allocation of roadspace. Therefore, it is necessary to evaluate the advantages and disadvantages to both users.

As mentioned in Chapter 5, busway system evaluation must be conducted comprehensively taking all aspects of public transport into consideration: administration, operators, public transport users, private car users and environment. The business of public transport operators will be especially impacted. These impacts must be properly evaluated.

8.2. FUTURE PASSENGER DEMAND ON TRUNK BUSWAY

8.2.1. OUTLINE OF EVALUATION

(1) Evaluation Items

The evaluations of trunk-feeder bus system in the years 2000 and 2005 are conducted separately. This is because the systems in both years are different in busway network and passenger demand. Figure 8.2-1 and Figure 8.2-2 summarize the evaluation items in 2000 and 2005, respectively. In 2000, the effects of the introduction of trunk bus system into the current bus system are evaluated, while the trunk bus system itself in 2005 with which the current system is replaced in the whole city is evaluated by comparing each alternative with "Without case".

The following items are evaluated:

1) Demand for trunk bus system by bus passengers
2) Effectiveness of trunk bus system which covers the effects of trunk bus system and impacts on transport in Bogota such as passenger cars
3) Influence of non-reciprocal bus operation by cutting a route at suburban bus terminals

With regard to the demand for trunk bus system by passengers in 2000, trunk bus passenger volume relates to the current bus service, i.e., its volume depends on a level of cutting current bus routes to overlap with trunk bus routes. Therefore, in order to avoid overlapping current bus routes with the trunk bus routes, the current bus routes where a length of route overlaps with busways on Caracas and Calle 80 for a distance of 2.5km or more are cut. The ratio of discontinued current bus routes to total is approximately 30%.

In 2005, there is a major question as to whether the passenger demand on 11 trunk busways will exceed the line flow capacity (maximum peak hour passenger flows) or not. This means, since the proposed trunk buses are operated on the 11 segregated trunk busways with trunk and feeder bus system, there is a question whether supply and demand

will be balanced. Therefore, the necessity for supplementary current bus operation was examined and confirmed. Consequently, approximately 55% of the current bus routes need to be continued until 2005. There are several busways with over passenger demand, even though supplementary current buses are operated. Those busways need to be augmented with urgent railway plan or additional trunk busways.

(2) Alternative Cases

In Chapter 7, each component of alternative cases such as bus route alternatives, bus fleet system, tariff system, busway cross section, bus stop and bus terminals was explained. In this Section, alternative plans simulated by transit assignment model are proposed as shown in Table 8.2-1.

In 2000, alternative Case-1 is "Without project case" which is the current public transport system but demand in 2000. Case-2 is the case which plans three (3) trunk busways with six (6) trunk bus routes on the assumption that the ordinary buses on the current bus system are operated.

In Case-4, as mentioned above, in order to obtain the more proper passenger demand of trunk buses, diversion from ordinary buses to trunk buses is examined by changing the number of cutting of current bus routes which overlap with trunk bus routes. From this examination, the current bus routes, where a length of route overlaps with the trunk busways by 2.5km or more, are cut. Case–4 is set as a base case in which 6 trunk bus routes are served on the current bus routes where about 30% of the total current bus routes that overlap with the trunk busways are cut.

Case-3 is similar to Case-4 except that in the inter-municipal routes, the influence of non-reciprocal bus operation is examined. That is a case where inter-municipal bus route which forms a bus network will have one route cut at suburban bus terminals mentioned in the Chapter 5. On the bus network, buses which belong to Soacha can not come into Bogota and Bogota's buses also can not operate into Soacha.

Evaluation Flow in 2000

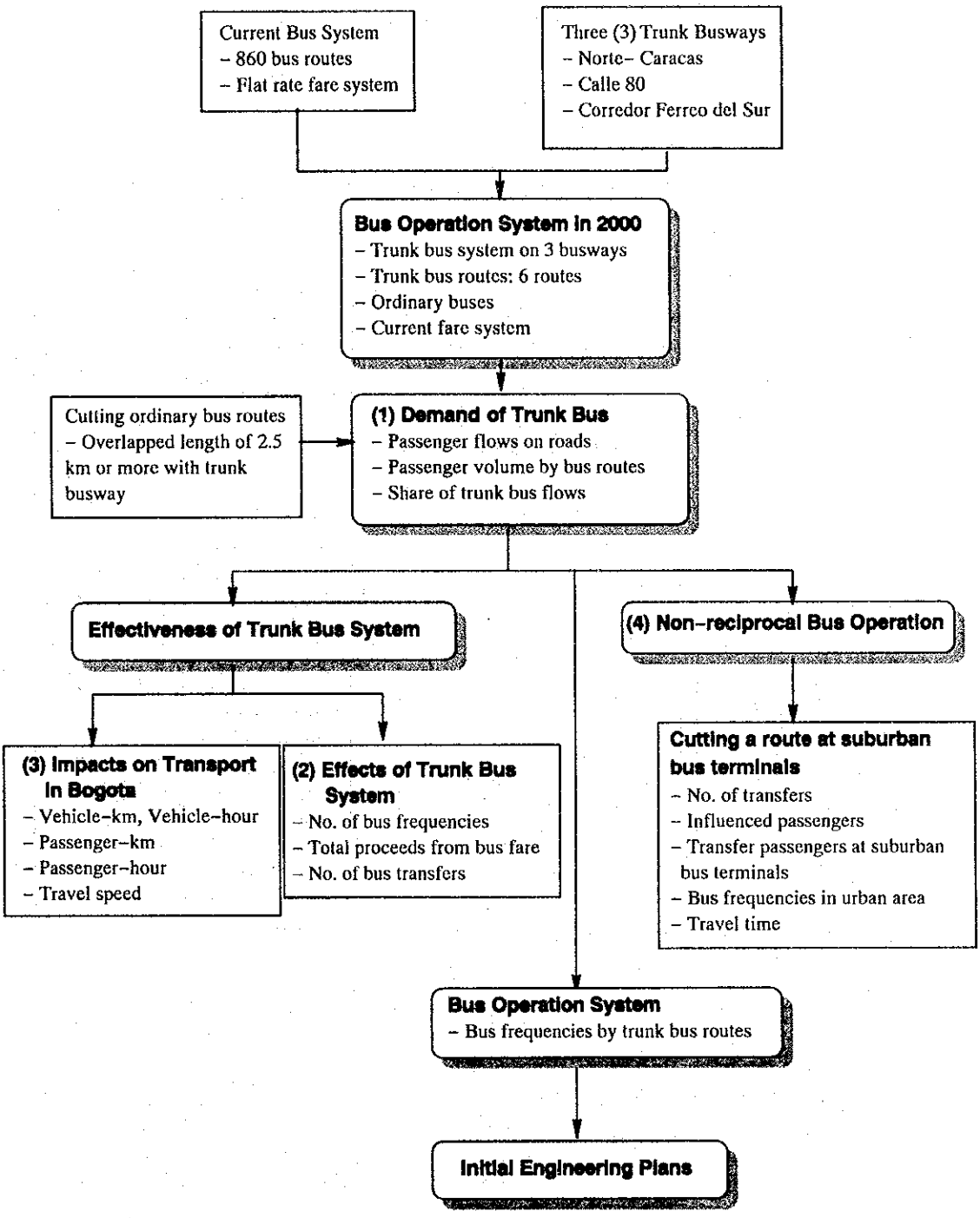

Figure 8.2-1 Evaluation Flow in 2000

Evaluation Flow in 2005

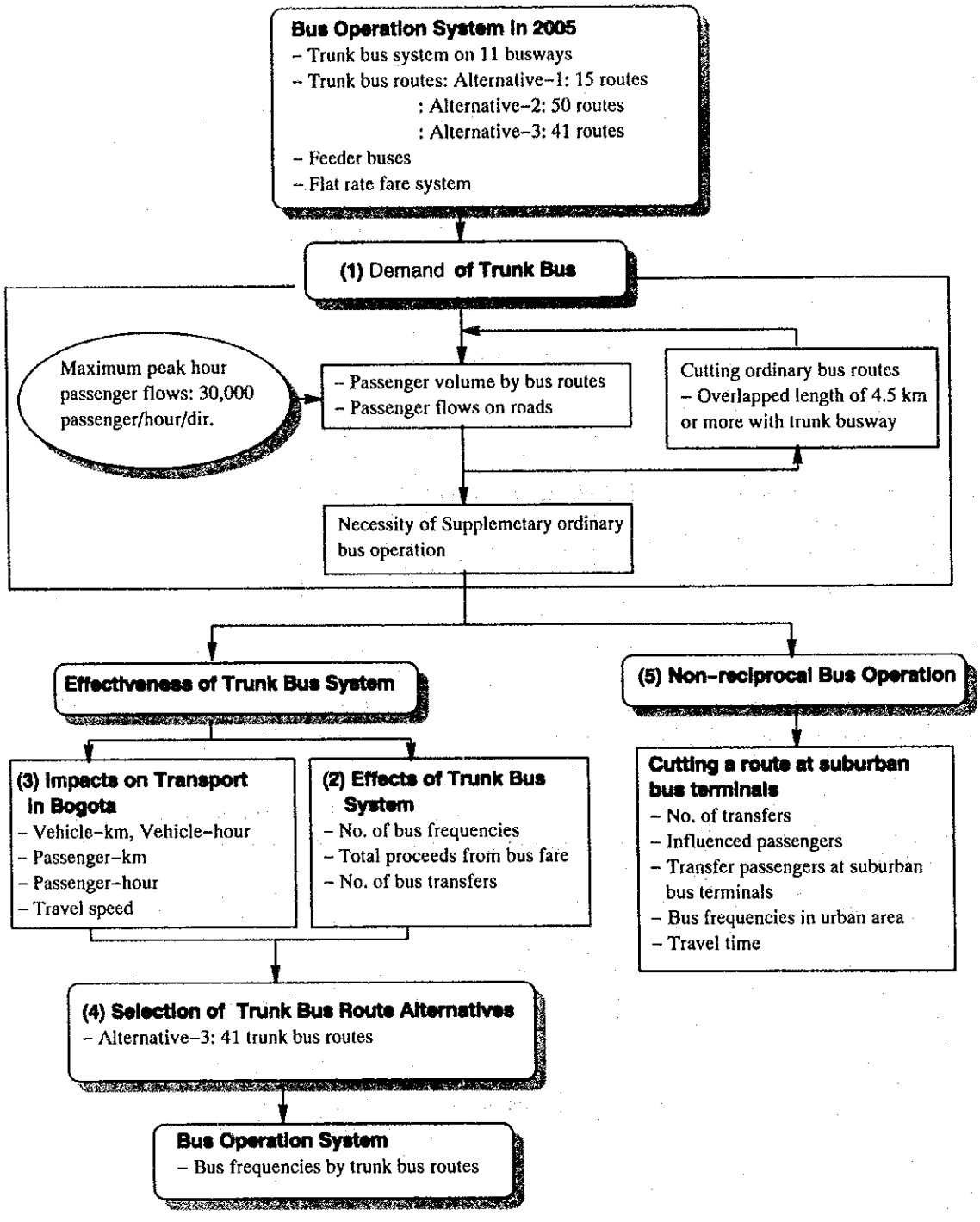

Figure 8.2-2 Evaluation Flow in 2005

In 2005, eleven (11) fully segregated busways are completed and the ordinary buses on the current bus operation system is not operated, and the existing bus routes basically change to new trunk bus routes. Case-1 is "do-nothing case". Case-2 is Alternative case-1 of trunk bus route with 15 trunk bus routes: a bus route network connecting only adjacent terminals to each other. Case-3 is Alternative case-2 with 50 trunk bus routes: bus routes connect adjacent terminals and several major bus terminals to each other.

However, in process of the Study, it is found out that the passenger demand on 11 trunk busways exceeds the maximum peak hour passenger flows, and supply of system is not enough to meet the demand. It is indispensable to operate supplementary ordinary bus service. Therefore, Case-5 is added for estimating the proper passenger demand of trunk buses by the same method as that in 2000. In Case-5, the trunk bus routes are also examined and the trunk bus route Alternative-3 is added with 41 bus routes.

Case-5 is set as a base case with Alternative case-3. Case-4 is the same case as Case-5 except for the inter-municipal routes. The influence of non-reciprocal bus operation is also examined the same manner as that in 2000.

Table 8.2-1 Alternative Cases in 2000 and 2005

In the Year 2000

Case	Trunk Bus Routes	Ordinary Bus Routes	Inter-municipal Routes	Fare System
1	-	Current System	Current System	Current System
2	6 routes on 3 Busways	ditto	ditto	ditto
3	ditto	To cut 30% of current bus routes	To cut a route at suburban bus terminals	ditto
4	ditto	ditto	Current System	ditto

In the Year 2005

Case	Trunk Bus Routes	Ordinary Bus Routes	Inter-municipal Routes	Fare System
1	-	Current System	Current System	Flat rate with as additional fare
2	Alternative-1 with 15 routes on 11 Busways	-	To connect into central terminal	ditto
3	Alternative-2 with 50 routes on 11 Busways	-	ditto	ditto
4	Alternative-3 with 41 routes on 11 Busways	To cut 45% of ordinaly bus routes	To cut a route at suburban bus terminals	ditto
5	ditto	ditto	To connect into central terminal	ditto

8.2.2. EVALUATION IN 2000

(1) Demand on Trunk Buses

1) Peak hour passenger flows on roads

Figure 8.2-3 to Figure 8.2-4 show the peak hour passenger flows on roads in Case-1 and Case-2 which are the number of passengers travelling in one direction past a point during one hour in the morning peak. Those numbers on bus network in the Figures indicate the flows in inbound and outbound directions per hour.

As can be seen, in Case-1, the heavy inbound passenger flows in 2000 are on Calle 80 with 25,000 passenger/hour/dir. On Av. Caracas, 30,000 - 35,000 passengers are assigned. In Case-2 where both trunk and ordinary buses are operated on the same busway, the passenger flows on those roads are heavier than those in Case-1. Those figures on both roads are approximately 35,000-40,000, respectively. These passenger flows on both roads

exceed the line capacity (maximum peak hour passenger flows/ hour/dir) which is approximately 20,000 – 25,000 passengers/hour/dir measured in several cities.

In 2000, it is obvious that the heavy passenger flows on major roads like Av. Caracas and Calle 80 is beyond the line capacity of the current system as shown in Do-nothing case (Case-1)and Case-2. Therefore, in order to reduce the load on the busways and to secure the more proper passenger demand of trunk buses, it is necessary to cut some current bus routes which overlap with trunk bus routes.

2) Influence of trunk buses after cutting diverted current bus routes

The trunk buses are operated on the fully segregated bus priority busways, while the ordinary buses do not operate on those busways. On the roads with busway, it is necessary that a current bus route overlapping with busway be cut in order to avoid overlapping current bus routes with the trunk bus routes, and to secure the more proper passenger demand of trunk buses. Therefore, the current bus routes to pass through Av. Caracas and Calle 80 are chosen and the overlapped lengths were identified. Assuming that the current routes passing through one or two blocks between major intersections on Av. Caracas or Calle 80 are saved, the share of trunk bus passengers to the ordinary bus passengers is examined. Finally, the current bus routes where the length of route overlapping with busways on Caracas and Calle 80 is 2.5km or more, were cut. The ratio of discontinued current bus routes to total is approximately 30%. This figure also takes into account the scheduled phase out of old fleet.

As mentioned in Chapter 4, according to Law 105, Dec. 1995, until 2001, the phasing out bus and buseta represent approximately 45% of the total buses and 44%, respectively, in contrast to 2% for microbus. Table 8.2-2 summarizes the scheduled phase out of old fleet. In the proposed system in 2000, it is more reasonable to cut approximately 30% of the total current routes in order to phase out the old fleets in consideration of the age distribution of bus fleets.

Figure 8.2-5 shows the peak hour passenger flows on roads in Case 4 which are the number of passengers travelling in one direction past a point during one hour in the morning peak. As can be seen, the heavy inbound passenger flows are on Calle 80 with 32,000 passenger/hour/dir, which is lesser than 42,000 in Case-2. On Av. Caracas, passengers in the peak hour are assigned with 24,000- 32,000. On Calle 80, ratio of the passenger flows in Case 4 to that in Case-2 decreases by 20% - 25%.

Table 8.2-2 Scheduled Phase Out of Old Fleet and Discontinued Bus Routes

	Year	2000
1)	Ratio of buses phased out	
	Bus	45%
	Buseta	44%
	Microbus	2%
2)	Ratio of discontinued routes	30%

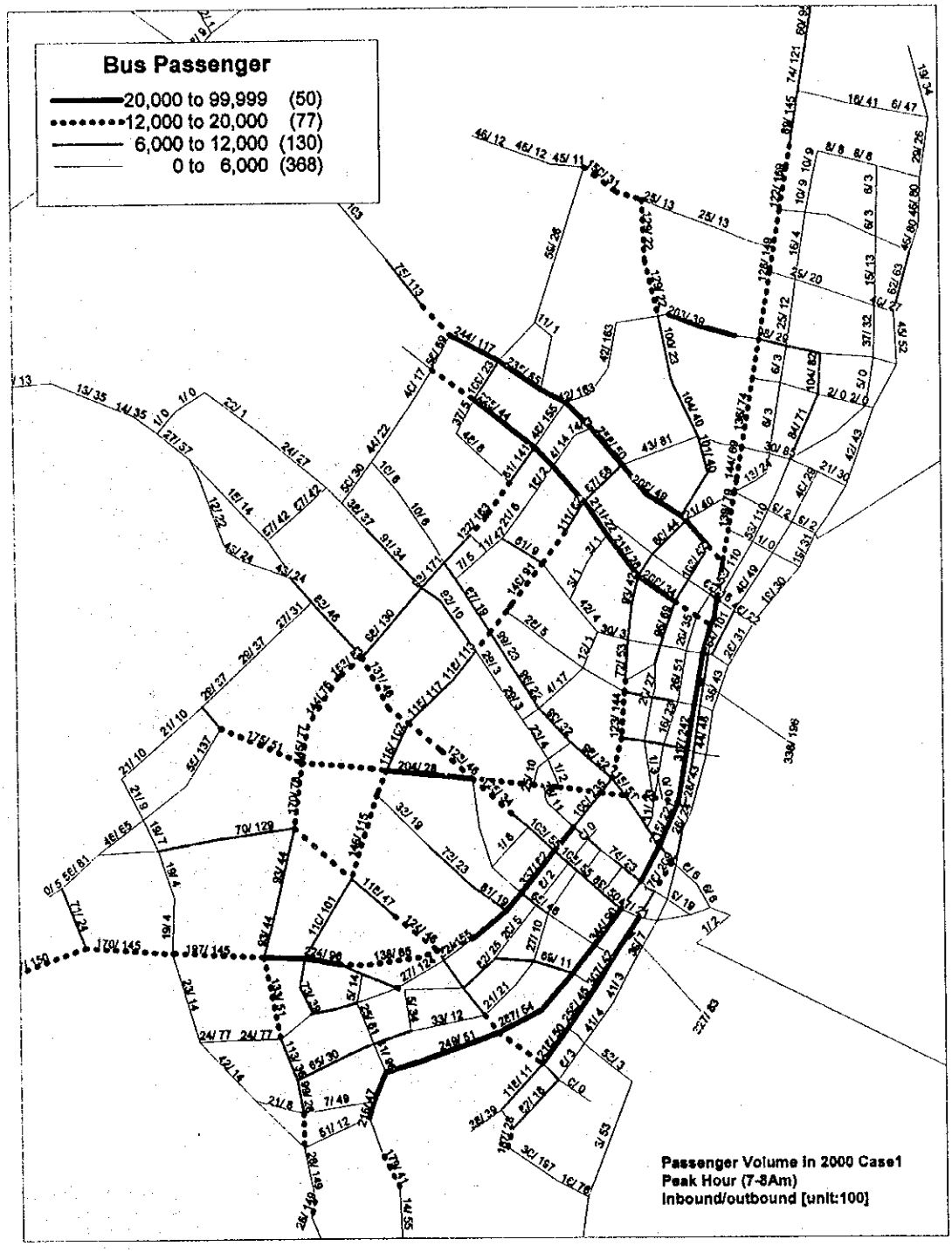

Figure 8.2-3 Peak Hour Bus Passenger Flows in 2000 (Case-1)

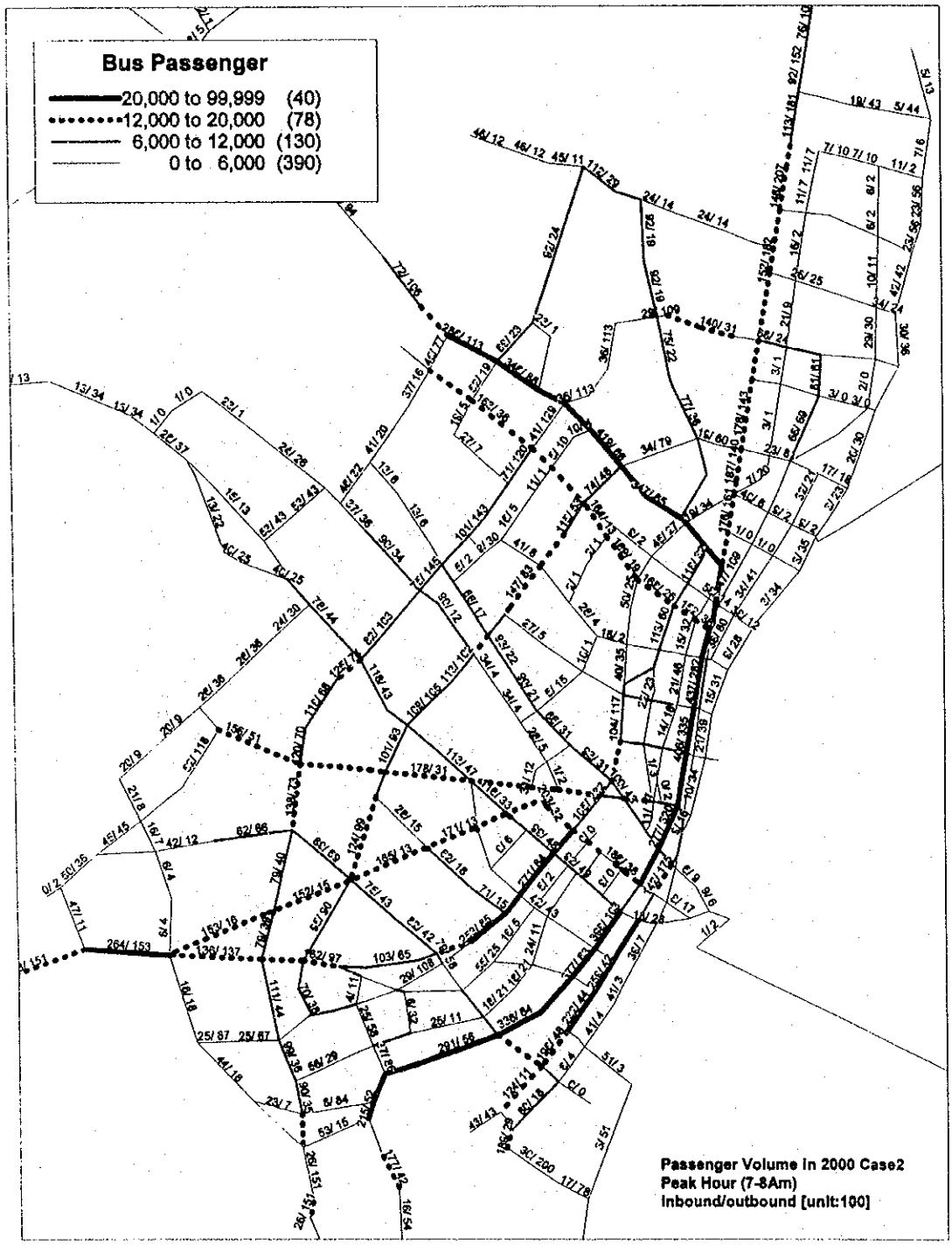

Figure 8.2-4 Peak Hour Bus Passenger Flows in 2000 (Case-2)

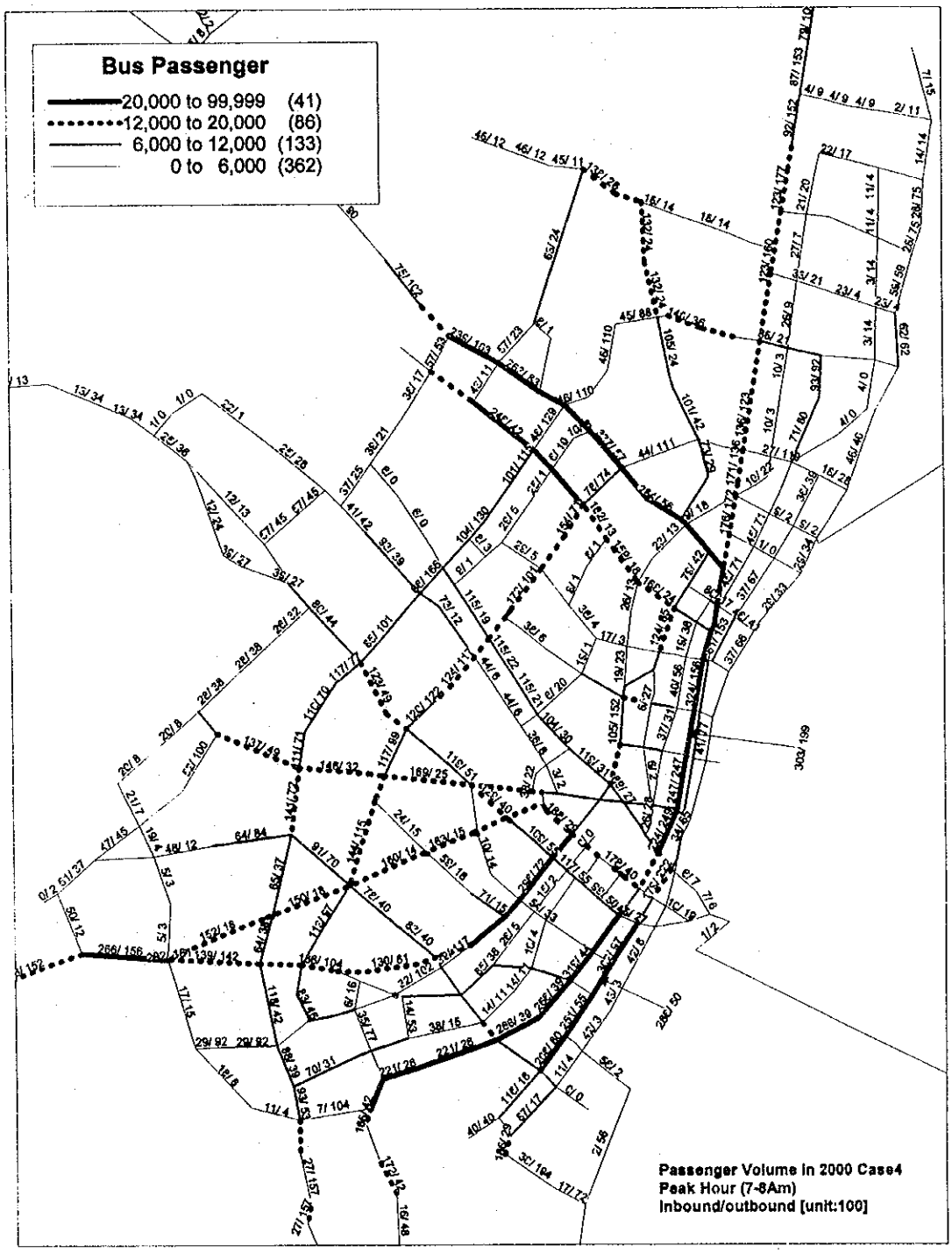

Figure 8.2-5 Peak Hour Bus Passenger Flows in 2000 (Case-4)

3) *Bus passenger volume on board by trunk bus routes*

Figure 8.2-6 to Figure 8.2-7 show passengers on board in Case-4 on six (6) trunk bus routes. As can be seen, the highest number of passengers is estimated on route No. T05 operated on Calle 80 through Av. Caracas. Its figures are from 10,000 to 20,000 per hour/dir in the peak hour. The routes with somewhat high volume are No. T06 (Corredor ferreo de Sur: 10,000- 16,000) and No.T04 (10,000 – 18,000). Passengers on Route No. 02 on Av. Caracas in southern segment is as low as 250. The remaining routes are estimated with 5,000 –10,000 per hour/dir.

Figure 8.2-8 shows discontinued current bus routes where a length of route, overlapping with busways on Caracas and Calle 80, is 2.5km or more.

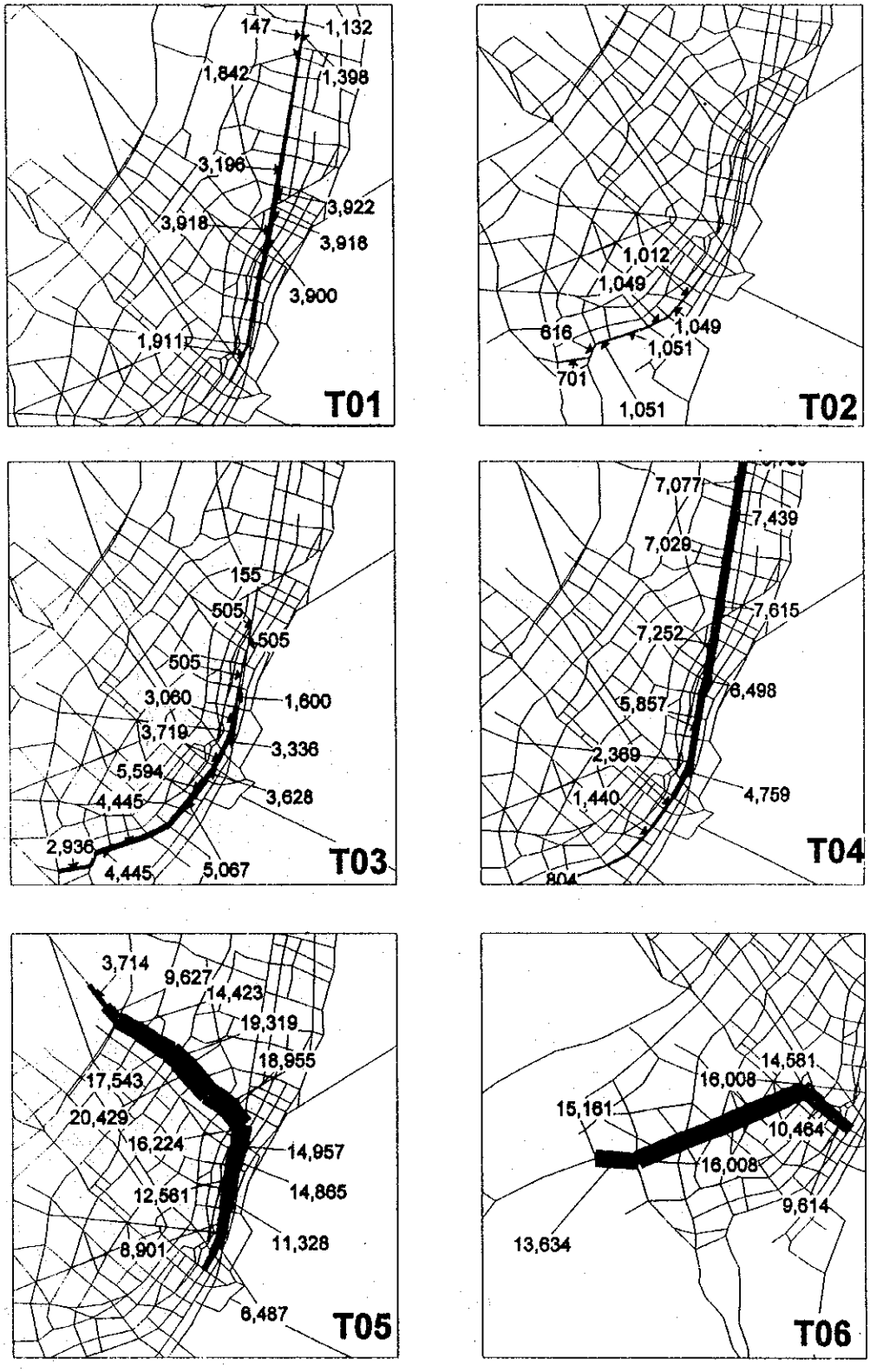

Figure 8.2-6 Trunk Bus Passengers on Board by Route in Case-4 (Inbound Direction)

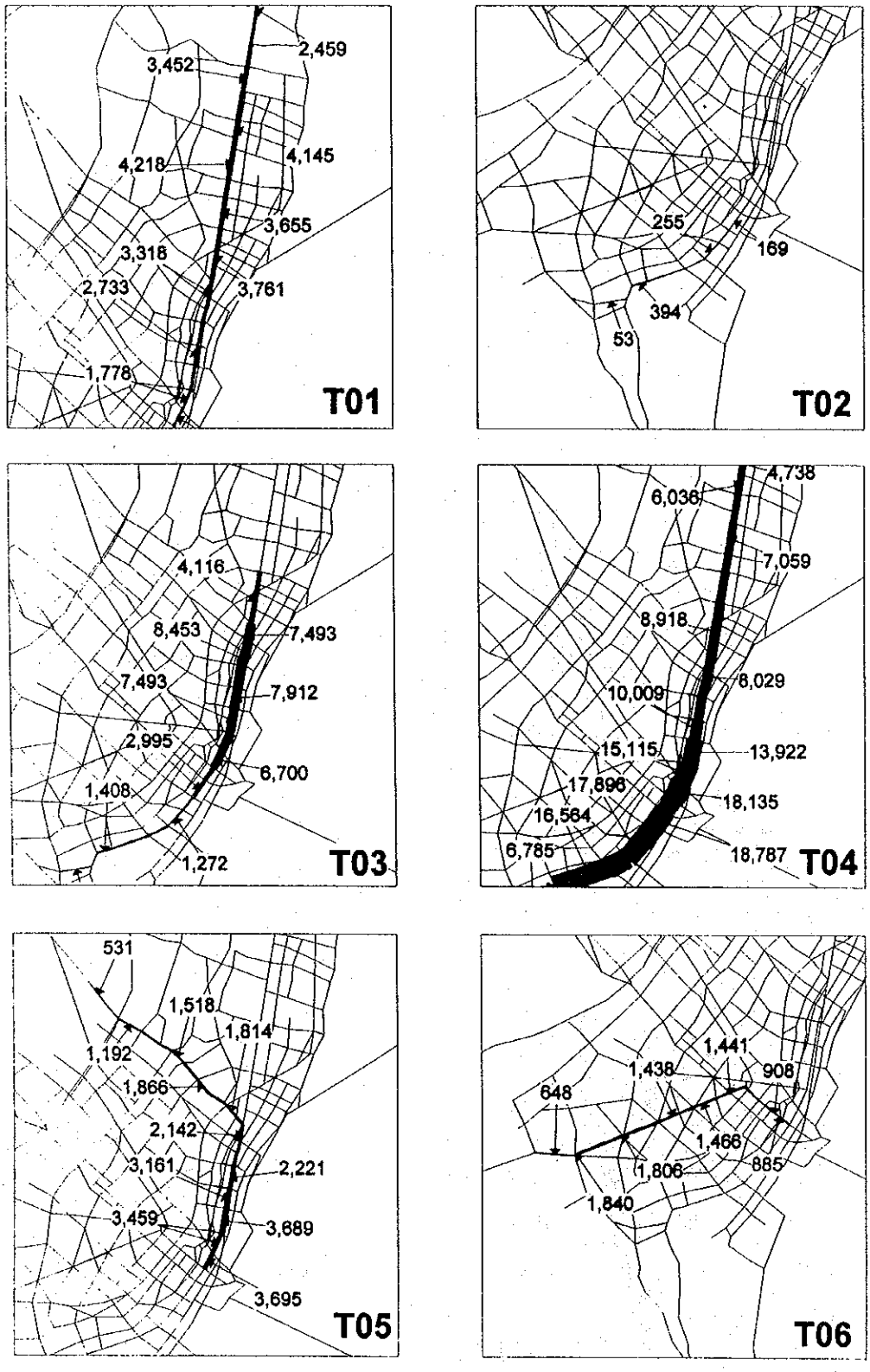

Figure 8.2-7 Trunk Bus Passengers on Board by Route in Case-4 (Outbound Direction)

Figure 8.2-8 Current Bus Routes Cut in Case 4

4) Share of trunk bus operation

Three (3) trunk busways with 6 trunk bus routes are introduced in 2000, while other major buses are operated on the current bus operation system. The share of trunk bus passengers on board is low as of 2000.

Figure 8.2-9 shows the shares of bus passenger-km by bus system which is classified into two (2) categories; trunk bus and ordinary bus. The shares of passenger-km by the categorized system in Case 4 are 20% for trunk bus passengers and 80% for ordinary bus passengers, in contrast to 10% and 90% in Case-2.

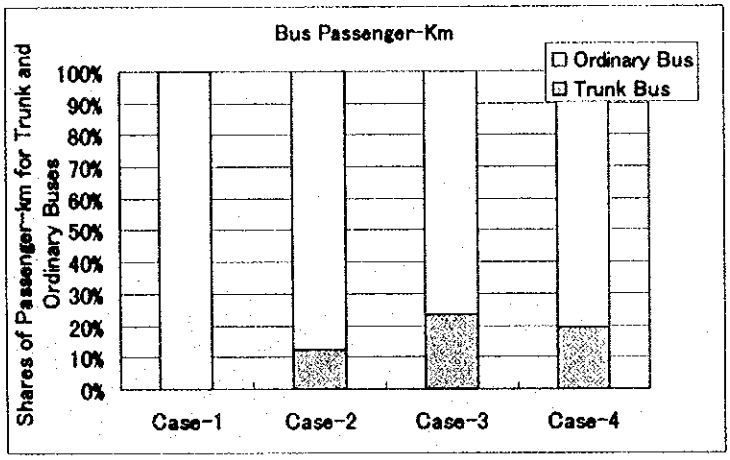

Figure 8.2-9 Shares of Passenger-Km by Trunk and Current Bus Routes

5) Ratios of trunk bus passenger and bus flows on roads

Figure 8.2-10 and Figure 8.2-11 show trunk and ordinary bus passenger flows on Av. Caracas and Calle 80. They represent the number of passengers travelling in one direction past a point in the morning peak hour (one hour). In this case, those figures show inbound direction in the morning peak hour.

Bus passenger flows on Av. Caracas in Case-2 are approximately 40,000 per direction/hour, of which 11,000 are trunk buses, equivalent to 30%. On Calle 80, the passenger flows in Case-2 are approximately 35,000 per direction/hour, of which 11,000 are on trunk buses (32% of total).

In Case-4, since 30% of the current bus routes are discontinued, particularly on Av. Caracas and Calle 80, the shares of trunk bus passengers to total flows on Caracas and Calle 80 increase to approximately 90% and 80%, respectively.

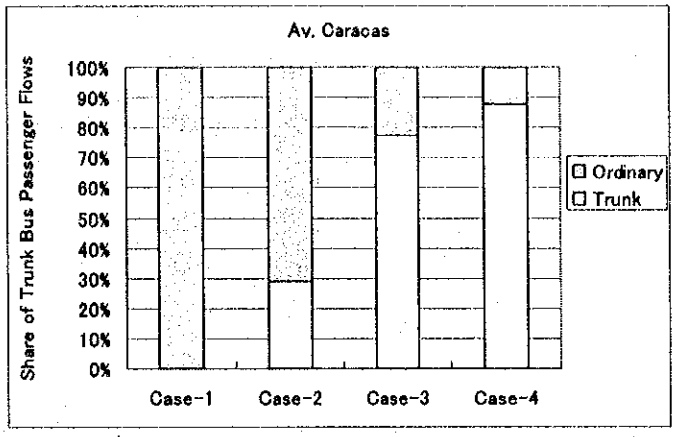

Figure 8.2-10 Passenger Flows of Trunk and Ordinary Buses on Av. Caracas

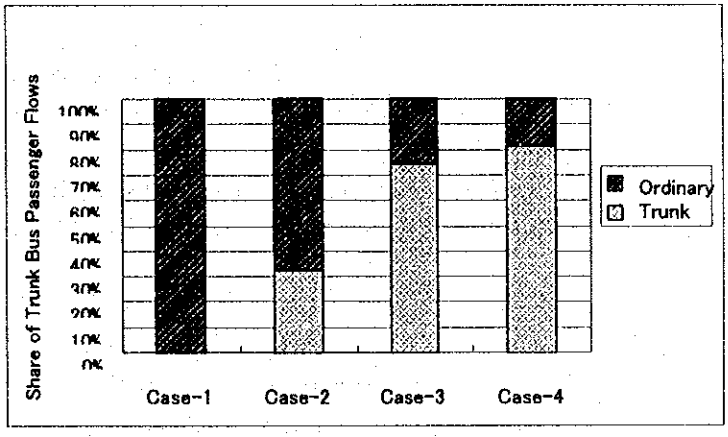

Figure 8.2-11 Passenger Flows of Trunk and Ordinary Buses on Calle 80

(2) Effectiveness of Trunk Bus System

The bus operation system in 2000 in connection with preservation of the current bus system is evaluated by comparing each alternative with "Without case". The effects of trunk bus system are conducted by the following evaluation parameters:

1) Number of bus service frequencies (number of operated buses)

2) Productivity of bus system

3) Number of transfers

4) Total proceeds from bus fare

1) Number of bus frequencies

Table 8.2-3 shows the number of bus service frequencies by cases. In 2000, total numbers of bus service frequencies in Case-2 are approximately 14,200 frequencies per hour, of which 400 are trunk buses and 13,800 are ordinary buses. The different figure in comparison with the Without case is as low as 3,200 frequencies.

In Case-3 which cuts an urban bus route at suburban terminals, i.e., non-reciprocal operation, trunk bus operation frequency increases to 690 due to supplemental operation

service for passengers who dwell outside Bogota. Case-4 is also low in bus service frequency due to cutting the diverted current bus routes. The total number of bus service frequencies in Case-4 is 13,200 frequencies per hour. Decrease ratio of Case-4 to Case-1 (Without) in total bus service frequencies is approximately 35%. This indicates that the efficiency of bus transport in terms of passengers per bus increases in the trunk bus system.

Table 8.2-3 Numbers of Bus Service Frequencies by Cases

Type of Buses	Case-1	Case-2	Case-3	Case-4
Trunk Bus	0	416	689	680
Ordinary Bus	17393	13762	13020	12558
Total	17393	14178	13709	13238
Ratio	1.00	0.82	0.79	0.76

2) *Productivity of bus system*

Bus travel conditions are improved by operation on fully segregated busways dedicated to the trunk bus system, while private car users are restricted with respect to travel convenience. Both impacts of private and public modes on travel conditions in whole Bogota are evaluated in terms of "transportation work" and "productivity".

Transportation is defined as the movement of *a number of buses or passengers (u)* over a *distance (s)* during as elapsed interval of *time (t)*. When a number of buses or passengers is transported over a bus route, ratios of those three elements (*u, s* and *t*) define basic performance attributes of that transportation service.

Transportation work (w) is the quantity of performed movement. It is computed as the number of transported buses multiplied by the distance over which they are carried:

$$w = u \times s$$

Work is one of the basic measures of a transportation system output. The work can be expressed in several different units: **person-km**, **vehicle-km**, etc.

Vehicle or Passenger productivity $\mathbf{P_p}$ is the product of bus flow or passenger flow (*P*) that can be transported on a line past a fixed point during one hour and operation speed or average travel speed (*Vc*). The concept of productivity is very useful: it incorporates flow and speed. The passenger productivity can be expressed in several different units: **person-hour** and **vehicle-hour**.

$$P_c = P \times V_c$$

Figure 8.2-12 shows a comparison of passenger-km of private and bus modes in "With cases" (Case-2 to Case-4) with those in the "Without case". The passenger-km of both bus and private modes are almost constant for every case.

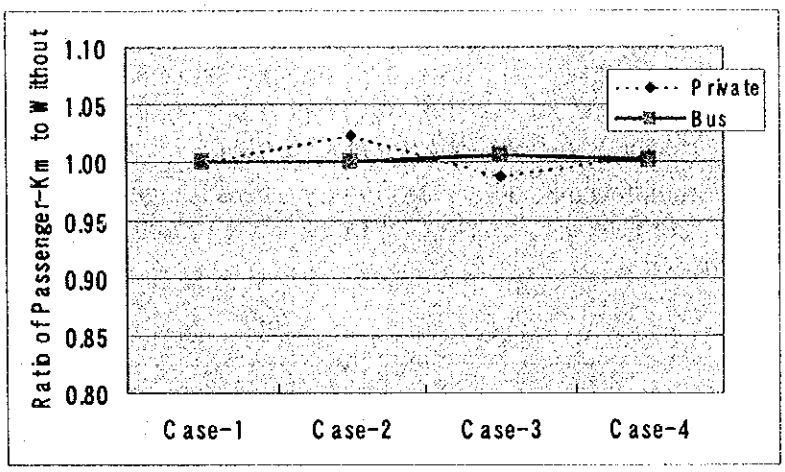

Figure 8.2-12 Ratio of Passenger-km of Private and Bus Modes to Without Case

Figure 8.2-13 also shows passenger-hour in the same manner as that for the passenger-km. The bus passenger-hour is calculated on the assumption that trunk bus operation speed is independent on traffic volume on same roads, while the ordinary bus speed reduces in proportion to traffic volume on roads. Bus passenger-hour in Case4 somewhat decreases by 6% to the Without case, while it is constant for the private. This shows that the passenger travel speed is improved by approximately 6%.

In the Without case, since the ordinary buses are operated on roads without segregated busway, or on the traffic lane with mixed transport, the bus travel speed is reduced according to traffic volume on roads. On the other hand, the trunk bus is not influenced by traffic volume on roads because of operation on segregated busway.

The variation of passenger-km and passenger-hour indicate that trunk bus operation on only three trunk busways is a little more efficient in time saving, in contrast to that in travel distance.

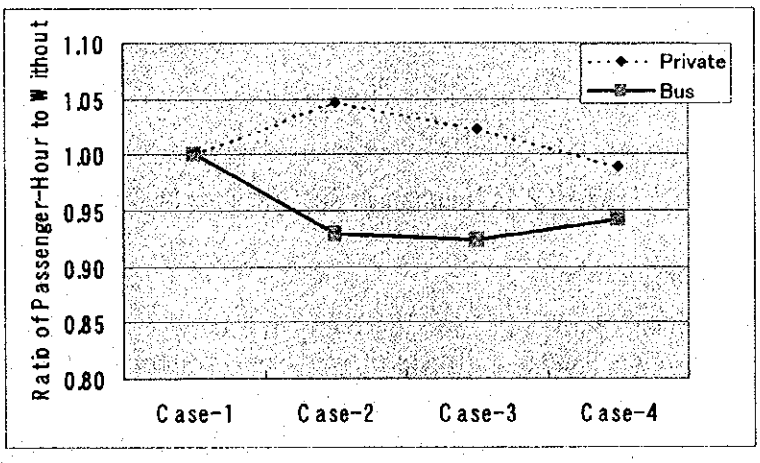

Figure 8.2-13 Ratio of Passenger-hour of Private and Bus Modes to Without Case

3) Number of transfers

Numbers of transfers at bus stops and terminals by each case are shown in Figure 8.2-14. In Case-1 and Case-2 the ratios of each transfer times are similar. The number of transfers with one or more times in Case-4 raises at 43%, in contrast to 33% for Case-1. Passengers who are forced to transfer in Case-4 (difference between Case-1 and Case-4) are approximately 57,000, equivalent to 10% of the passengers.

Since the share of trunk bus passengers to ordinary bus passengers is low in 2000, the ratio of passengers who are forced to transfer by trunk buses (comparing between Case-1 and Case-4) is also low.

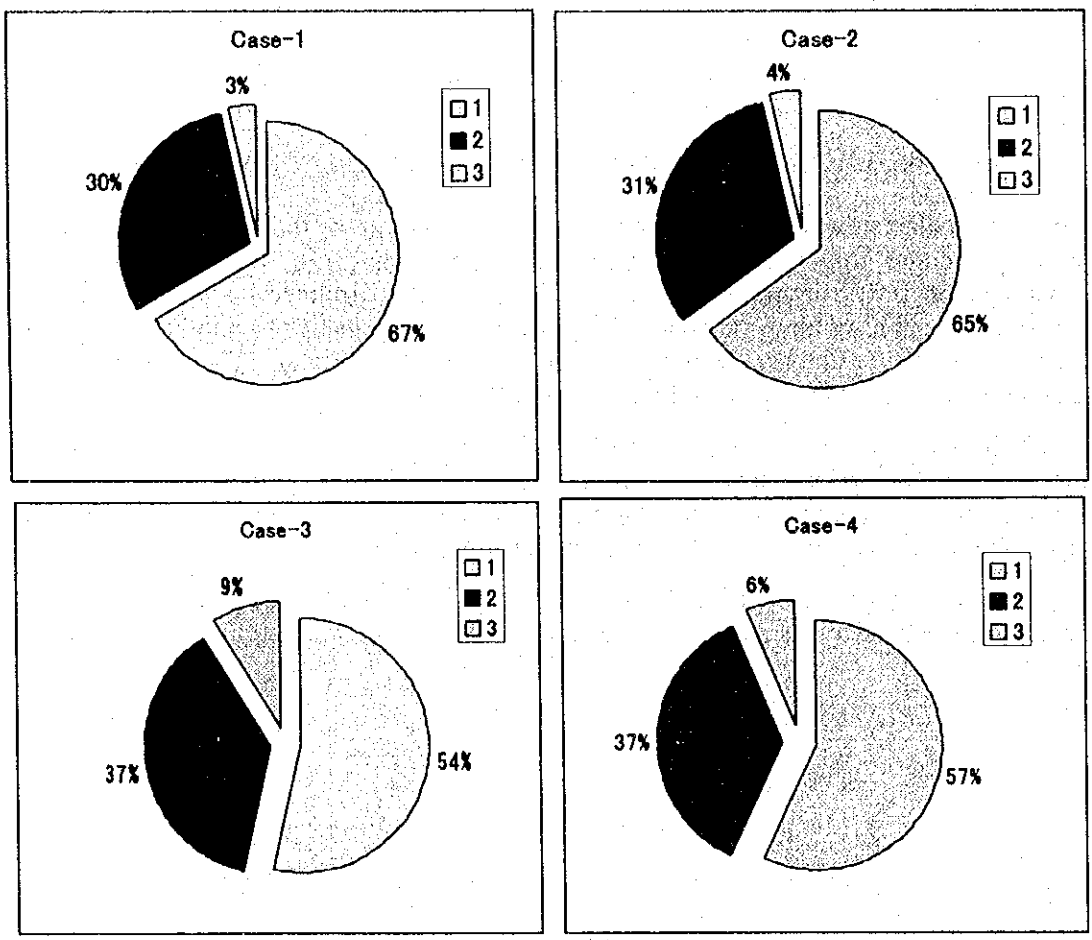

Figure 8.2-14 Numbers of Bus Transfers by Cases

4) Total proceeds from bus fare

Total proceeds from bus fare collection are compared between "With" (Case-2 to 4) and "Without" cases to understand the effects of trunk bus system in 2000 (see Table 8.2-4). $430 pesos are applied for both trunk and ordinary bus fares.

As can be seen, total fare collection in Case-2 is similar to that in Do-nothing case. It indicates that not much is expected from the effects of trunk bus system. As for Case-3 and 4, the total proceeds raise at 13% and 10%, respectively, comparing to Without case. This relates that bus transfer times somewhat rise. This indicates that it is possible to cut bus

fare rate by approximately 10% in Case4. The total proceeds per frequency-km in Case-4 rise at 1.3 times in comparison with the Without case.

Table 8.2-4 Total Proceeds from Bus Fare

	Total Proceeds ($pesos)	Ratio to Case-1	Per Frequency-Km
Case-1	343,543,770	1.00	1.00
Case-2	347,812,380	1.01	1.23
Case-3	389,855,200	1.13	1.63
Case-4	375,726,690	1.09	1.32

(3) Impacts on Transport in Bogota

1) Travel speed

Travel speeds outside bus lanes on roads with the segregated trunk busways decrease after constructing the busways, while other roads without busways don't change. Figure 8.2-15 shows the travel speeds on through traffic lanes outside bus lanes on major roads. The travel speed on Av. Caracas/ Norte in Case-4 compared to "Without" case reduces to approximately 70%, in contrast to 80% on Calle 80.

On the other hand, the travel speeds on the roads without trunk busway slightly change in Case-2 to Case-4. Therefore, the introduction of trunk busway on the existing roadway disadvantages private vehicles which pass through on that road at the travel speed.

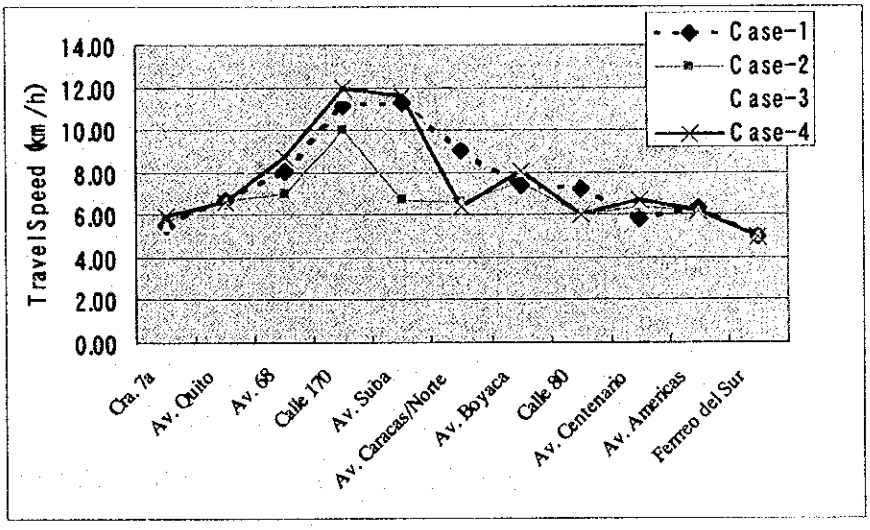

Figure 8.2-15 Travel Speed on Roads

2) Traffic congestion

The travel speeds of private vehicles passing through the outside lane on road with busway will be somewhat reduced. With regard to the travel speed for private vehicles, this indicates that the traffic congestion on the road will become severe. Those travel conditions are estimated in terms of PCU-km and PCU-hour for private vehicles on road section with less than a travel speed of 10 km/hr. Table 8.2-5 shows the change of PCU-km and PCU-hour to the Without case in the whole study area. The congested length and delay in the whole area in Case-4 to Without case in terms of PCU-km and PCU-hour will slightly decrease. Those figures show that the ordinary bus flows on roads without

busways will decrease by 30% on the current bus routes, and travel conditions for private vehicles are slightly improved, while travel speeds on roads with busways will decrease.

Table 8.2-5 Change of PCU-km and PCU-hour for Private Vehicles on Road Section with less than a Travel Speed of 10 km/h

Items	Case-1	Case-2	Case-3	Case-4
PCU-Km on 10km/h or less	1.00	1.05	0.96	0.97
PCU-hour on 10km/h or less	1.00	1.05	0.96	0.97

(4) Non-reciprocal Bus Operation

1) Increase of transfers at suburban bus terminals

In the alternative Case-3, inter-municipal bus routes form a bus network configuration to force transferring bus at suburban bus terminals. On this bus network, buses which belong Soacha can not come into Bogota and Bogota's buses also can not operate into Soacha. Therefore, the number of bus passengers who transfer at suburban bus terminals raises at every suburban bus terminal (see Figure 8.2-16). Figure 8.2-17 shows the peak hour bus passenger flows in Case-3.

Increase of passengers who transfer at the suburban bus terminals directly influences the dimensions of bus parking facility such as number of berths, passenger facilities, etc. In several terminals, number of transferring passengers raises at 1.6 – 1.8 times. It is necessary to acquire additional land space to accommodate the increase.

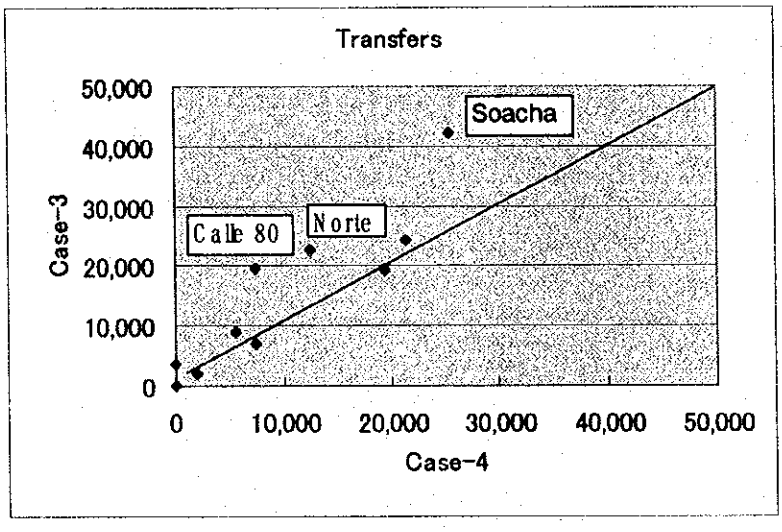

Figure 8.2-16 Comparison of Number of Transfers at Suburban Bus Terminals

2) Increase of total transfer times

Figure 8.2-18 shows the ratio of transfer by number of times among all bus passengers including suburban area. The passengers without transfer reduce to 54% (Case-3) from 57% (Case-4), while the passengers who transfer 1 or 2 times increase at 46% in Case-3. Approximately 18,000 (3% of total) passengers are forced to transfer at suburban terminals comparing to Case-4.

3) *Increase of bus service in urban area*

Table 8.2-6 shows the numbers of bus passengers on board in the urban area in Case-4 and Case-3 which are classified into three categories: trunk buses, ordinary buses inside urban area and buses operated outside urban area. On the bus network in Case-3, urban bus passengers within the city of Bogota are increased in order to transport the passengers who dwell outside Bogota.

Since bus passengers who were forced to transfer at bus terminals change a bus operated inside Bogota, supplementary bus service frequency rises for those passengers. The increase ratios of those bus passengers in Case-3 to those in Case-4 are approximately 4%. The different numbers of bus passengers between Case-3 and Case-4 somewhat increases by 33,000 of which 163,000 are inside Bogota and –130,000 are outside Bogota.

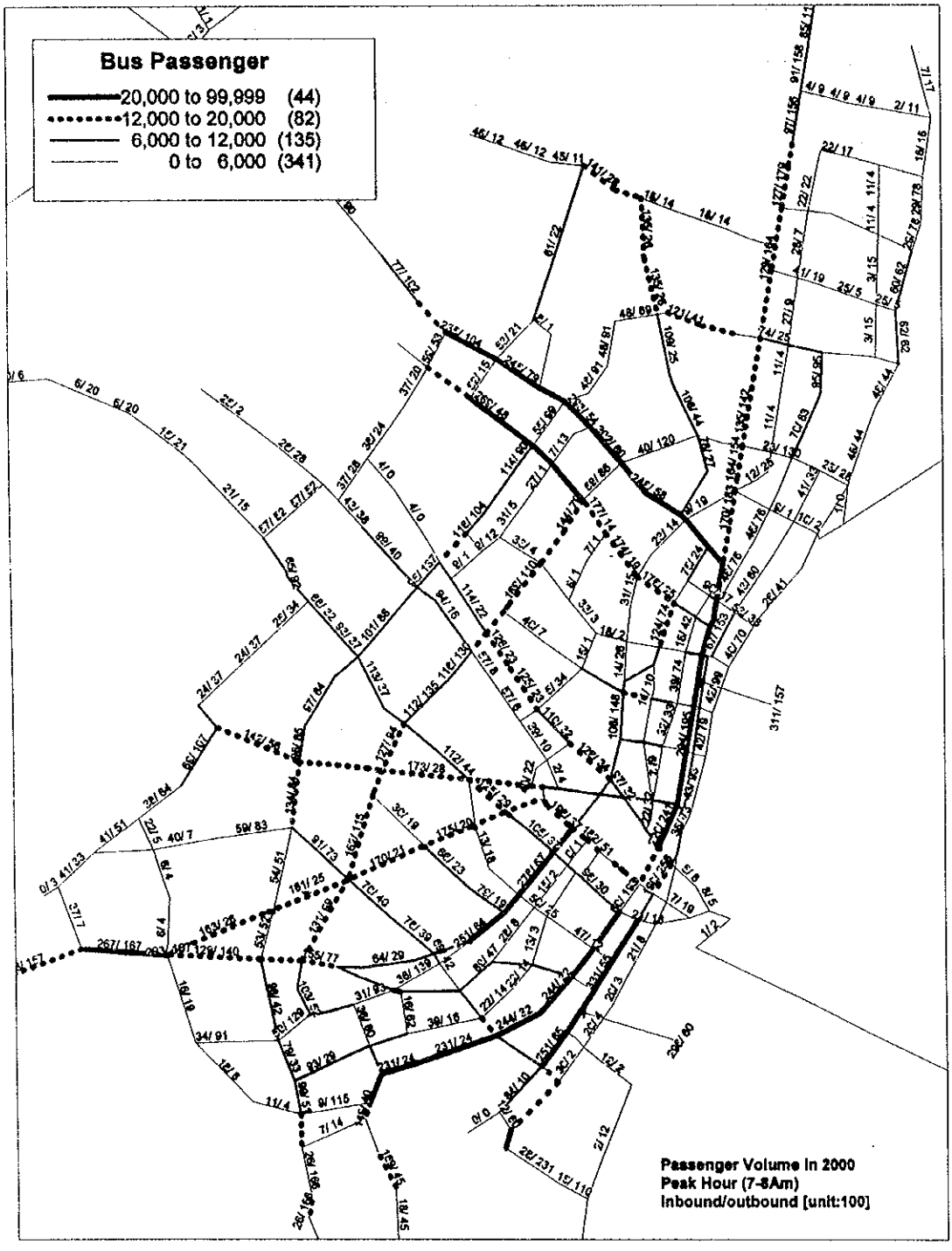

Figure 8.2-17 Peak Hour Bus Passenger Flows in 2000 (Case-3)

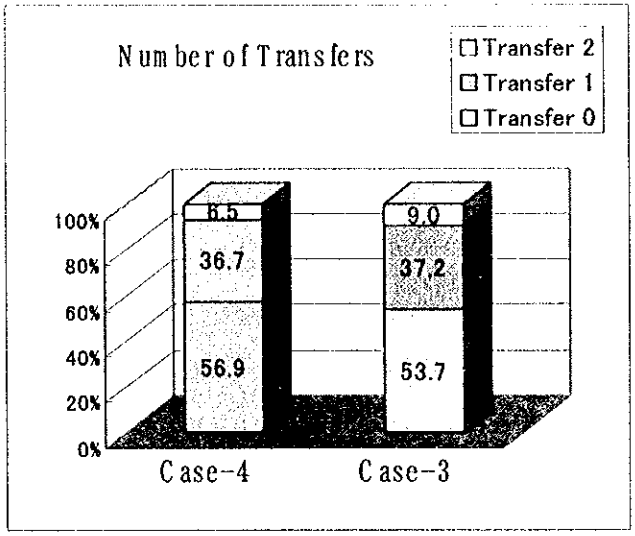

Figure 8.2-18 Number of Bus Transfers

Table 8.2-6 Number of Bus Passengers Operated in Case-3 and Case-4

Case	Bogota		Buses from Outside (Case-4) and operated in Outside (Case-3)	Total
	Trunk	Bus		
Case-3 (Stopped at Boundary)	149,985	693,081	63,574	906,640
Case-4 (base)	120,566	558,847	194,370	873,783
Difference	29,419	134,234	-130,796	32,857
Ratio (Diff/Case-4)	24.4%	24.0%	-67.3%	3.8%

8.2.3. EVALUATION IN 2005

(1) Demand on Trunk Buses

1) Peak hour passenger flows on roads

Figure 8.2-19 to Figure 8.2-21 show peak hour passenger flows on roads in Case-1 to Case-3 which are the number of passengers travelling in one direction past a point during one hour in the morning peak. Those numbers on bus network in the Figures indicate the flows in inbound and outbound directions per hour.

As can be seen, in Case-1 (Do-nothing case) the heavy inbound passenger flows in 2005 are on Av. Caracas, Auto. Sur, Calle 80, and Av. 10 with 30,000-38,000, 30,000- 40,000, 25,000-28,000 and 25,000-32,000 passenger/hour/dir, respectively. Since on those major roads, the passenger flows exceed the line capacity (maximum peak hour passenger flows/ hour/dir), the operation on the current bus system will be difficult as of 2005. It is, therefore, necessary to introduce the trunk and feeder bus system by 2005.

In Case-2, the heavy inbound passenger flows are on Calle 80, Av. Caracas, Av. 10 and Av. Sur with 57,000-62,000, 45,000-85,000, 30,000-38,000 and 30,000-37,000 passenger/hour/dir, respectively. Those figures exceed the line capacity. Those passenger flows in Case-3 are reduced, when compared to those in Case-2. The decrease ratios of the flows are 10 – 30%. However, the passenger flows on those roads are heavy with 30,000 – 50,000 passengers/hour/dir.

Case-2 and Case-3 associate with fully trunk and feeder bus system, while ordinary bus on the current bus operation system is not operated and existing bus routes basically change to new trunk bus routes. Under this operation system, it is obvious that the heavy passenger flows on major roads like Calle 80 and Caracas are beyond the line capacity. Therefore, in order to reduce the load of passenger flows on the busways, it is necessary to supplement current bus routes and not to overlap with trunk bus routes.

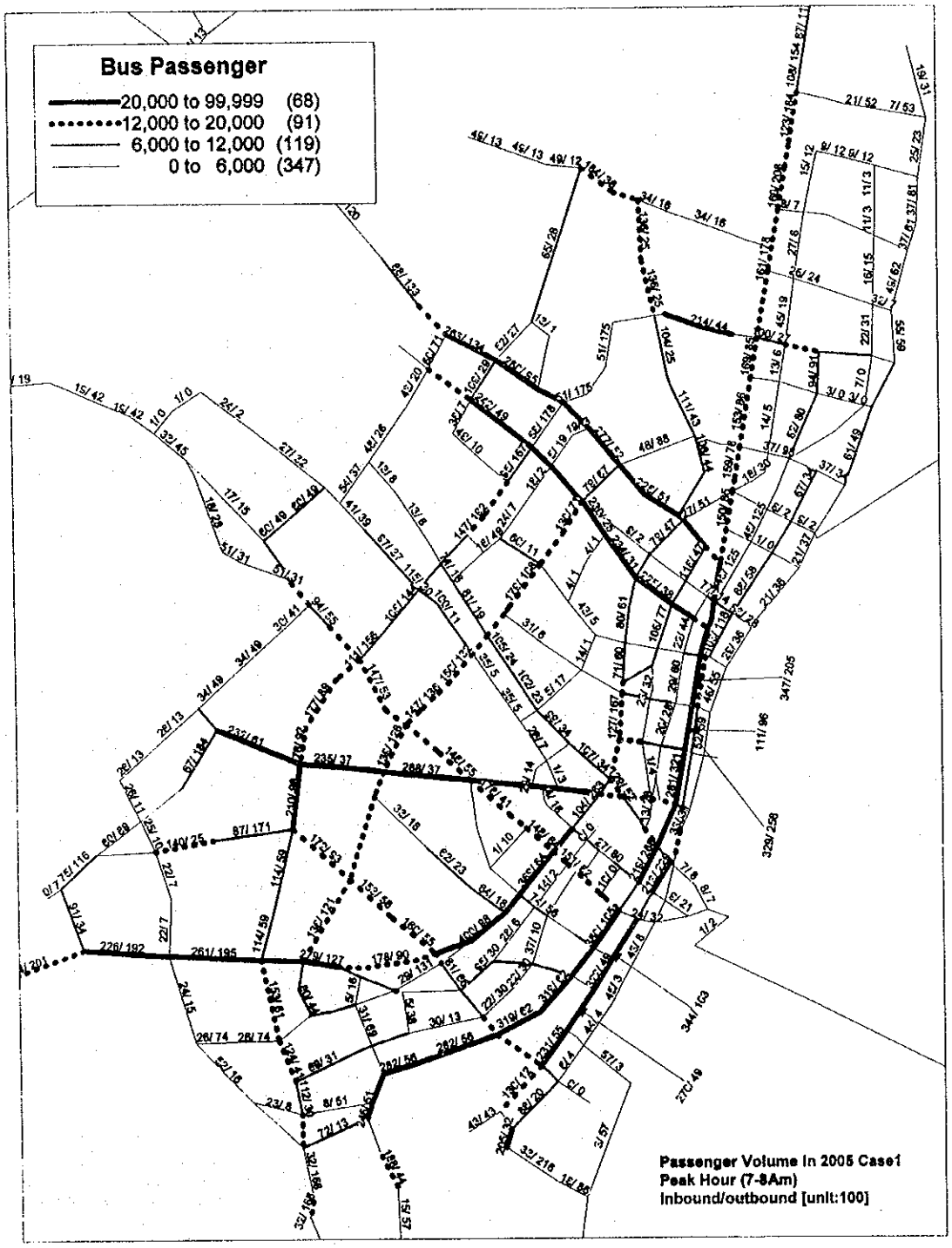

Figure 8.2-19 Peak Hour Bus Passenger Flows in 2005 (Case-1)

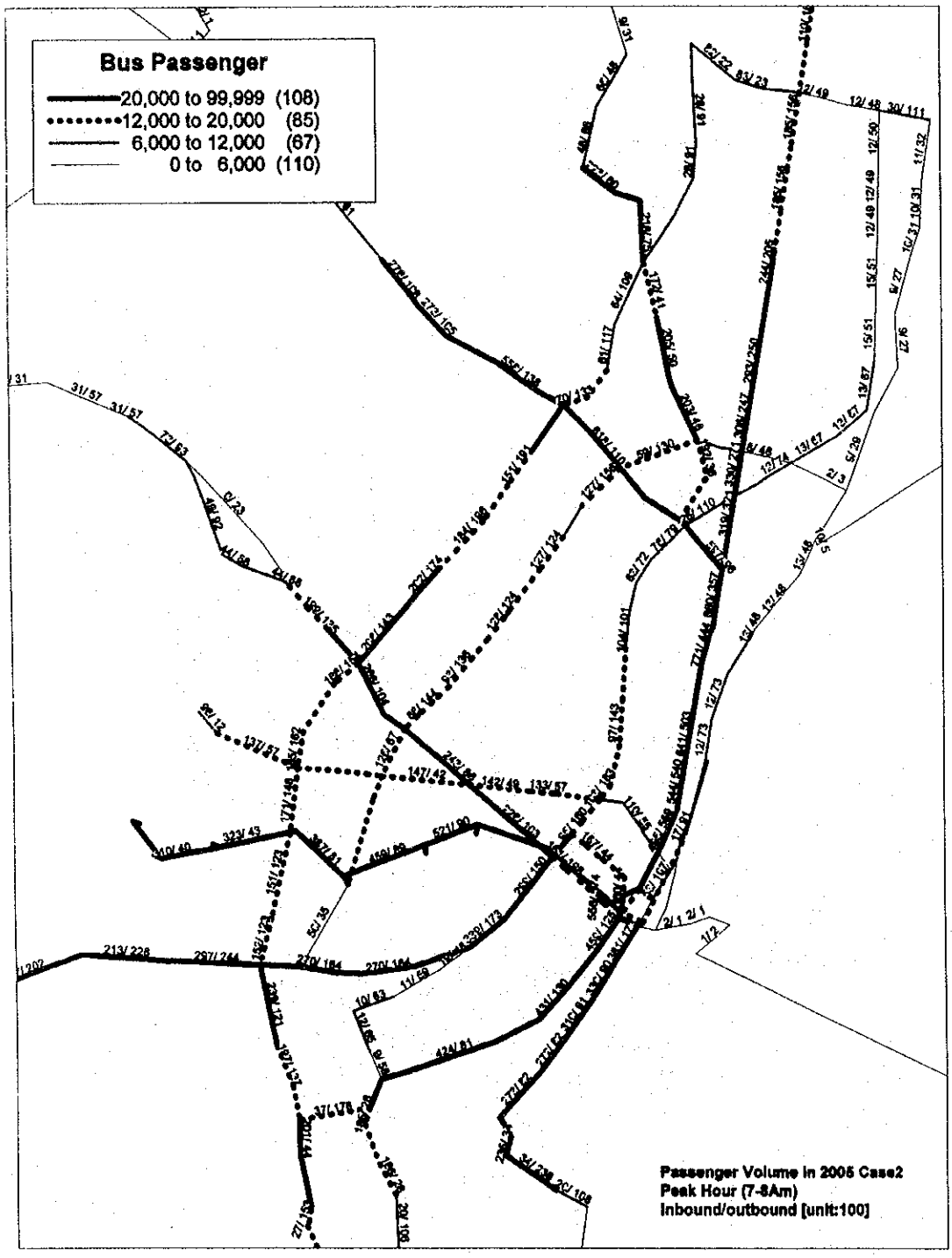

Figure 8.2-20 Peak Hour Bus Passenger Flows in 2005 (Case-2)

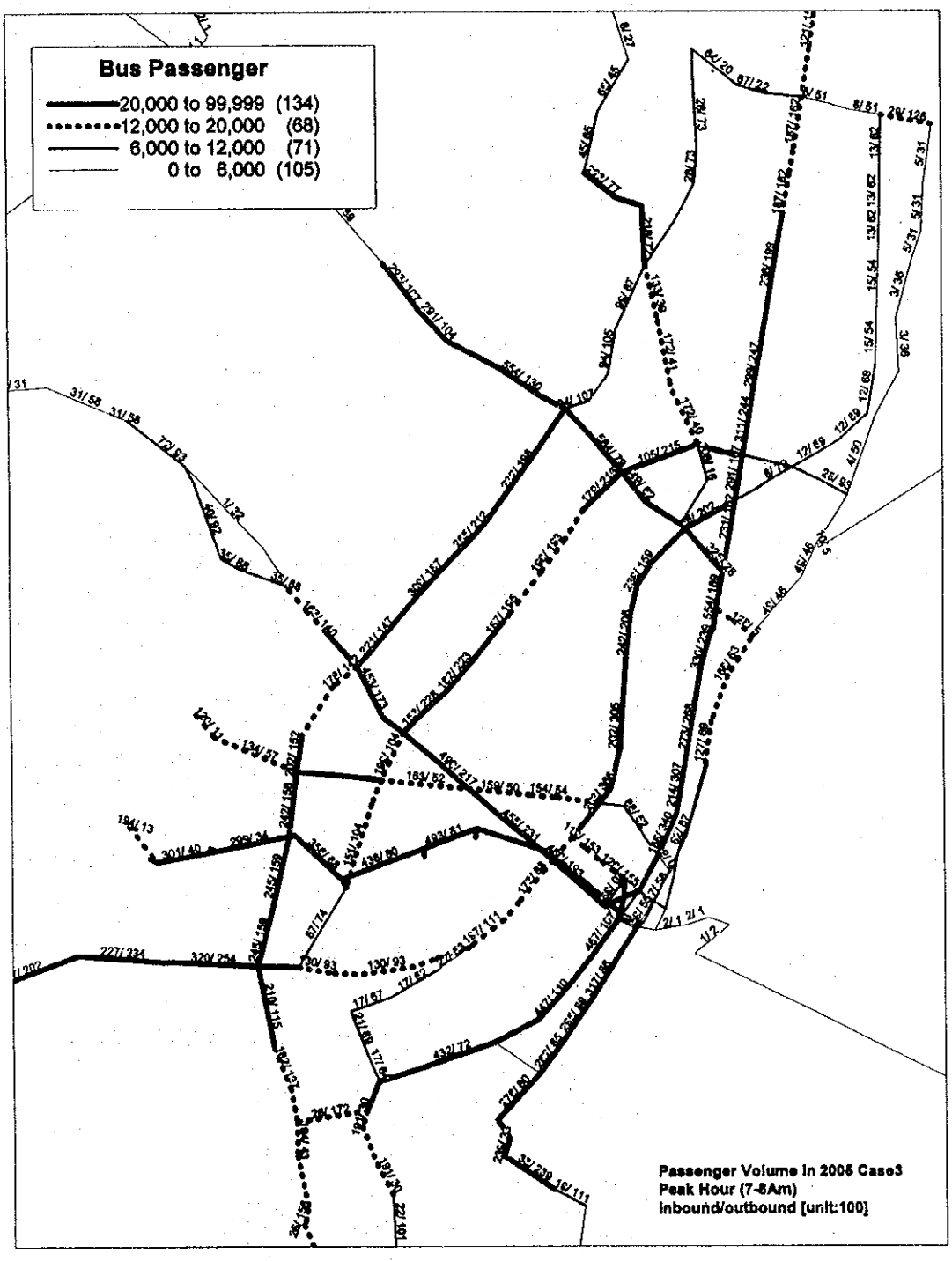

Figure 8.2-21 Peak Hour Bus Passenger Flows in 2005 (Case-3)

2) *Necessity for supplementary current bus routes*

Only trunk and feeder bus system without the current bus operation becomes over-capacity on the trunk busways. The current bus routes not to overlap with the trunk busways are necessary on the trunk bus system. Therefore, the current bus routes with an overlapped length of 4.5km or more with Av. Caracas and 9.0km or more with other busways are cut in the same manner as that in 2000. The criterion of overlapped length is set with longer lengths than in 2000, since the cutting ratio of the current routes will become higher because many busways are planned in 2005.

On the above conditions, approximately 45% of the total current routes will be cut taking into account the share of trunk bus passenger flows and the schedule phase out of old bus fleet during the period of transition of the new system. Table 8.2-7 summarizes the scheduled phase out of old fleet. In the proposed system in 2005, it is more reasonable to cut approximately 45% of the total current routes in order to phase out the old fleets in consideration of the age distribution of bus fleets.

In Case-5, those supplemental current bus routes with cutting of the overlapped current routes are added on Alternative-3 of trunk bus routes on which 50- trunk bus routes of Alternative-2 are cut and integrated into 41 routes by following manner.

1) A route with longer length is cut.

2) A route with small passenger demand is cut.

Figure 8.2-22 shows peak hour passenger flows and frequency on roads in Case 5. As can be seen, the heavy inbound passenger flows are estimated on Av. Caracas, Calle 80, Autopista Sur and Centenario. Those figures are 33,000-35,000, 41,000-53,000, 23,000-30,000, and 37,000-42,000 passenger/hour/dir. The passenger flows on other busways in Case-5 are approximately 10,000 – 25,000 per hour/dir.

Supplement any, bus routes not overlapping with trunk busways would be effective for alleviating the load of passenger flows on trunk busways. Figure 8.2-23 shows the bus routes cut in Case 5. In 2005, the bus system is operated on the 11 trunk busways with 41 trunk bus routes, and the supplementary ordinary buses on routes with 45% of the current bus routes are also operated.

In the above discussion, the several busways take the over passenger demands in 2005, even though the ordinary buses are operated on the supplemental current bus routes on roads, not on the trunk busways. Those busways will need to be augmented by a railway plan for the high demand for bus transportation or by additional trunk busways to alleviate the load of busway. These issues will be discussed in Chapter 9.

Table 8.2-7 Scheduled Phase Out of Old Fleet and Discontinued Bus Routes

Year	2005
1) Ratio of buses phased out	
Bus	53%
Buseta	80%
Microbus	6%
2) Ratio of discontinued routes	45%

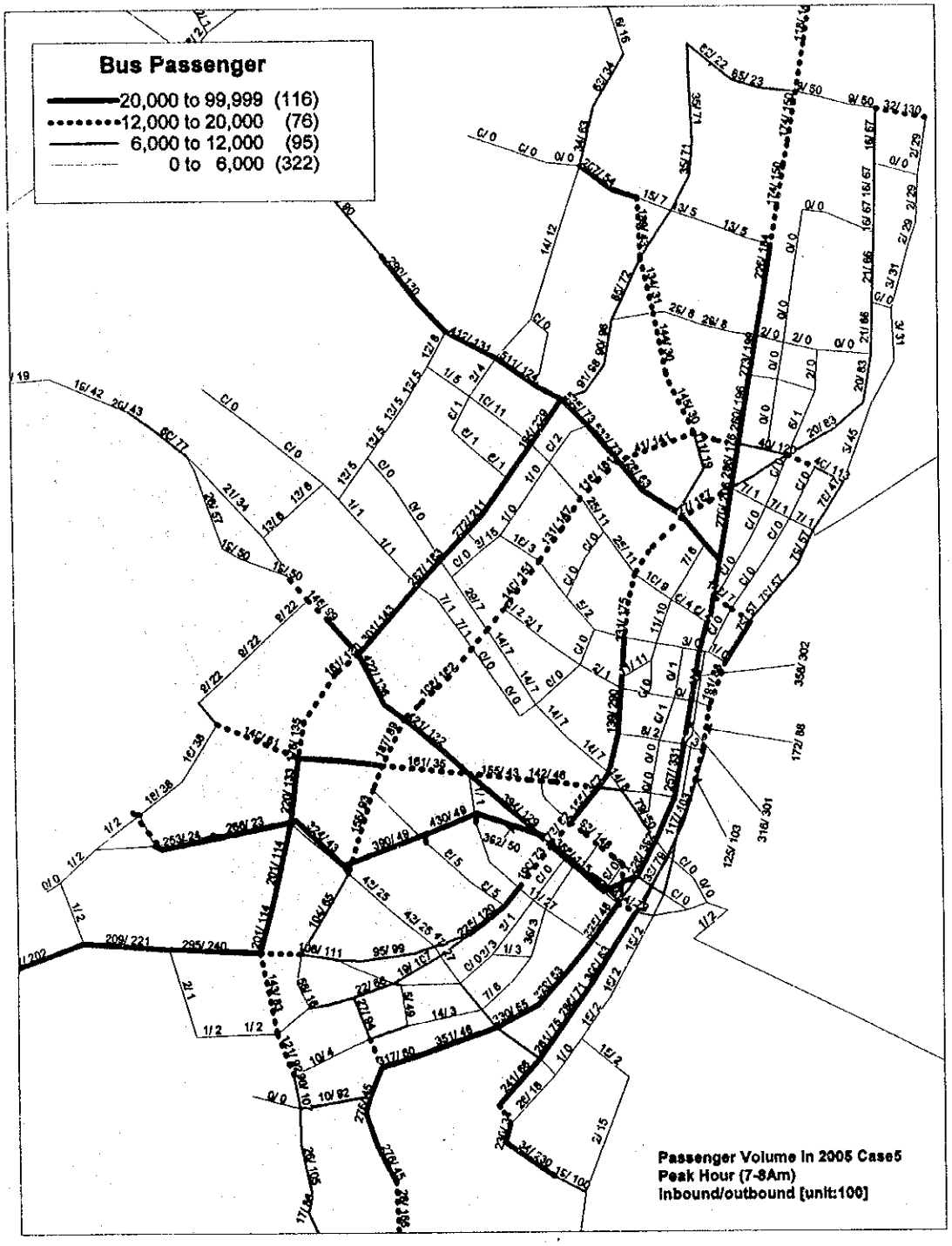

Figure 8.2-22 Peak Hour Bus Passenger Flows in 2005 (Case 5)

Figure 8.2-23 Bus Routes Cut in Case 5

3) Share of trunk bus operation

Eleven (11) trunk busways are introduced in 2005 on the conditions that the ordinary buses are operated on the ordinary roads. The shares of trunk bus passengers become a higher ratio, in contrast to those in 2000.

Figure 8.2-24 shows the shares of trunk bus passenger-km which are classified into two (2) categories; trunk and ordinary buses. The shares of passenger-km by the categorized buses in Case-5 are approximately 65% for trunk bus passengers and 35% for other passengers.

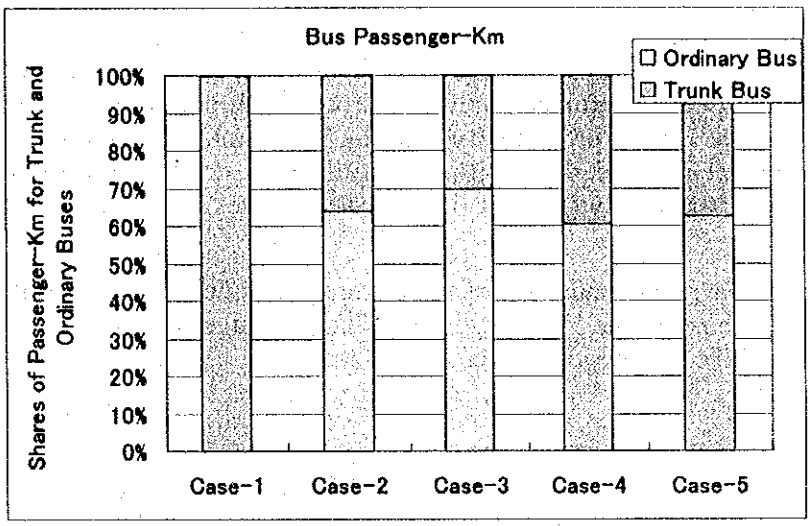

Figure 8.2-24 Shares of Passenger-km by Trunk and Current Bus Routes

(2) Effectiveness of Trunk Bus System

The trunk bus system in 2005 is evaluated by comparing each alternative with the Without case. The effects of trunk bus system are conducted by the following evaluation items:

1) Number of bus service frequencies (number of operated buses)

2) Productivity of bus system

3) Number of transfers

4) Total proceeds from bus fare

1) Number of bus service frequencies

Table 8.2-8 shows the number of bus service frequencies in 2005. Total numbers of bus service frequencies in Case-5 are approximately 8,600 frequencies per hour. The different figure between Case-5 and the Without case is approximately 11,000 frequencies. The decrease ratio of Case-5 to Case-1 (Without) in total bus frequencies is approximately 65%. This indicates that the efficiency of bus operation in terms of passengers per bus increases in the trunk bus system.

Case-2 with only connecting adjacent terminals with each other, shows the minimum in bus service frequency. Decrease ratio of Case-2 to Case-1 (Without) in total bus service frequencies is approximately 73%.

Table 8.2-8 Numbers of Bus Service Frequencies by Cases

Type	Case-1	Case-2	Case-3	Case-4	Case-5
	Without	With Case			
Trunk Bus	0	3,208	4,676	3,680	3,765
Ordinary Bus	19,639	2,071	1,629	6,212	4,826
Total	19,639	5,279	6,305	9,892	8,591
Ratio	1.00	0.27	0.32	0.50	0.44

2) *Productivity of bus system*

Bus travel conditions are improved by operation on fully segregated busways with trunk bus system, while private car users are restricted for travel convenience. Both impacts for private and public modes on travel conditions in whole Bogota are evaluated in terms of "transportation work" and "productivity" in the same manner as those in 2000. The transportation work can be expressed in several different units: **person-km, vehicle-km,** etc. The passenger productivity is also expressed in several units: **person-hour** and **vehicle-hour.**

Figure 8.2-25 compares passenger-km of private and bus modes in the "With" cases (Case-2 to Case-5) with those in the "Without" case. The passenger-km of both bus and private modes in the "With" cases are unchanged.

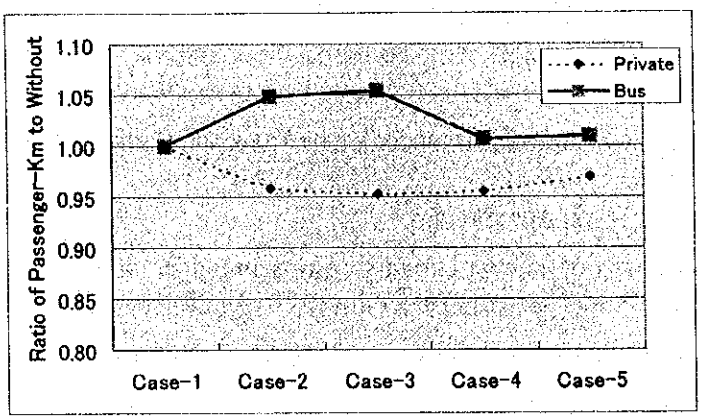

Figure 8.2-25 Ratios of Passenger-km of Private and Bus Modes to Without Case

Figure 8.2-26 also shows bus passenger-hour in the same manner as that in 2000. The bus passenger-hour is calculated on the same assumption as that in 2000. The passenger-hour in Case-5 considerably decreases as against the Without case, while the passenger-hour on private mode slightly decreases. Those decrease ratios of the figures for the bus and the private mode in Case-5 to Case-1 are approximately 0.6 and 0.94, respectively. This shows that the bus passenger travel speed is improved at approximately 1.7 times.

Since the ordinary buses are operated on roads without segregated busway, or on the traffic lane with mixed transport, the bus travel speeds will reduce according to traffic volume on roads. On the other hand, the trunk bus is not influenced by traffic volume on roads because of operation on segregated busway. In 2005, the ordinary bus flows will be reduced due to cutting by 45% of the current bus routes, and travel conditions on roads will slightly improve because of decrease in the ordinary bus flows, in spite of reduction of mixed traffic lane, exclusive of major roads with express busways.

The variation of passenger-km and passenger-hour indicate that by trunk bus operation on trunk busways, travel conditions for passengers are improved, while private users will not be substantially affected.

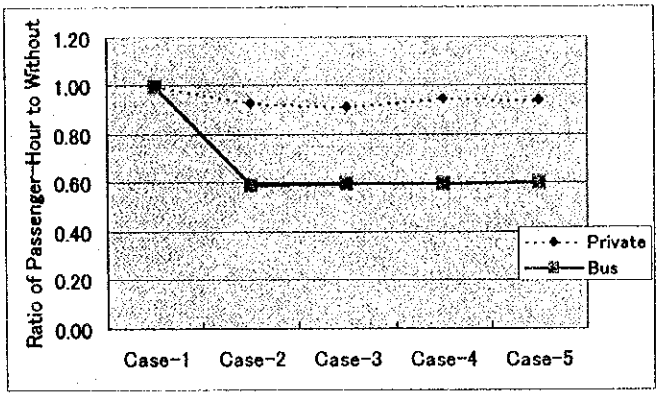

Figure 8.2-26 Ratios of Passenger-hour of Private and Bus Modes to Without Case

3) Number of transfers

Numbers of transfers at bus stops and terminals by each case are shown in Figure 8.2-27. The passengers with transfers (1 time or more) in Case-5 represent 37% of the total, in contrast to 34% for Case-1 (Without case). Passengers who are forced to transfer in Case-5 (difference between Case-1 and Case-5) are approximately 26,000, equivalent to 4% of the passengers. In Case-2 where shuttle buses are operated between adjacent bus terminals, the transferred passenger ratio to total increases to approximately 50%.

4) Total proceeds from bus fare

Total proceeds from bus fare collection are compared between "With" (Case-2 to 5) and "Without" cases to understand the effects of trunk bus system in 2005 (see Table 8.2-9). $430 pesos are applied for both trunk and ordinary bus fares, respectively.

As can be seen, total fare collection in Case-5 is increased by only 2%, as compared to the Without case. The total proceeds per frequency-km in Case-5 rise at 2.5 times in comparison with the Without case. The proceeds per bus operation (frequency-km) are improved in the trunk bus system.

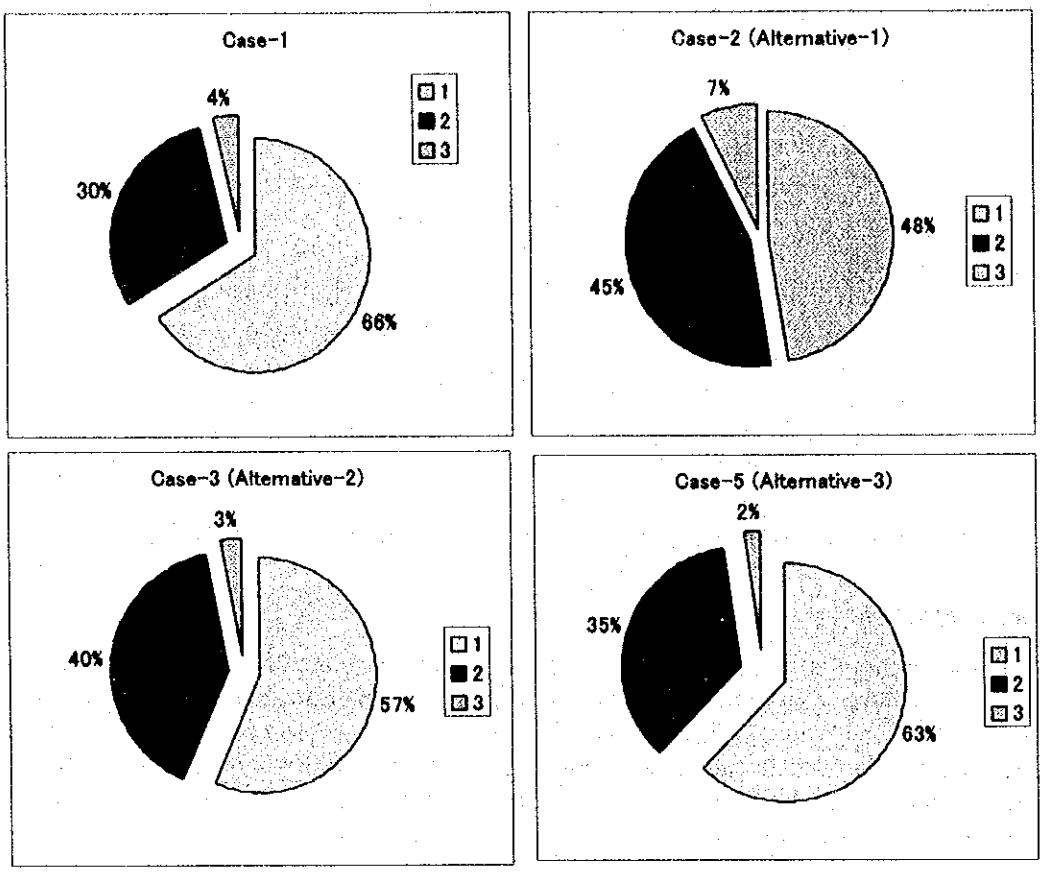

Figure 8.2-27 Numbers of Bus Transfers

Table 8.2-9 Total Proceeds from Bus Fare

	Total Proceeds ($pesos)	Ratio to Case-1	Per Frequency-Km
Case-1	391,261,300	1.00	1.00
Case-2	455,171,340	1.16	3.36
Case-3	417,398,420	1.07	3.17
Case-4	418,231,760	1.07	2.40
Case-5	398,927,340	1.02	2.47

(3) Impacts on Transport in Bogota

1) Travel speed

Travel speeds outside bus lanes on roads with the segregated trunk busways decrease after constructing the busways. Figure 8.2-28 shows the travel speeds on through traffic lanes outside bus lanes on major roads. The travel speeds of the private vehicles vary a little from the Without case. The speeds on Av. Caracas and Quito-Sur somewhat rise at 5-10%, while Calle 80 and Av. 68 show a slight decrease in the speed (5-6%).

In 2005, traffic conditions in Without Case-1 are severe according to increase in demand, not related the busway construction, and the travel speeds on major roads are less than 10km/h. In With Case-5, the ordinary bus flows on roads are reduced due to cutting of 45% of the current bus routes, especially on Av. Caracas. The travel conditions on roads are slightly improved because of decrease of the ordinary bus flows, in spite of reduction of mixed traffic lane, except on major roads with express busways.

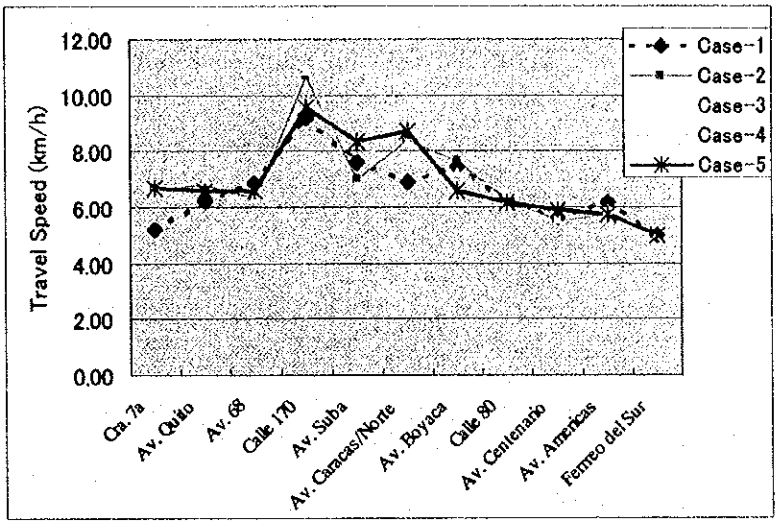

Figure 8.2-28 Change of Travel Speed outside Bus Lanes

2) *Traffic congestion*

The travel speeds of private vehicles passing through outside lane on road with busway are somewhat reduced. Those travel conditions are estimated in terms of PCU-km and PCU-hour for private vehicles on road section with travel speed of less than 10 km/hr. Table 8.2-10 shows the change of PCU-km and PCU-hour relative to the without case in the whole study area. In Case-5, the congested length and delay in terms of PCU-km and PCU-hour show a slight decrease. Those figures show that travel conditions for private vehicles are slightly improved due to decrease of the ordinary buses.

In Case-2 and Case-3 without the supplementary ordinary bus operation which are only operated with trunk and feeder system, the congestion and delay are also improved.

Table 8.2-10 Change of PCU-km and PCU-hour for Private Vehicles on Road Section with Travel Speed of Less than 10 km/h

Items	Case-1	Case-2	Case-3	Case-4	Case-5
PCU-Km on 10km/h or less	1.00	0.92	0.89	0.95	0.93
PCU-hour on 10km/h or less	1.00	0.91	0.89	0.95	0.92

(4) Influence of Non-reciprocal Bus Operation

1) *Increase of transfers at suburban bus terminals*

In 2005, the trunk buses are operated on the 11 trunk busways and the supplementary ordinary buses are also operated on the ordinary roads. Therefore, considerably more passengers concentrate at suburban bus terminals in order to transfer, board or alight, as compared to those in 2000 when passengers disperse due to configuration of bus route

network. At the same time, by non-reciprocal operation, the number of bus passengers who transfer at suburban bus terminals increases at every suburban bus terminal.

In several terminals, the number of transfer passengers increases 1.2 – 1.3 times exclusive of suburban bus terminal in Bosa where number of transfers is 50,000 in Case-4, in contrast to 10,000 in Case-5 (see Figure 8.2-29). The heavy passenger volume from Soacha is forced to transfer at the Bosa terminal.

The volume directly influences the dimensions of bus parking facility such as number of berths, passenger facilities, etc. Figure 8.2-30 shows the peak hour bus passenger flows in Case-4.

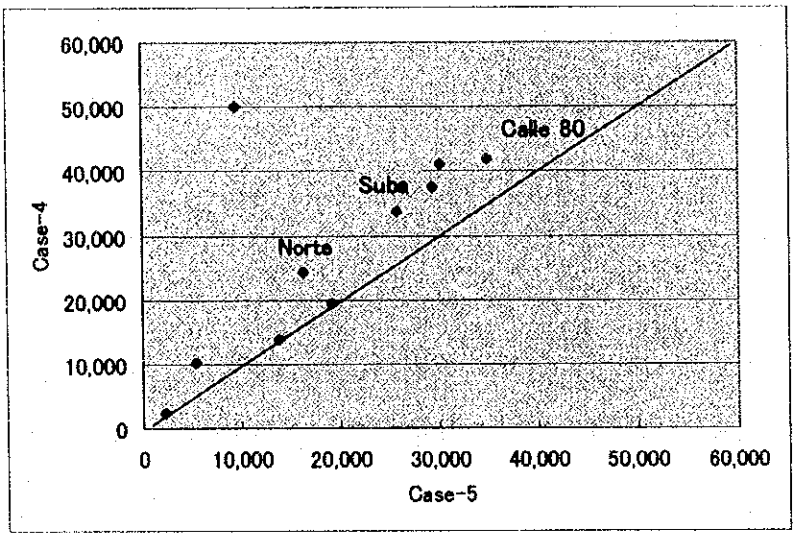

Figure 8.2-29 Comparison of Number of Transfers at Suburban Bus Terminals

2) *Increase of total transfer times*

Figure 8.2-31 shows the ratio of transfer by number of times among all bus passengers. The passengers without transfer are reduced to 58% (Case-4) from 62% (Case-5), while the passengers who transfer 1 or 2 times increase to 42% in Case-4. Approximately 26,000 (4% of total) passengers are forced to transfer at sub-urban bus terminals as compared to Case-5.

3) *Increase of bus service in urban area*

Table 8.2-11 shows the numbers of bus passengers in the urban area in Case4 and Case-5 who are classified in terms of ridership into three categories: trunk bus, ordinary buses inside urban area and buses operated outside urban area. On the bus network in Case-4, urban bus passengers within the city of Bogota are increased because of the passengers who dwell outside Bogota.

Since bus passengers who are forced to transfer at bus terminals change a bus operated inside Bogota, supplementary bus service frequency is increased for those passengers. The increase ratios of bus passengers in Case-4 to those in Case-5 are approximately 5%. The different numbers of bus passengers between Case-4 and Case-5 somewhat increases by 45,000 (62,000 are inside Bogota and –17,000 are outside Bogota).

Table 8.2-11 Numbers of Bus Passengers in Case-4 and Case-5

Case	Bogota		Buses from Outside (Case-5) and operated in Outside (Case-4)	Total
	Trunk	Bus		
Case-4 (Stopped at Boundary)	644,056	238,200	90,376	972,632
Case-5 (base)	654,434	165,552	107,752	927,738
Difference	-10,378	72,648	-17,376	44,894
Ratio (Diff/Case-5)	-1.6%	43.9%	-16.1%	4.8%

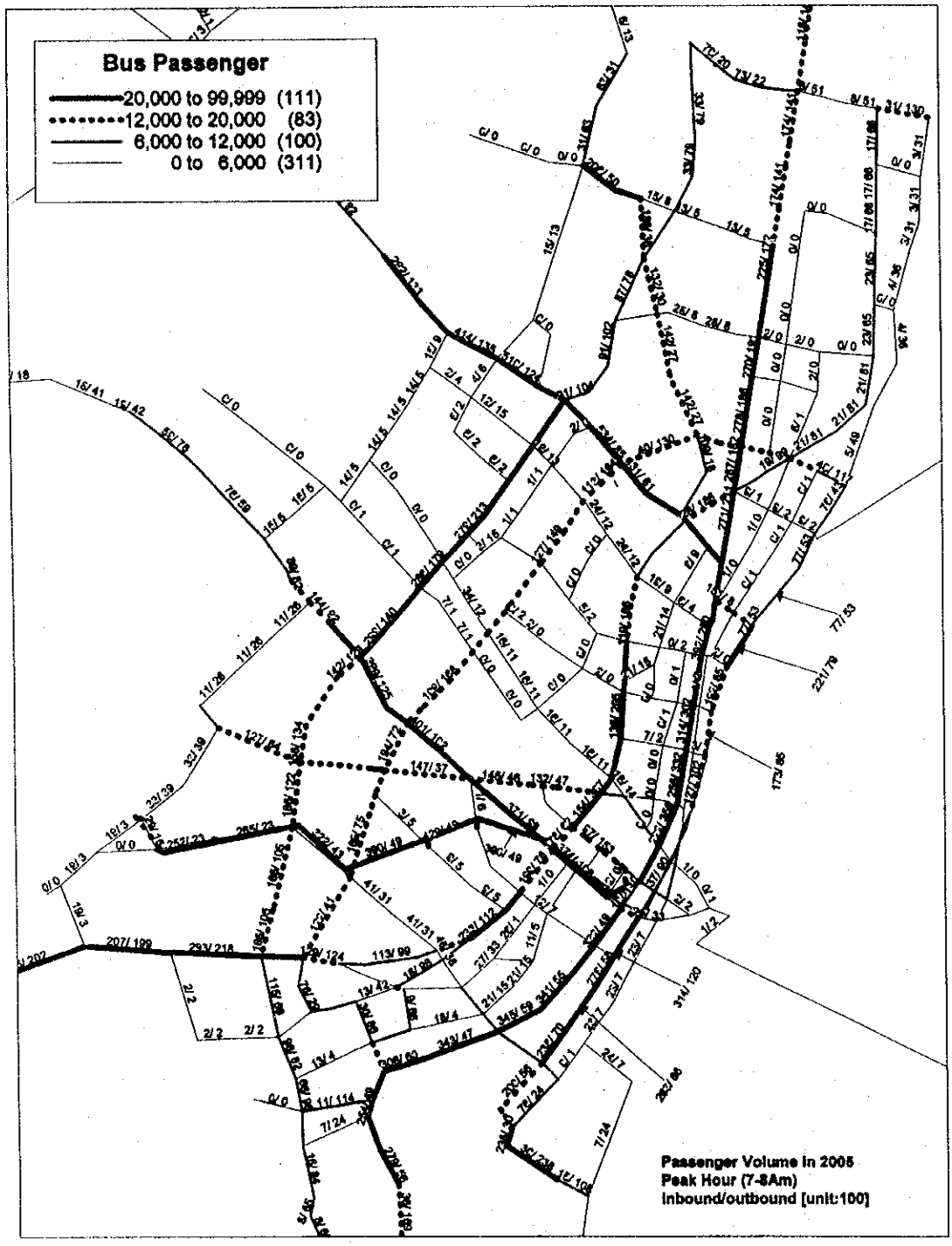

Figure 8.2-30 Peak Hour Bus Passenger Flows in 2005 (Case-4)

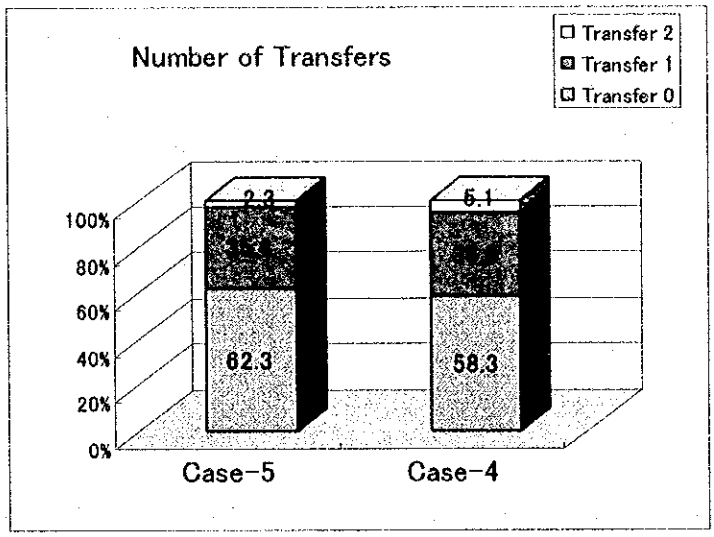

Figure 8.2-31 Numbers of Bus Transfers

8.2.4. SUMMARY OF EVALUATION

The evaluations of trunk-feeder bus system in 2000 and 2005 were conducted separately. The plan in 2000 for three (3) trunk busways with six (6) trunk bus routes is proposed on the conditions that the ordinary buses on the current bus system continue to be operated. The effects for introducing trunk bus system into the current bus system were evaluated. In 2005, eleven segregated or bus priority busways are planed, and the ordinary buses on the current bus operation system will be discontinued and the current bus routes basically will change to new trunk bus routes. The trunk bus system itself with which the current system is replaced was evaluated by comparing each alternative with the Without case.

As for demand of trunk bus passengers in 2000, trunk bus passenger volume relates with the current bus service, i.e., its volume depends on a level of cutting current bus routes which overlap with trunk bus routes. Therefore, in order to avoid overlapping current bus routes with the trunk bus routes, the current bus routes, where a length of route overlapping with busways on Caracas and Calle 80 is 2.5km or more, will be cut.

In Do-nothing case (Without case) in 2000, passenger flows on several major roads will exceed beyond the line capacity and it will be more difficult to operate buses on the current bus system. In the proposed system, it will be necessary to cut approximately 30% of the total current routes in order to avoid overlapping current bus routes with the trunk bus routes, and to meet the proper passenger demand for trunk buses. This figure also takes into account the scheduled phase out of old fleet.

In 2005, the proposed trunk buses will be operated on the 11 trunk busways with trunk bus and feeder bus system. The passenger flows on several major busways will exceed the line capacity. Therefore, the necessity for supplementary current bus operation was examined and confirmed. The optimum cutting ratio will be approximately 45%. The bus system will be operated on the 11 trunk busways with approximately 41 trunk bus routes and the supplementary current buses will be also operated on the ordinary roads with 45% of the current bus routes.

However, there are several busways with excessive passenger demand, even though supplementary ordinary buses are operated. Those busways will need to be supplemented

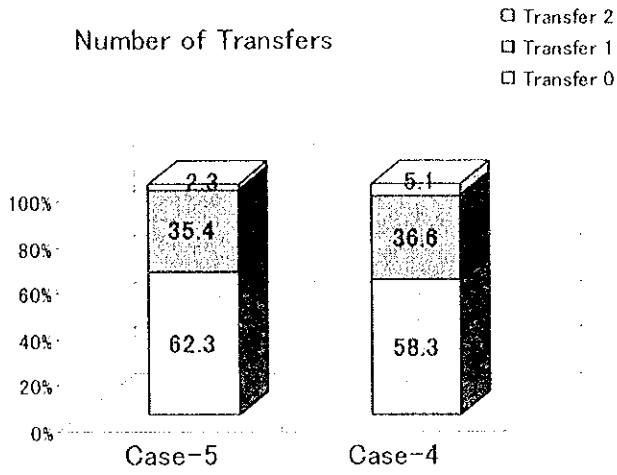

Figure 8.2-31 Numbers of Bus Transfers

8.2.4. SUMMARY OF EVALUATION

The evaluations of trunk-feeder bus system in 2000 and 2005 were conducted separately. The plan in 2000 for three (3) trunk busways with six (6) trunk bus routes is proposed on the conditions that the ordinary buses on the current bus system continue to be operated. The effects for introducing trunk bus system into the current bus system were evaluated. In 2005, eleven segregated or bus priority busways are planed, and the ordinary buses on the current bus operation system will be discontinued and the current bus routes basically will change to new trunk bus routes. The trunk bus system itself with which the current system is replaced was evaluated by comparing each alternative with the Without case.

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In Do-nothing case (Without case) in 2000, passenger flows on several major roads will exceed beyond the line capacity and it will be more difficult to operate buses on the current bus system. In the proposed system, it will be necessary to cut approximately 30% of the total current routes in order to avoid overlapping current bus routes with the trunk bus routes, and to meet the proper passenger demand for trunk buses. This figure also takes into account the scheduled phase out of old fleet.

In 2005, the proposed trunk buses will be operated on the 11 trunk busways with trunk bus and feeder bus system. The passenger flows on several major busways will exceed the line capacity. Therefore, the necessity for supplementary current bus operation was examined and confirmed. The optimum cutting ratio will be approximately 45%. The bus system will be operated on the 11 trunk busways with approximately 41 trunk bus routes and the supplementary current buses will be also operated on the ordinary roads with 45% of the current bus routes.

However, there are several busways with excessive passenger demand, even though supplementary ordinary buses are operated. Those busways will need to be supplemented

by a railway plan for over capacity of bus transportation or additional trunk busways to alleviate the load on the busways.

Effectiveness of trunk bus system and influence of non-reciprocal bus operation are evaluated.

Figure 8.2-32 and Figure 8.2-33 summarizes the system evaluation in 2000 and 2005, respectively. The summarized figures evaluated the trunk bus system from the following viewpoints.

1) Administration

2) Operator

3) Public transport passengers

4) Private car users

1) Summary in 2000

In 2000, operators may possibly reduce the bus service frequency by the trunk bus system. Comparing to Do-nothing case, the frequency reduces by approximately 35% in the morning peak hour. Since at the same time, approximately 30% of the current bus routes which overlap with trunk bus routes will be cut, operators are forced to change bus routes operated on the current bus system.

Travel time for bus passengers is somewhat improved and is reduced by approximately 6% compared to the without case. As for travel distance, the average travel distance is not changed in case of the new trunk bus system. The passengers with transfers (1 time or more) will somewhat increase. Passengers who are forced to transfer (difference between the Without and Case-4) are approximately 57,000, equivalent to 10% of the passengers.

As for private car users, they are restricted for allocation of roadspace, since the segregated bus priority lanes are constructed on the existing right-of-way. They may suffer disadvantage of travel speed. Especially, on roads with fully segregated bus priority lanes, travel speeds are decreased by 20- 30% in comparison with the without case. Though traffic congestion on those roads will be severe, the congested length and delay in the whole study area in terms of PCU-km and PCU-hour on road section with travel speed of less than 10 km/hr will slightly decrease by 3%.

Administration of public transport will have to construct the 3 trunk busways on the existing roads and control the proposed 6 trunk bus routes. And also, manage route rearrangement by cutting 30% of current bus routes which overlap with trunk bus routes.

It is necessary to discuss non-reciprocal bus operation from the viewpoint of bus passengers, bus operators, land use planning, urban development, etc. In this section, the influence of bus passengers, operators and land use is summarized. Bus passengers who transfer 1 or 2 times increase to 46% from 43% and the influenced passengers are approximately 18,000 (3% of total), as compared with reciprocal operation. In several terminals, the number of transfer passengers increases 1.6 – 1.8 times. It is necessary to acquire additional land space for those. Bus operators need to prepare additional bus service frequency in the urban area. Since bus passengers who are forced to transfer at bus terminals, change a bus operated inside Bogota, supplementary bus service frequency becomes necessary for those passengers. The increased ratios of those bus passengers by the non-reciprocal operation are approximately 4%.

2) Summary in 2005

In 2005, operators may possibly reduce the bus service frequency by the trunk bus system. Comparing to Do-nothing case, the frequency reduces by approximately 45% in the

morning peak hour. Since at the same time, approximately 45% of current bus routes will be cut, operators are forced to change bus routes operated on the current bus system.

Travel time for bus passengers is considerably improved and is reduced to approximately 0.6 compared to the without case. As for travel distance, the average travel distance is not change in case of the new trunk bus system. The passengers with transfers (1 time or more) will slightly increased. Affected passengers are approximately 26,000, equivalent to 4% of the passengers.

As for private car users, they are restricted for allocation of roadspace, since the segregated bus priority lanes are constructed on the existing right-of-way. They may suffer disadvantage of travel speed. Especially, on roads with fully segregated bus priority lanes, travel speed is decrease by 10% on Calle 80 or increased by 5-10% on Av. Caracas in comparison with the without case. Though traffic congestion on those roads will be severe, the congested length and delay in the whole study area in terms of PCU-km and PCU-hour on road section with a travel speed of less than 10 km/hr will slightly decrease by 7%.

Administration of public transport will have to construct the 11 trunk busways on the existing roads and control the proposed 41 trunk bus routes. And also, manages route rearrangement by cutting 45% of current bus routes which overlap with trunk bus routes.

As for non-reciprocal bus operation, bus passengers who transfer for 1 or 2 times increase at 42% and the affected passengers are approximately 26,000 (4% of total), when compared to the reciprocal operation. In several terminals, the number of transfer passengers increases 1.2 – 1.3 times exclusive of suburban bus terminal in Bosa where the number of transfers varies from 10,000 to 50,000 for non-reciprocal operation. The volume directly influences the dimensions of bus parking facility such as number of berths, passenger facilities, etc. Bus operators need to prepare additional bus service frequency in the urban area. The increased ratios of the bus passengers by the non-reciprocal operation are approximately 5%.

Summary in 2000

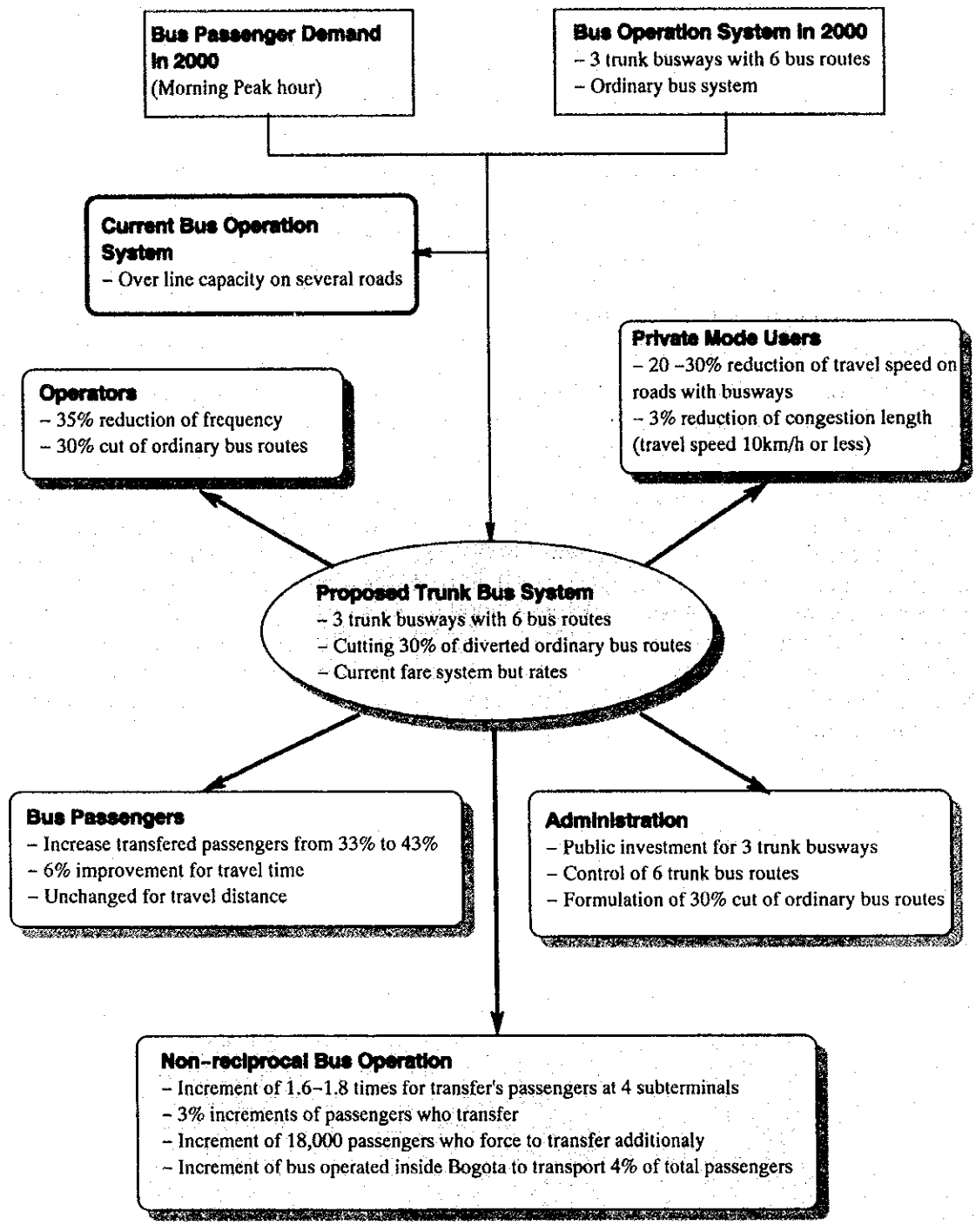

Figure 8.2-32 Summary of Evaluation in 2000

Summary in 2005

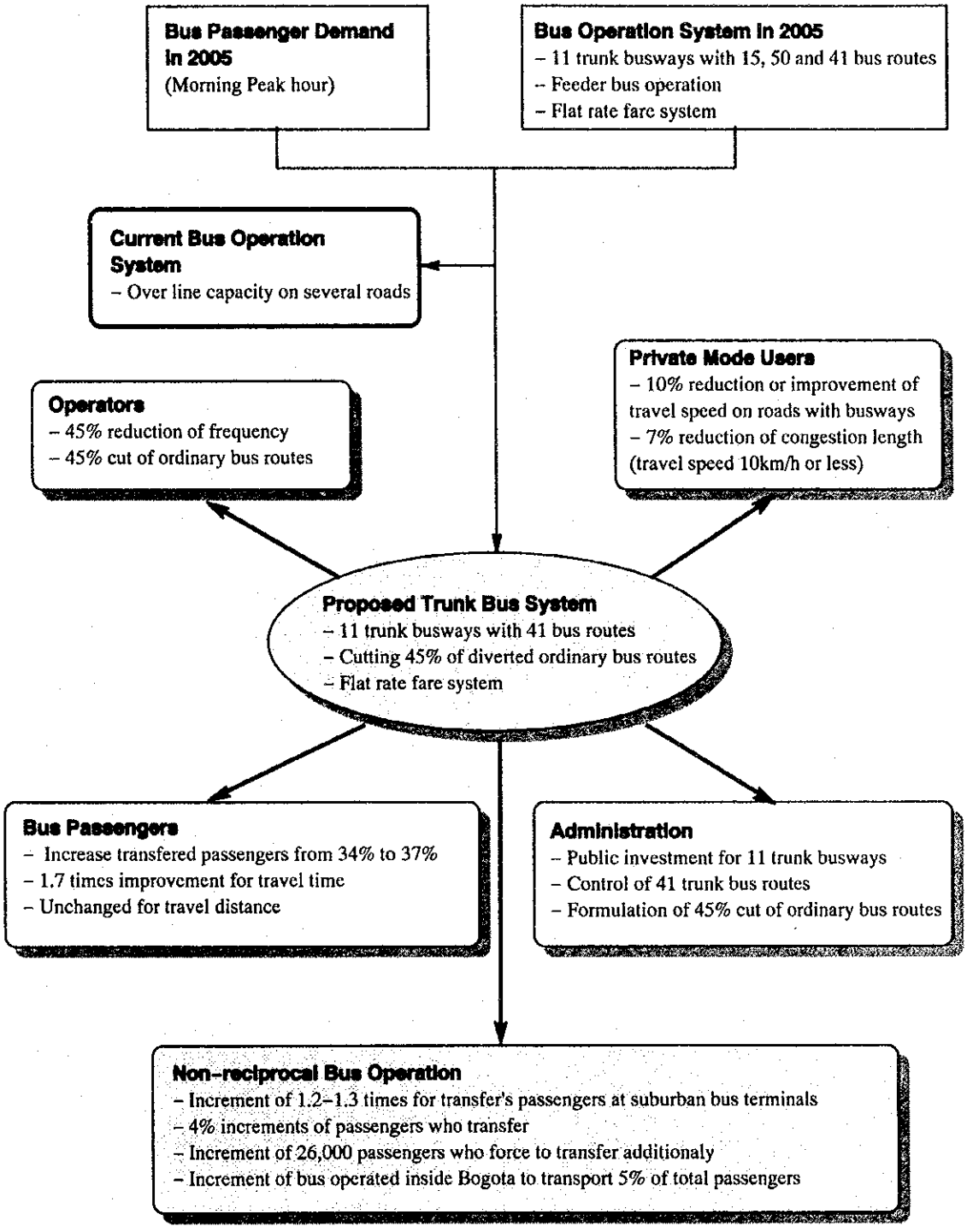

Figure 8.2-33 Summary of Evaluation in 2005

CHAPTER 9
Trunk Bus System Plan

9. TRUNK BUS SYSTEM PLAN

9.1. GENERAL

Trunk bus passenger demands on trunk bus ways were estimated on the 6 and 41 trunk bus routes in the years 2000 and 2005 in Chapter 8. This chapter conducts further examination of trunk bus routes such concepts as passenger demands and route configuration, taking into account the aspect of actual operation system and engineering.

In 2000, six (6) trunk bus routes are examined and final trunk bus routes are converged on four (4) routes by cutting the bus routes with small demand or long length. In 2005, by cutting winding routes, and those which overlap with other routes, as well as long or small demand routes, the operating routes are finally integrated into approximately 30 bus routes. Although the number of bus routes become fewer in this manner, it would be better for passengers to be served with many service frequencies on the same bus route.

Finally, on the cut and integrated bus routes, express and trunk bus operation system, in the peak hour with scheduled frequency, headway and allocated bus fleets, is proposed. With regard to the allocated bus fleets, the number of provided bus fleets by trunk and express buses, including purchase of a bus fleet, are also discussed.

Figure 9.1-1 shows the procedures on trunk bus system planning.

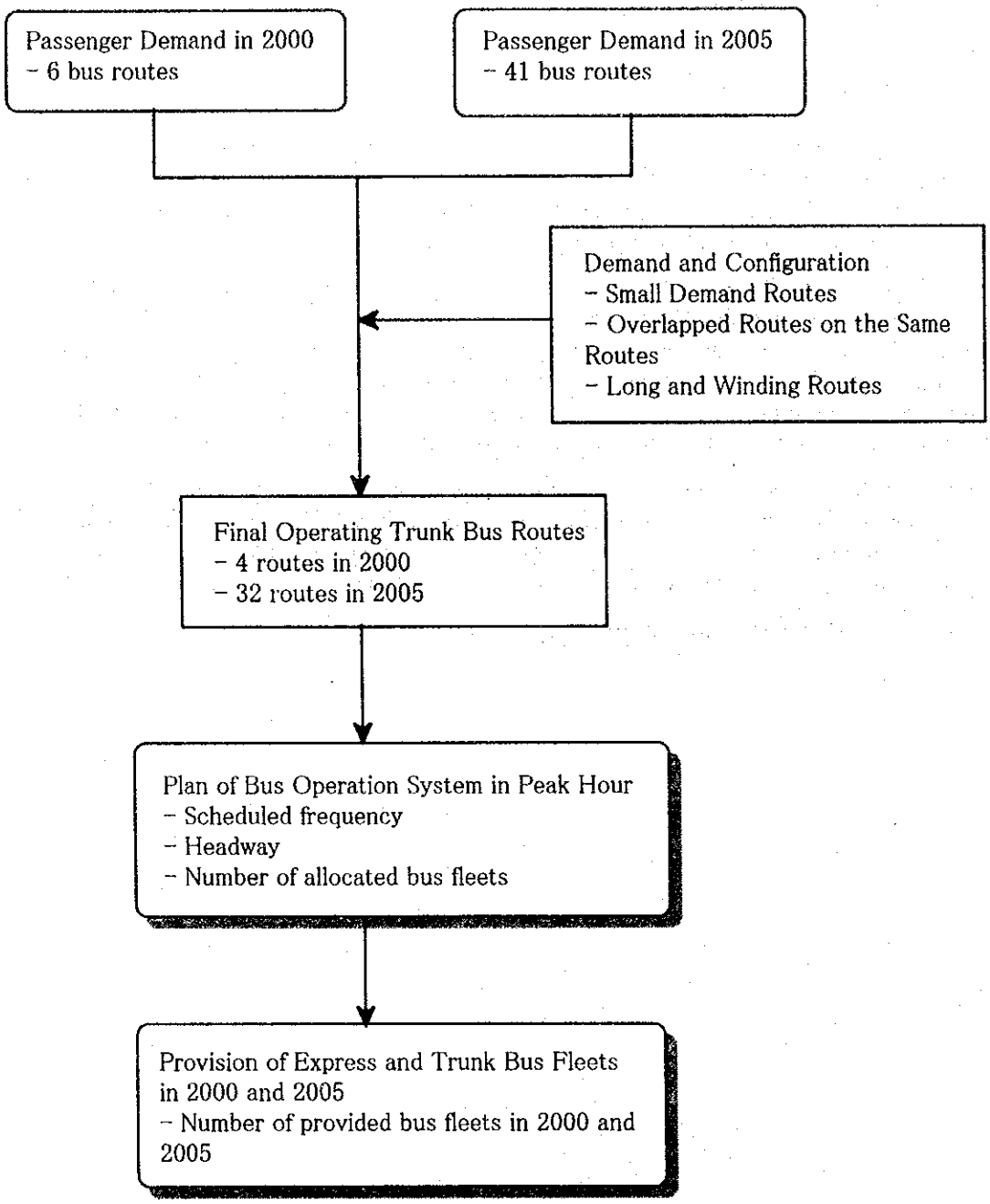

Figure 9.1-1 Procedures of Trunk Bus System Planning

9.2. BUSWAY CONFIGURATION

9.2.1. COVERED AREA BY TRUNK BUSWAYS

In the Study, in 2005, the trunk and express buses are operated on the 11 trunk busways with approximately 40 trunk bus routes, augmented by the supplementary ordinary buses that are operated on the ordinary roads with the current bus system. The 11 busways are planned on the existing major roads in Bogota. Those roads function as arterial roads. The road configuration is composed of circulating and radial roads. The radial corridors connect the city center with outer suburbs. The areas along the radial corridors are mainly residential areas. These residents commute to the city center by public transport on the radial corridors. Since those radial corridors finally connect into Av. Caracas, the busway on this road is a very busy one in terms of bus flows.

Those busways will cover the major areas of Bogota in 2005. Figure 9.2-1 shows population inside the areas covered which are within 500m and 1km along the trunk busways. The estimated covered population is grouped in two classified areas: the urban area surrounded by Av. Caracas and Calle 170 and the suburban area surrounded by the remaining area. The areas covered within a width of 500m and 1km on either side of the eleven (11) trunk busways are defined in the estimate as the population influenced by trunk bus system. As can be seen, the ratio of covered population within 1km width to the total is approximately 80% in the urban area and 30% in the others. Since in 2000, only three (3) trunk busways are planned, the covered population ratio within 1km width is approximately 40% in the urban and 10% in the others.

According to the above figures, almost all the residents in the urban areas surrounded by Av. Americas and Calle 170 directly receive a service of the trunk bus system, while the benefit by residents in the suburban areas from this system is somewhat low.

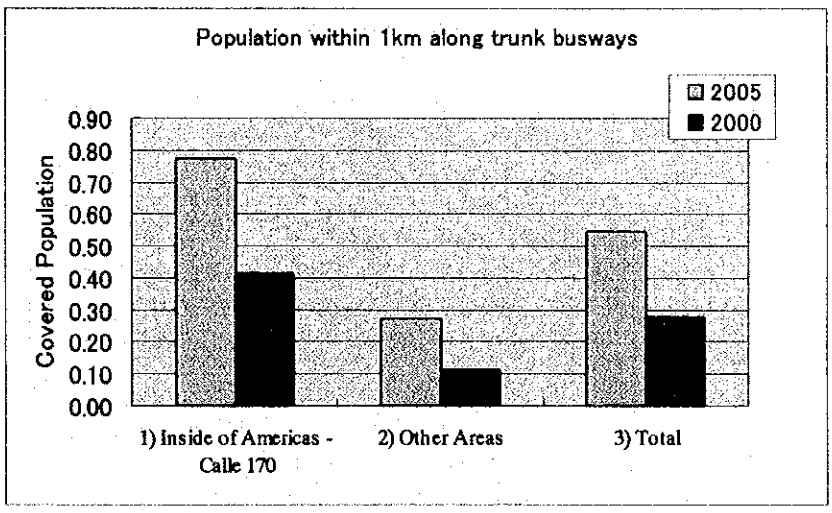

Figure 9.2-1 Covered Area of Trunk Busways

9.2.2. ROUTE LENGTH

In general, it is better to plan a bus route with short length in an urban area. It is desirable to plan a bus route 20km or less in length, or a ride of one hour or less per one-way. The longer the bus routes are, the more difficult the control of operation is. The overlap of

several bus routes should be avoided except within central business districts. It is desirable to plan a maximum of 2 or 3 bus routes on the same road.

Figure 9.2-2 summarizes a comparison between trunk bus route length with ordinary route length, whose figures show the distribution of bus route length. As can be seen, the trunk bus route length on approximately 50 trunk bus routes ranges from 10 km to 30km. The average length is around 10 –20 km, in contrast to 20- 30 km in the current bus routes.

Figure 9.2-3 shows an accumulative percentage of distribution of route length by the trunk and ordinary buses. The 50 percentiles of route length are approximately 20 km for the trunk bus routes and 25km for the current routes. The ratios of long length routes with 25km or more are 25% for the trunk routes and 50% for the current routes, respectively.

The trunk bus route length is shorter than that in the current routes and almost all the routes are less than 25km.

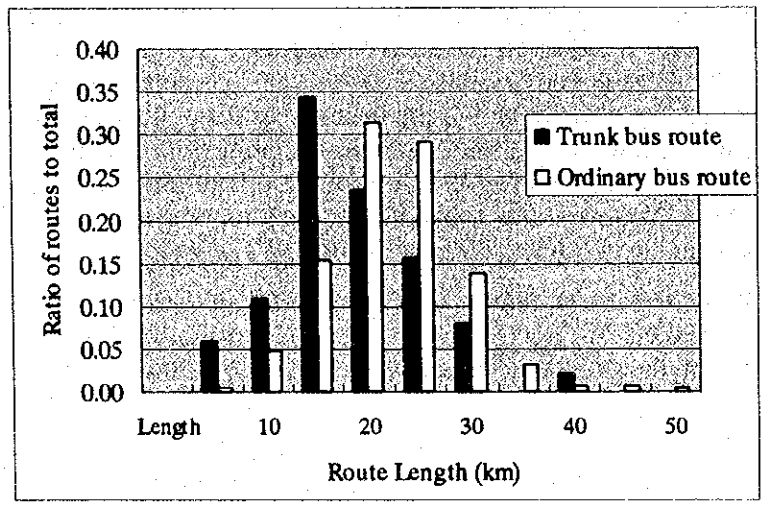

Figure 9.2-2 Distribution of Trunk and Ordinary Bus Route Distance

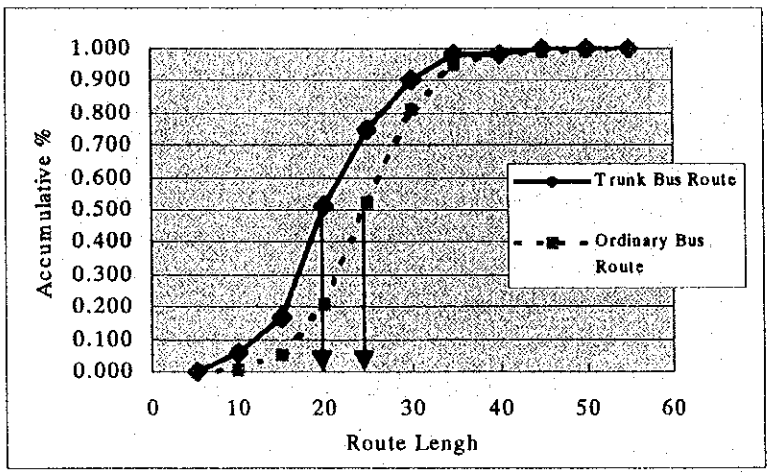

Figure 9.2-3 Accumulative Percentage of Route Distance Distribution

9.3. BUSWAY CAPACITY

9.3.1. OPERATING CONDITIONS

(1) Line Capacity

Vehicle line capacity or passenger line capacity (C) is the maximum number of buses or passengers that can be transported on one bus line (route) past a fixed point during one hour.

Scheduled line capacity C_0 is the number of passengers that are transported past a fixed point under a given operating schedule. Obviously,

$$Co \leq C$$

Table 9.3-1 shows the guideline for frequency and scheduled passenger line capacity. The line capacity is computed as the bus capacity, multiplied by frequency, on the assumption that buses are operated by headway of 1 minute or less.

The number of buses that pass a point on a line during an hour is the *service frequency f*, which is the inverse of *service headway h*, the average time interval between two successive buses:

$$f = \frac{3600}{h}$$

Table 9.3-1 Guideline of Scheduled Passenger Line Capacity

	Bus Capacity (no. of passengers per unit)	Headway (sec.)	No. of passengers transported (No. of passengers per/hour/dir.)
Express Bus	200	45 - 60	12,000 - 16,000
Trunk Bus	100	45 - 60	6000 - 8,000
Feeder Bus	20	45 - 60	1200 -1,600

(2) Service Frequency and Headway

Transportation is defined as the movement of *a number of buses or passengers (u)* over a *distance (s)* during an elapsed interval of *time (t)*. When a number of buses or passengers is transported over a bus route, ratios of those three elements (*u, s* and *t*) define basic performance attributes of that transportation service.

$$\text{frequency } f = \frac{u}{t}$$

Most of these attributes are used extensively in describing transit systems and their service. Frequency and its inverse, headway, are the basic elements for scheduling. The transit performance measures and concepts defined up to now, are presented graphically in Figure 9.3-1.

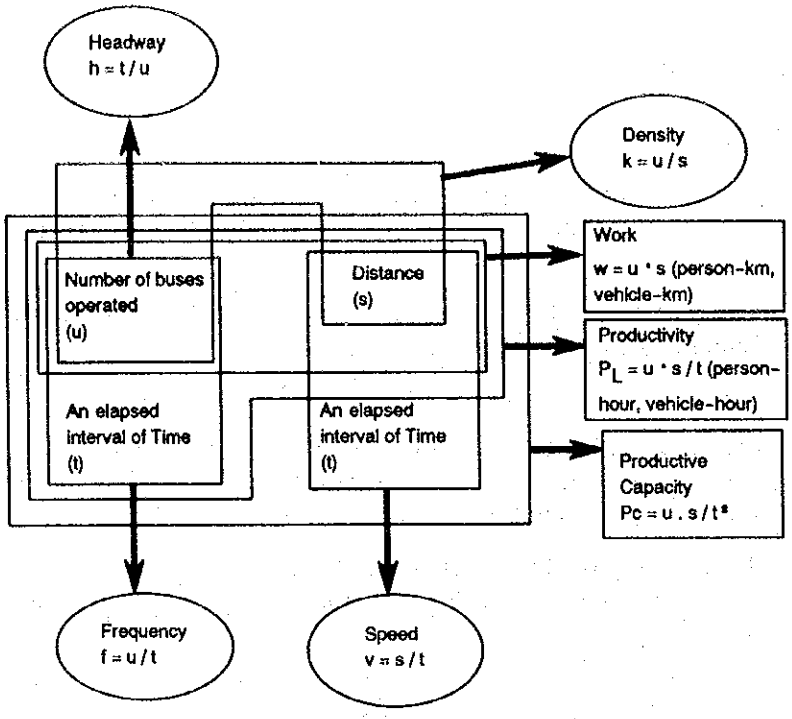

Figure 9.3-1 Basic Bus System Performance Measures

(3) System Criteria of Trunk Busway

According to Research report 329 of TRRL, the maximum recorded passenger flows varied from 7,300 passengers/hour/direction (p/h/d) in Ankara, to 26,100 p/h/d in Assis Brasil, Port Alegre, during the morning peak hour when alighting predominated. The corresponding maximum recorded passenger flows during the evening peak periods varied from 6,500 /hour in Ankara to 20,300 /hour in San Paulo, where overtaking lanes at bus stops facilitate high flows.

In Bogota, the maximum passenger flows recorded by the Study team are approximately 30,000 – 33,000 passengers/hour/dir in the inbound direction on Av. Caracas with bus segregated busway and 2 lane/dir in the period of 7:00 and 8:00 a.m. These figures are estimated by multiplying the number of buses by the average passengers on buses. The numbers of buses vary from 550 to 600/h/d and the average number of passengers per bus is approximately 55 –60 with standees between 10 and 20. The passenger flows on Av. Caracas are classified into the highest group in the world.

The busway flow capacity will be able to transport a passenger flow of 30,000 p/h/d on a consistent basis. The scheduled line capacity on busway in the Study will be approximately 30,000 p/h/d under a given operating schedule.

Table 9.3-2 summarizes a system criterion of trunk busway in order to plan an operation system in proportion to the demand on each trunk busway. The criterion considers the bus operation system with components such as express and trunk bus operations, service frequency, headway and number of lanes according to passenger demand.

As can be seen, in the case the passenger demand on busway is 10,000 or less, the number of service frequencies is 100 or less. In this case, it is possible to operate trunk buses on the trunk busway with one lane per direction. On the other hand, in the case where passenger demand is over 10,000, it is necessary to operate trunk and express

buses on the trunk busways provided for each bus system. Two (2) lane busway per direction is needed.

Table 9.3-2 System Criterion of Trunk Busway

Rank of Passenger Demand	Bus System	Headway (min)	Frequency (/hour)	Busway (No. of lanes)
1) 3,000 or less	Trunk Bus	2 to 5	12 to 30	1 lane/dir
2) 3,000 to 6,000	Trunk Bus	1 to 2	30 to 60	1 lane/dir
3) 6,000 to 10,000	Trunk Bus	0.6 to 1	60 to 100	1 lane/dir
4) 10,000 to 20,000	Trunk Bus	0.6 to 1.2	50 to 100	1 lane/dir
	Express Bus	0.6 to 1.2	50 to 100	1 lane/dir
5) 20,000 or more	Trunk Bus	0.6 or less	100 or more	1 lane/dir
	Express Bus	0.6 or less	100 or more	1 lane/dir

9.4. TRUNK BUS DEMAND

9.4.1. CUTTING AND INTEGRATION OF TRUNK BUS ROUTES

In 2000, the 6 trunk bus routes are proposed on the three (3) busways, while about 40 routes are planned on the 11 busways in 2005. There are several routes with small demand or overlapping on the same busway. Especially, in 2005 there are some winding routes which pass through both circulating and radial corridors of trunk busways. It is easy to see that those routes overlap with other routes.

In general, the basic conditions to plan bus routes are as follows:

1) The overlap of several bus routes should be avoided excluding central business districts.
2) It is desirable to allocate a maximum of 2 or 3 bus routes on the same road or busway.
3) A bus route with heavy demand should operate express and trunk bus services.
4) A longer bus route should be avoided because of difficulty of operating control.
5) A bus route should be operated in both directions.
6) A bus route passing through a central commercial area is needed. In this case, it is better to connect short routes with the area or terminal, rather than longer. The transfer at a terminal where a headway is longer in the off-peak is inconvenient for passengers. Timed-Transfer system is effective in this transfer condition. The transfer between bus routes with long headway should be organized, i.e., bus would arrive at terminal and then, connecting buses operated on other routes would leave the terminal within 5 minutes. By such system, transfer time (waiting time at terminal) is reduced.

In actual bus operation, some trunk bus routes are not realistic for both bus operators and passengers. The small demand routes are not economical for bus operators. The long and winding routes are also difficult in the control of operation and inconvenient for passengers. Therefore, several trunk bus routes will be cut or integrated according to the above discussion.

9.4.2. TRUNK BUS DEMAND BY ROUTE

(1) Demand in 2000

Figure 9.4-1 shows the peak hour passenger flows on roads with four (4) trunk bus routes in 2000 which is the same case as that in Case 4 in 2000 but with 6 trunk routes. Two (2)

trunk bus routes (No. T02 and T04) are cut because of small demand and long route. The passenger – load on the route No. T02 is a low as a few hundred. On the other hand, the route length on the No.T04 is as long as 37km in one-way. Both routes No.T01 and T03 are available as alternative routes of T02 and T04. Passengers who travel long journeys on the route T04 from south suburban bus terminal to deep north area will be inconvenienced due to transfer. Those passengers, however, are minor in volume (see Figure 9.4-2).

Figure 9.4-3 and Figure 9.4-4 show passengers on board in the direction of inbound and outbound on four (4) trunk routes, respectively. Passengers in the inbound on the routes T01 and T03 increase to a maximum of 12,000 on T01 and 20,000 on T03 due to cutting T02 and T04. As for the outbound, the passengers also increase by approximately 2- 2.5 times.

In the operation system, those passenger volumes on the four routes are used to schedule frequency and headway.

(2) Demand in 2005

Figure 9.4-5 shows the examination flowchart for bus operation system in 2005. In the previous section, passenger demands on the forty-one (41) trunk bus routes were estimated. In order to examine the actual bus operation system, several trunk bus routes are cut or integrated in the same manner as 2000, and then, the trunk bus routes are reduced to 31 trunk bus routes.

The 41-trunk bus routes are cut and integrated into 31 routes in the following manner.

1) A route with longer length is cut.
2) A route with low passenger demand is cut.
3) A winding route passing through both circulating and radial corridors of trunk busways is cut.
4) A route where similar other trunk bus routes are in existence is cut.
5) A route where it is possible to replace by other routes is cut.

After integrating the routes, passenger demands are estimated again for the examination of the operation system. The condition of assignment is the same case as that in Case-5 but with 41 trunk bus routes. It is found out that the passenger demands on Av. Suba and Calle 80 exceed the line capacity on the busway. Bus passenger flows on Av. Suba are approximately 15,000 – 21,000 /h/d in the inbound. Calle 80 also is very busy in passenger volume. The figure is approximately 40,000- 54,000 /h/d in the inbound. It is difficult to widen the right of way for the busway on Av. Suba because there are many buildings along this road and land acquisition is difficult. Therefore, a new busway from Av. Suba to Av. Caracas by way of Av. 127 to Autopista Norte is proposed altering the busway on Av. Suba in 2005.

Figure 9.4-6 shows the peak hour bus passenger flows on thirty-two (32) trunk bus routes in 2005, which add to new Suba busway to the basic 31 routes. Passenger flows on Av. Suba are approximately 10,000 – 11,000 /h/d in the inbound and also approximately 10,000 – 12,000/h/d on Av. 127. Those demands are within a busway capacity with 1-lane exclusive bus lane.

As for Calle 80, the trunk buses on the proposed system cannot meet bus passenger demands. Since these exceed the limit of bus line capacity, it is indispensable to complete Stage-2 in SITM's railway project by 2005 as planned on Calle 68 and running parallel to Calle 80, in order to integrate the systems to each other.

Figure 9.4-18 shows the peak hour bus passenger flows on thirty-two (32) trunk bus routes in 2005 which add the Stage-2 in SITM's railway project. As can be seen, when the Stage-2 will be completed, passengers on Calle 80 will be diverted to the railway. The passengers on Calle 80 will decrease to 20,000 – 30,000 /h/d in the inbound. On the other hand, the railway passengers are estimated at approximately 30,000 /h/d in the inbound. On this condition, the passenger demands on Calle 80 will not exceed the line capacity.

Figure 9.4-7 to Figure 9.4-17 show passengers on board in both the direction of inbound and outbound on the trunk bus routes, respectively in the same case on the thirty-two (32) routes without the Stage-2 in SITM's railway project. In those figures the passenger demands on each trunk bus route are drawn with a wide line in proportion to passengers on board. The star mark in those figures presents a beginning bus terminal. In the operation system, those passenger volumes on the thirty-two (32) routes are used to schedule frequency and headway.

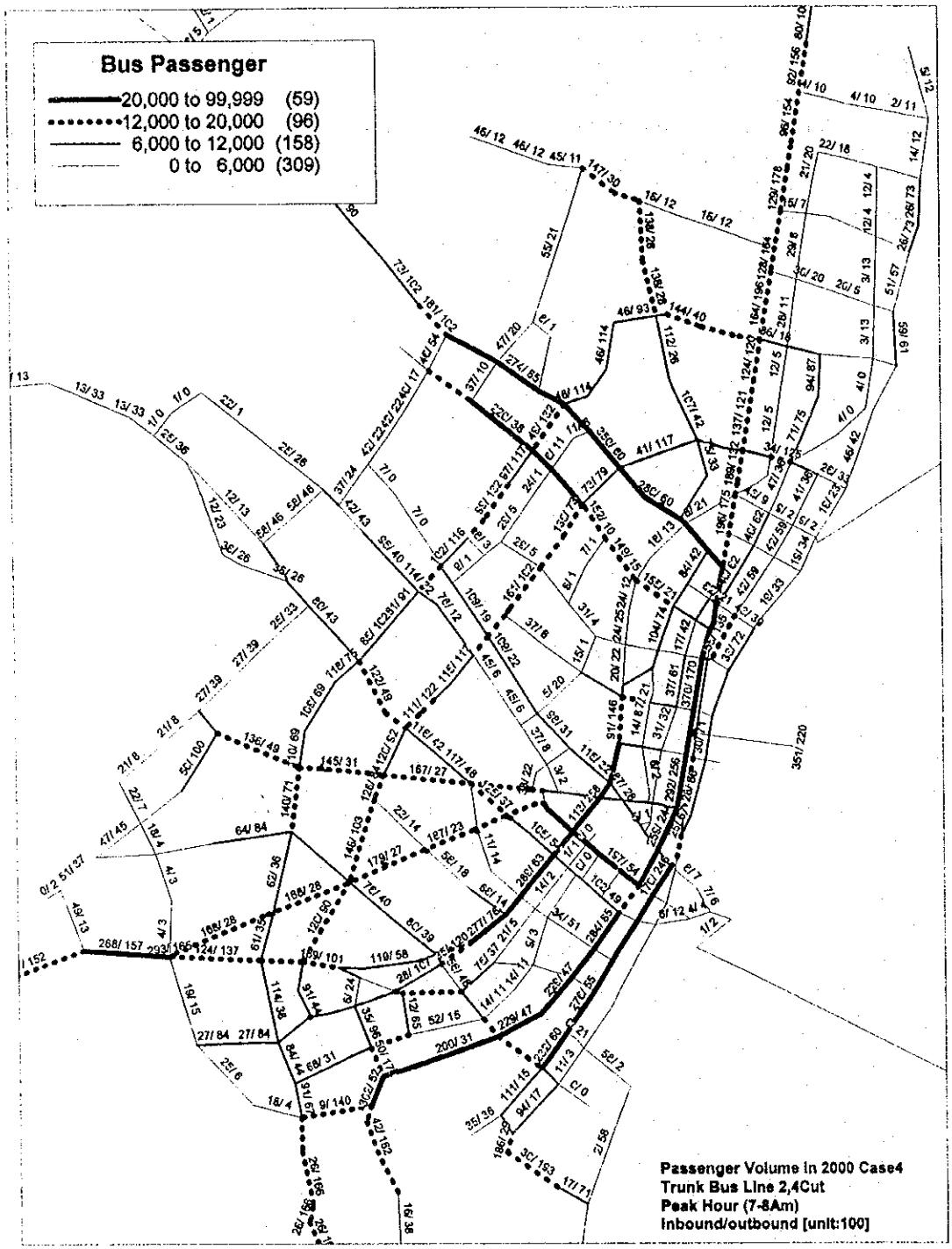

Figure 9.4-1 Peak Hour Bus passenger Flows in 2000 on Four (4) Trunk Bus Routes

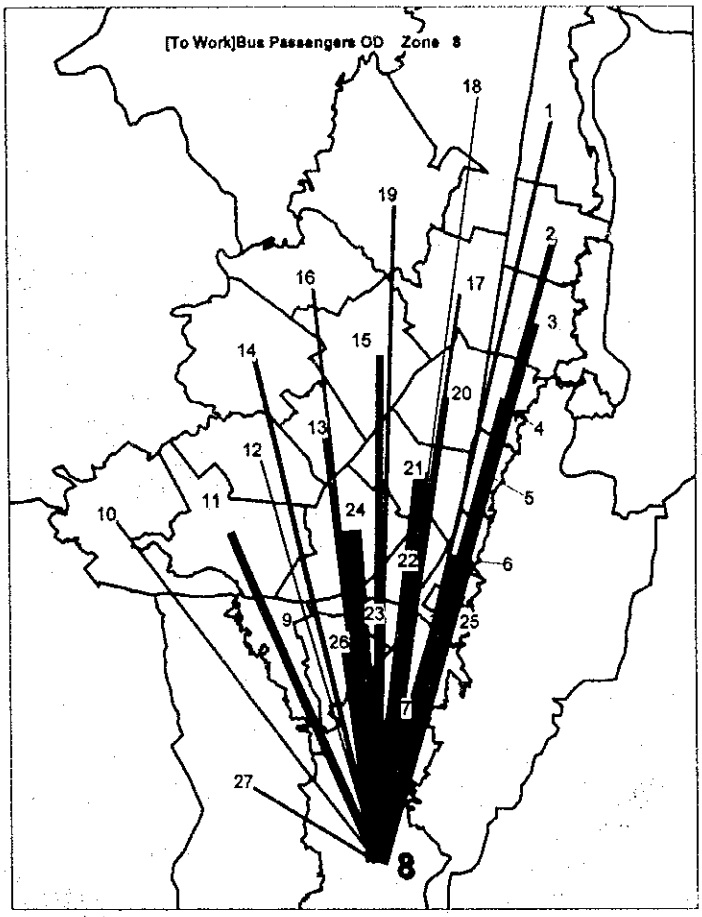

Figure 9.4-2 Desire Lines of Bus Users in the South Area (Zone 8)