6.3. TECHNICAL ANALYSIS OF THE TRUNK BUS SYSTEM

6.3.1. DEMAND ANALYSIS OF THE TRUNK BUS SYSTEM

In the Feasibility Study, the demand forecast for the trunk bus operation system plan is made in the morning peak hour, but a daily basis is used for the economic analysis, based on the demand forecast in 2010 and 2025 of the JICA Master Plan Study mentioned in the Chapter 5, Future Transportation Demand Forecast.

The demand analysis of trunk and feeder bus operation in the morning peak hours in 2010 is done based on the trunk and feeder bus line network shown in Figure 6.2-12. This network system serves as a Base Case. Passenger demand is forecast on the assumption of the integrated fare system of S./1.5. In order to identify the effect of the trunk bus system, the comparison to a "Without" project case which maintains the conventional bus system with 202 line system is also done. The demand analysis is also done in the year 2025 which is the target year of the Master Plan done by JICA to see sustainability of the trunk bus system.

(1) Total Passengers in the Trunk Bus System

Table 6.3-1 shows the total number of bus passengers in the morning peak hour by bus mode composed of the trunk bus, the feeder bus and the conventional bus. The feeder bus passengers are classified into the areas where the feeder bus is prepared. This figure indicates that when a passenger uses both the trunk bus and the feeder bus in one trip, the passenger is counted into both "trunk bus passenger" and "feeder bus passenger".

The total number of trunk bus passengers in 2010 on the east-west line is approximately 41,000 passengers/hr and the feeder bus passengers in the Callao, the Santa Clara and Huaycan areas are 1,900, 6,700 and 6,300 passengers/hr, respectively. The passenger volume in Callao is lighter than that in Santa Clara and Huaycan. This is because in Callao trip generation and attraction and trip distribution in the direction of the east-west corridor are relatively low in comparison to the Santa Clara and Huaycan areas. In 2025, the total passengers in the trunk bus system will rise 1.27 times in comparison with that of 2010, in which the trunk bus passengers are 1.25 times.

Table 6.3-1 Total Number of Hourly Bus Passengers in the Trunk Bus System

(Unit: passengers/hr)

Area	Mode	With (Passengers)		With (Composition)		Increase Ratio
		2010	2025	2010	2025	2025/2010
EW Line	Trunk Bus	41,064	51,523	73.4%	72.6%	1.25
Callao	Feeder Bus	1,880	2,872	3.4%	4.0%	1.53
Santa Clara	Feeder Bus	6,708	6,798	12.0%	9.6%	1.01
Huaycan	Feeder Bus	6,326	9,736	11.3%	13.7%	1.54
Total	Trunk-Feeder Bus	55,978	70,929	100.0%	100.0%	1.27

(2) Demand on the East-West Corridor

1) Bus Passenger Flows

Figure 6.3-1 shows the forecasts of trunk bus passengers by road segment in 2010. The numbers in the figure indicate passengers on board in the dual directions per morning peak hour. The maximum passengers are on Av. Ayllon at 22,000 passenger/hr/dual dir. The heavy passenger flows are on the segment between Av. Grau and Carretera Central. The passengers on the Callao side from Av. Grau are somewhat light. Table 6.3-2 shows maximum line passengers, operated bus fleets and minimum headway on the EW-trunk busway in 2010 and 2025. Those values indicate the sum of passengers or bus fleets by each line shown in Figure 6.2-3. The maximum values show maximums from among the sum on each segment on the trunk busway. The maximum number of line passengers in 2010, is approximately 14,000/hr/dir in the inbound direction, which increase 1.2 times in 2025. The operating headway in 2010 is equivalent to 44 sec and in 2025 the headway reduces to 35 sec. From the viewpoint of operating headway, the EW trunk bus system will be close to line capacity in 2025. In the event that the passenger demand for the EW-trunk busway became large enough to require a headway shorter than 30 seconds, it would be more appropriate to introduce the bi-articulated bus linking three vehicles (capacity of 200 or 240 passengers). Under these conditions, the EW-trunk bus system will be used to try to prolong the life of the system.

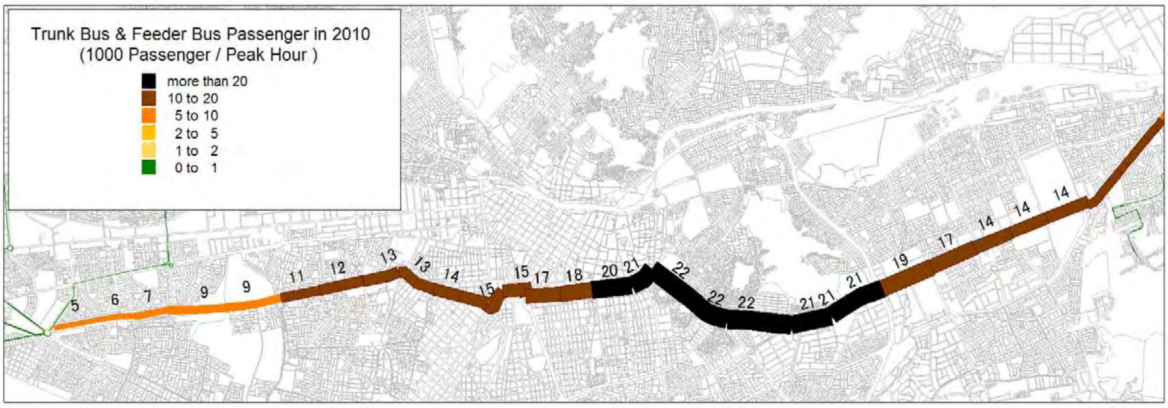


Figure 6.3-1 Trunk Bus Passenger Flows in the Morning Peak Hour per Dual Directions

Table 6.3-2 Maximum Line Passengers on the EW-Trunk Busway

Items	2010	2025	2025/2010
Passengers/hr/dir	13,685	16,755	1.22
Bus Fleets/hr/dir	82	103	1.26
Headway (sec)	44-60	35-40	-

As for the off-peak hour, according to the hourly fluctuation of bus passengers on Carretera Central from the bus counting survey as shown in Figure 6.3-2, the passengers and bus fleets decrease by about 50% of the peak hour. Therefore, the operating headway in the off-peak will be estimated at about 1.5-minute intervals in 2010 on the assumption of the same hourly fluctuation as at present.

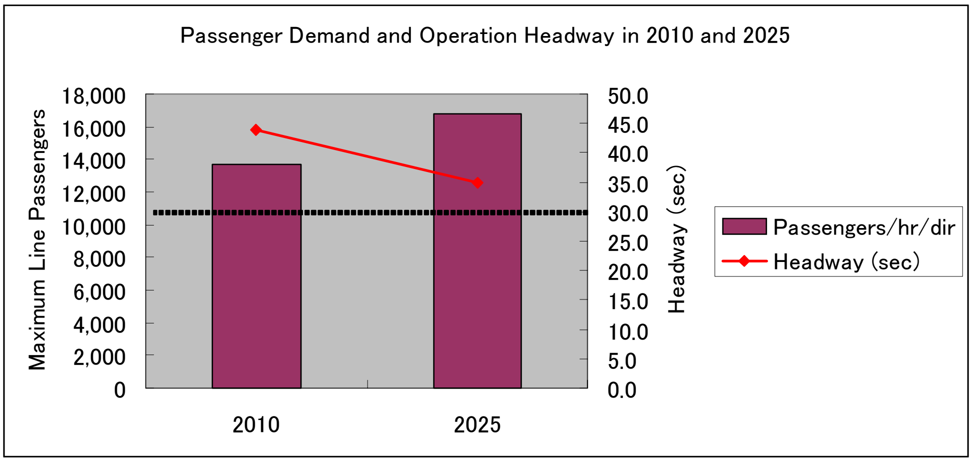
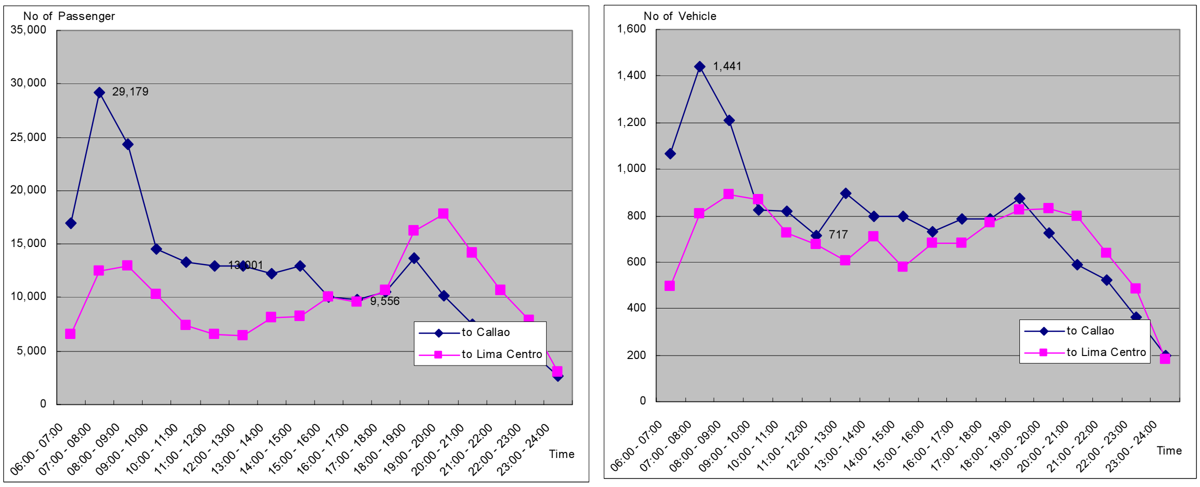


Figure 6.3-2 Line Passenger Demand/hour/dir and Minimum Operating Headway in 2010 and 2025 on the EW-Trunk Busway



Bus Passengers

Bus Fleets

Figure 6.3-3 Hourly Fluctuation of Bus Passengers and Fleets on Carretera Central in 2006

Figure 6.3-4 and Figure 6.3-5 show the feeder bus passengers by road segment in Callao, Santa Clara and Huaycan in the base case in 2010. In Callao, the heavy volume of passengers concentrates near the trunk bus terminal, and its figures range between 200 to 600 passengers/hr/dual dir. On the other hand, the volume of feeder bus passengers in Santa Clara and Huaycan is heavier than that in Callao. A maximum of approximately 1,900 passengers in Santa Clara use the feeder bus. Since the feeder bus lines concentrate on the segments near the Santa Anita terminal, the volume of passengers near the terminal surprisingly rises to 4,200 passengers/hr/dual dir.

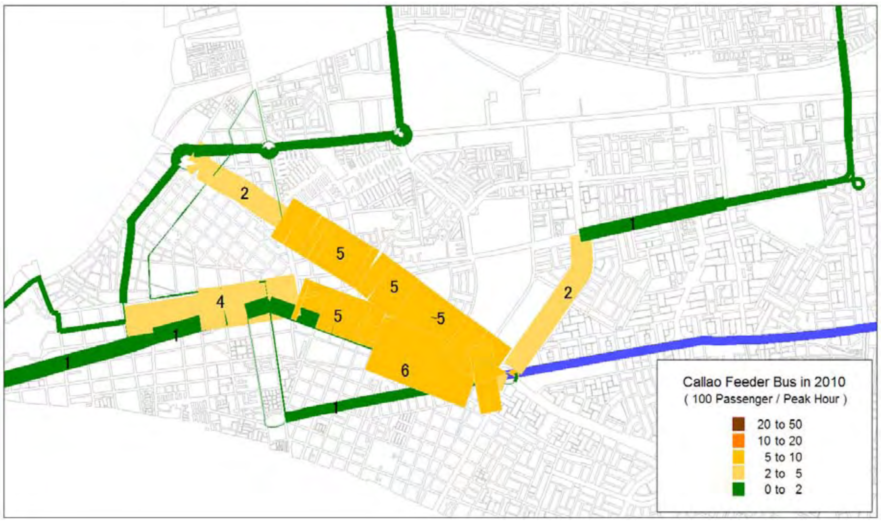


Figure 6.3-4 Feeder Bus Passenger Flows per Dual Directions in Callao

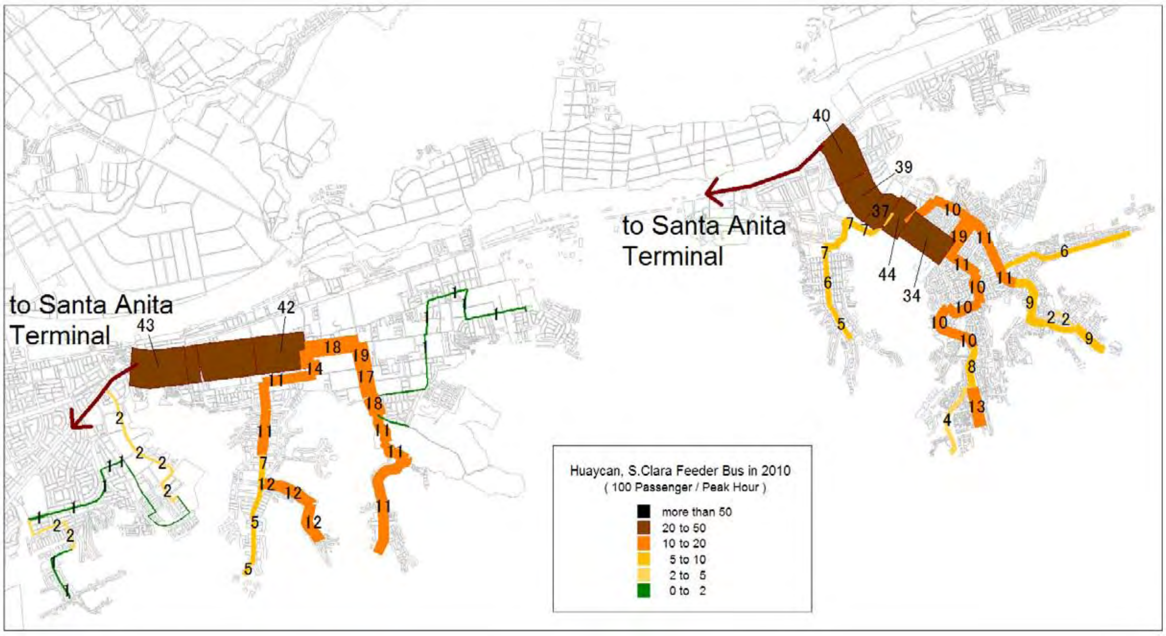


Figure 6.3-5 Feeder Bus Passenger Flows per Dual Directions in Santa Clara and Huaycan

2) Bus Traffic Flows

Figure 6.3-6 shows the trunk bus volumes in the morning peak hour in the dual directions by road segment. The maximum trunk bus volumes are 138 bus fleets/hr/dual dir on the segment between Av. Grau and Santa Anita terminal, while 108 trunk bus fleets are on Av. Venezuela. The maximum line bus fleets in 2010 are approximately 82 trunk buses/hr/dir in the inbound direction on Carretera Central as shown in Table 6.3-2.

On the other hand, the feeder bus volumes are shown in Figure 6.3-7 in Callao and in Santa Clara and Huaycan, respectively. In Callao, a maximum of approximately 20 bus fleets/hr/dual dir are operated near the terminal. Near the Santa Anita terminal, a maximum of 127 feeder buses/hr/dual dir are operated.

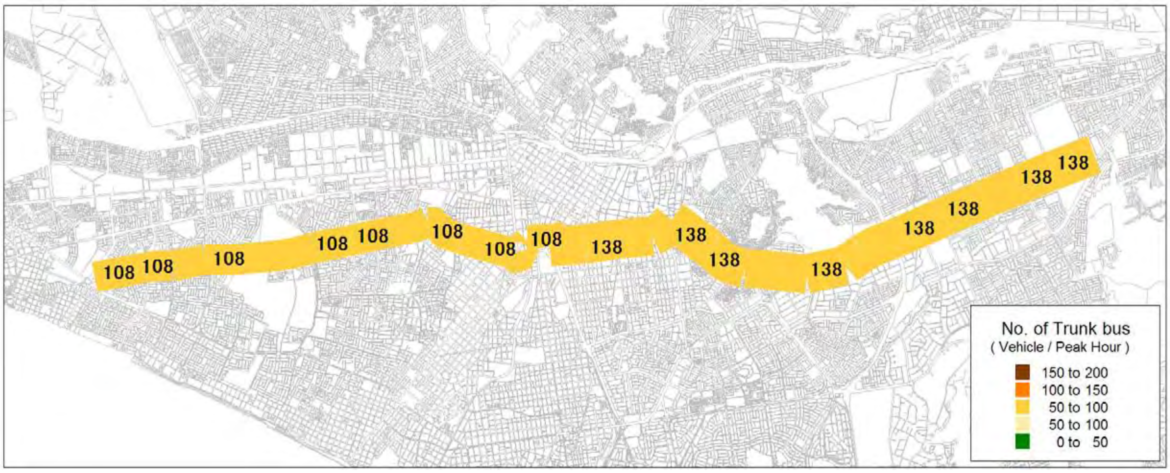


Figure 6.3-6 Trunk Bus Volumes in the Morning Peak Hour/Dual Directions

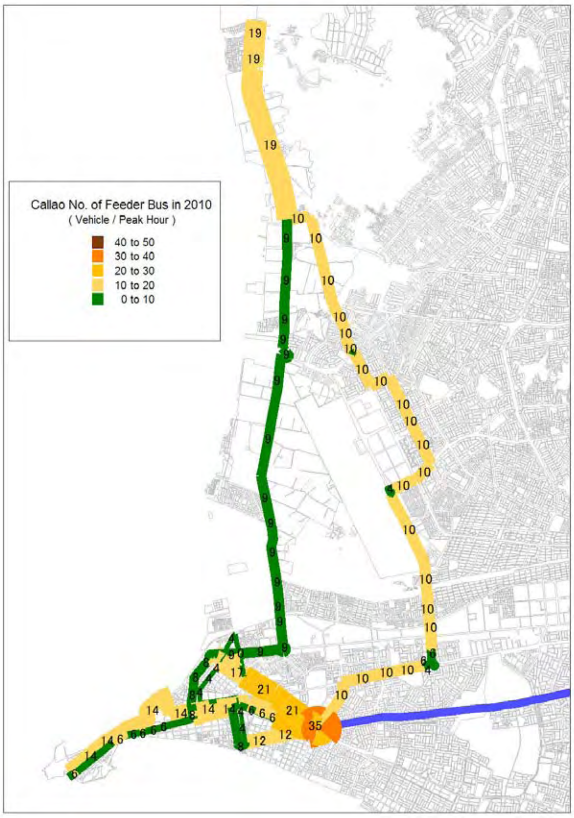


Figure 6.3-7 Feeder Bus Volumes in the Morning Peak Hour/Dual Directions in Callao

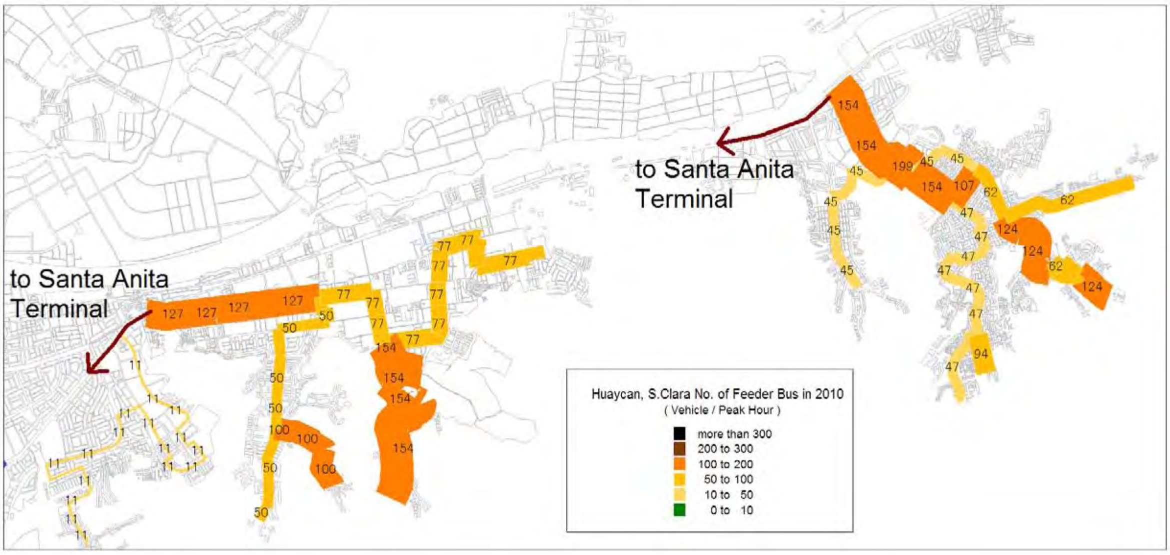


Figure 6.3-8 Feeder Bus Volumes in the Morning Peak Hour/Dual Directions in Santa Clara and Huaycan

(3) Line Characteristics

1) Passengers by Transferred Modes in the Trunk Bus System

In the EW-trunk bus system, passengers transfer from the trunk bus to other buses. The classification of passengers who transfer or not is shown in Figure 6.3-9 and Table 6.3-3 in which EW-trunk bus only, feeder bus only and their combined use are categorized. The trunk bus alone has as many as 13,300 passengers/hr in 2010, equivalent to 33% of the total in the trunk bus system which is approximately 40,000 passengers/hr. On the other hand, only the feeder bus is lower in passengers with a figure of approximately 1,800. The combinations with other buses such as trunk-feeder buses and feeder-conventional buses have higher passenger volumes. In 2025, the passengers in the system rise 1.24 times in comparison to that in 2010.

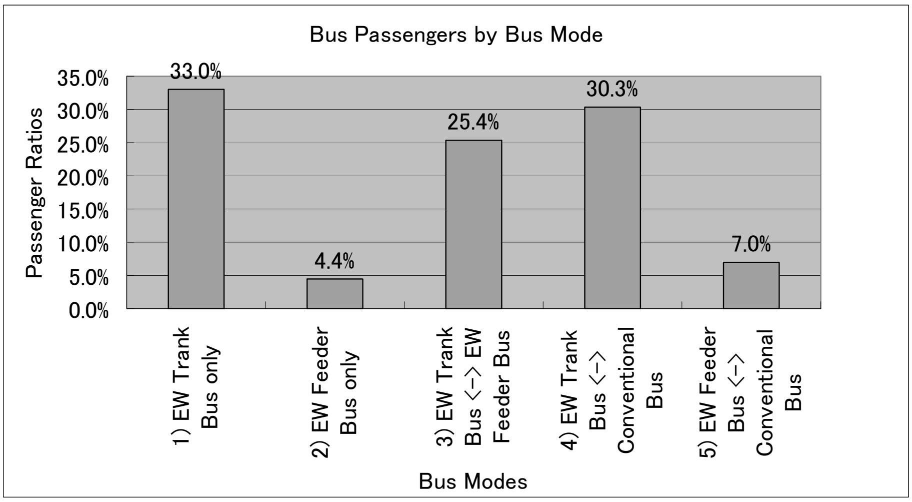


Figure 6.3-9 Bus Passengers by Bus Transferred Modes

Table 6.3-3 Number of Passengers by transferred Modes in the EW-Trunk Bus System

(Unit: passengers/hr)

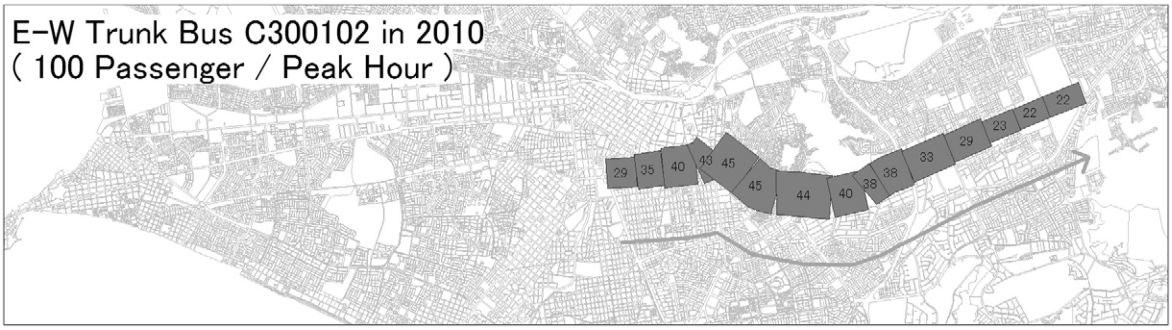
Transfer	With		With		2025/2010
	2010	2025	2010	2025	
	Passengers		Ratio		
1)EW Trunk Bus only	13,332	14,261	33.0%	28.3%	1.07
2)EW Feeder Bus only	1,775	2,119	4.4%	4.2%	1.19
3)EW Trunk Bus <->EW Feeder Bus	10,255	12,959	25.4%	25.8%	1.26
4)EW Trunk Bus <->Conventional Bus	12,224	16,723	30.3%	33.2%	1.37
5)EW Trunk Bus <->EW Feeder Bus	2,822	4,251	7.0%	8.4%	1.51
Total	40,428	50,313	100.0%	100.0%	1.24

2) Passengers on Trunk Bus Lines

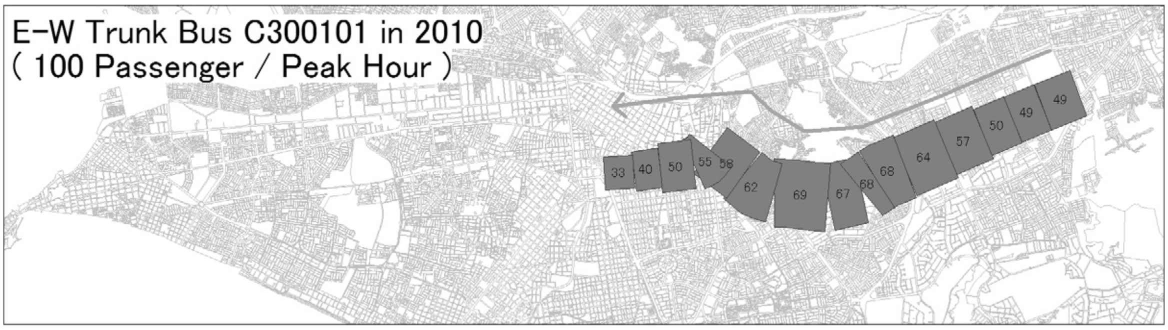
Through Figure 6.3-12 show the peak hour inbound and outbound bus passengers in the morning peak hour by the trunk bus line in 2010. The trunk bus line configuration on the east-west trunk bus system is already shown in Figure 6.2-3 in which the trunk bus line consists of three lines/round. The line Nos.C300101 and 102 operated on the segment between Av. Grau and the Santa Anita terminal transports 6,900 line passengers/hr/dir in the inbound direction, in contrast to 4,500 in the outbound direction.

In the line Nos.C300111 and 112 in the Callao side as shown in Figure 6.3-11, a maximum of approximately 3,800 line passengers/hr/dir in the outbound direction are used, while 2,300 line passengers/hr/dir are used in the inbound direction.

Figure 6.3-12 shows passenger volumes on lines No. C300121 and 122 which connect the two terminals. The maximum volume of line passengers is approximately 6,900/hr/dir on Av. Grau in the direction of the Santa Anita terminal.

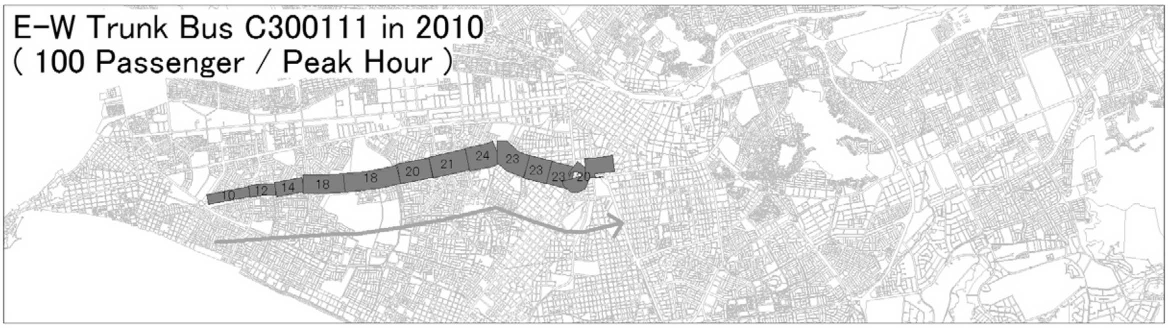


(Inbound Direction)

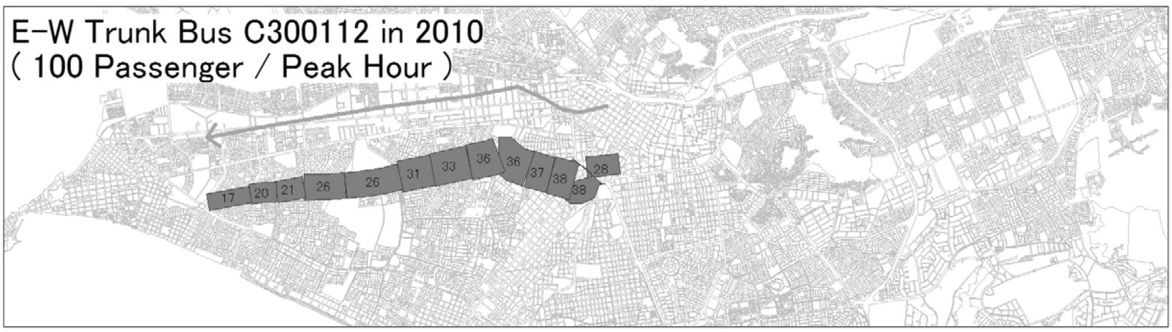


(Outbound Direction)

Figure 6.3-10 Trunk Bus Passengers on Board

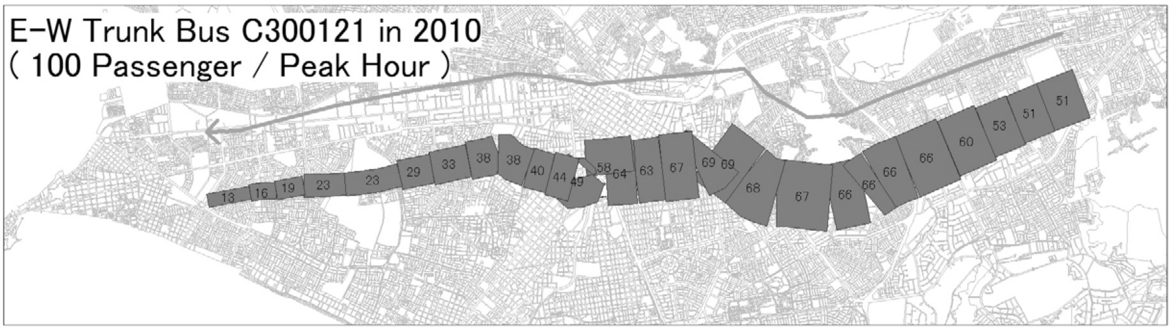


(Inbound Direction)

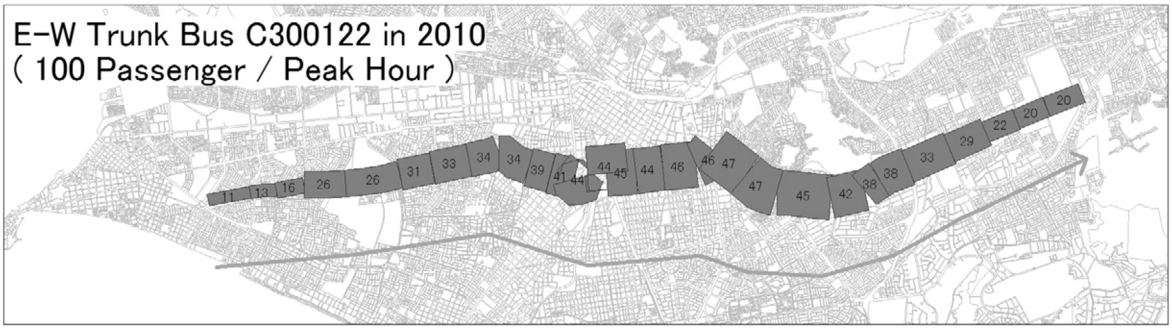


(Outbound Direction)

Figure 6.3-11 Trunk Bus Passengers on Board



(In the Direction of the Santa Anita Bus Terminal)



(In the Direction of the Callao Bus Terminal)

Figure 6.3-12 Trunk Bus Passengers on Board

(4) Boarding and Alighting Behaviors of Trunk Bus Passengers

Figure 6.3-14 to Figure 6.3-16 show the peak hour boarding and alighting passengers at bus stops on EW trunk busway in 2010. Bars indicate the boarding and the alighting passengers at each bus stop and the line shows the on-board passengers. Figure 6.3-12 shows the bus stop locations on the trunk busway.

Figure 6.3-14 shows Line No. C300121 (from Santa Anita to Callao Terminals) and Line No. C300122 (the opposite direction to Line No. C300121). Line No. C300121 has nearly 5,000 boarding passengers per hour at Santa Anita Terminal and picks up some passengers along the way until Centro, where the on-board passengers decline to nearly 500 per hour. After Centro, passengers begin to alight, reaching nearly 400-500 per hour at a bus stop on Av Venezuela. C300122 has nearly 1,200 boarding passengers at Callao Bus Terminal, and by picking up passengers along the way, the line has about 4,500 on-board passengers near Av Grau. And then, the on-board passengers peak around 4,700 near Av 28 de Julio. After that, more than 500 passengers alight per hour. More than 2,000 passengers per hour alight at a bus stop at the Santa Anita Terminal. Those characteristics of boarding and alighting passengers show a similar tendency to that of the field survey data.

Figure 6.3-15 and Figure 6.3-16 show Line No. C300101 (from Santa Anita Terminal to Centro) and C300111 (Callao Terminal to Centro), respectively. Both Lines have many boarding passengers at the terminals and pick up some passengers along the way until a halfway between Centro. And then, passengers begin to alight.

The number of operated buses is estimated by dividing the maximum passengers on board of each line by a bus fleet capacity of 170 as shown in Figure 6.3-14 to Figure 6.3-16. However, those operated numbers are too much in actual operation. The detailed analysis of the actual number of dispatched buses will be carried out in Section 6.5, Trunk Bus Operation Plan.

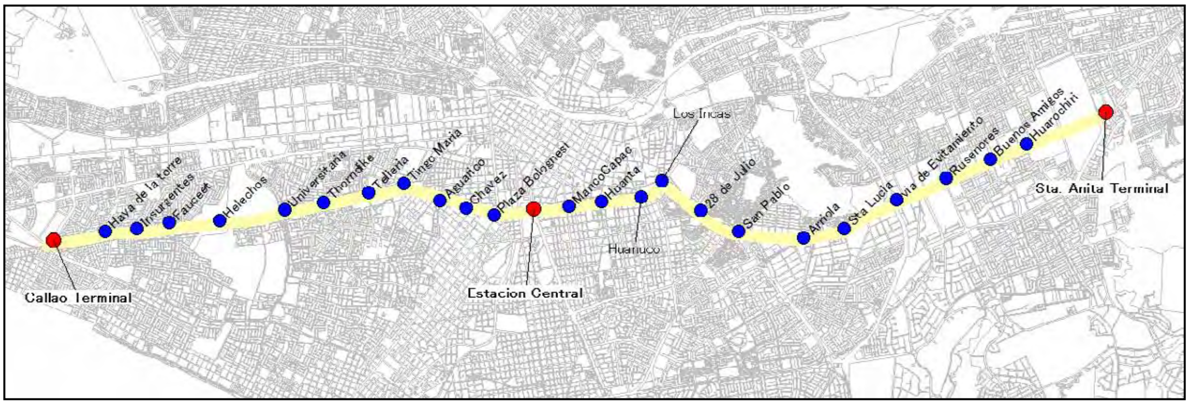
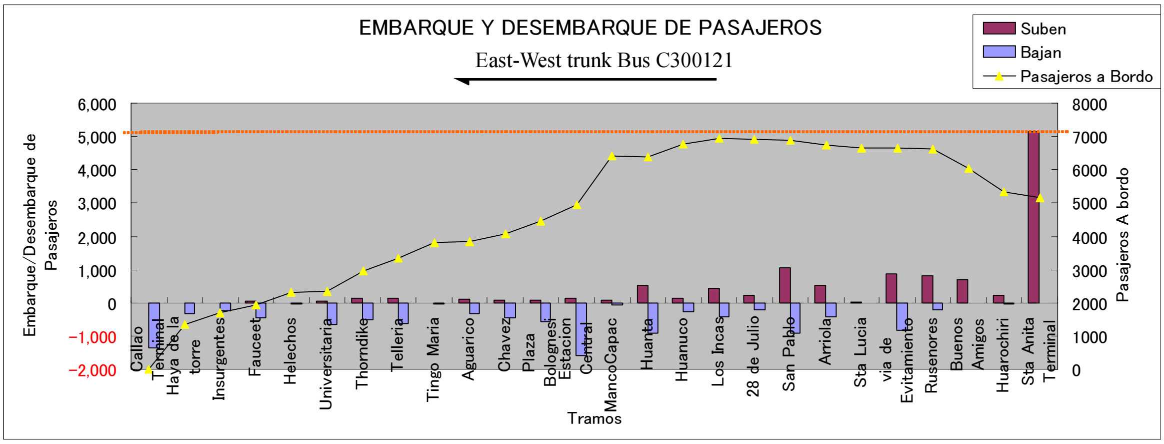
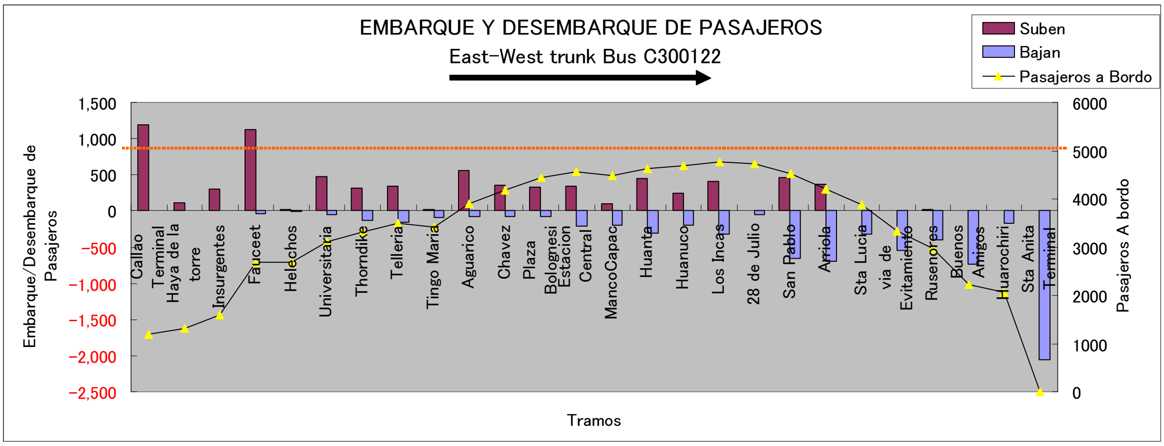


Figure 6.3-13 Bus Stop Locations



Direction from Santa Anita Terminal to Callao Terminal (Line No.: C300121)



Direction from Callao Terminal to Santa Anita Terminal (Line No.: C300122)

Figure 6.3-14 Boarding and Alighting Passengers at Bus Stops, and Passengers on Board (Line Nos. C300121 and C300122)

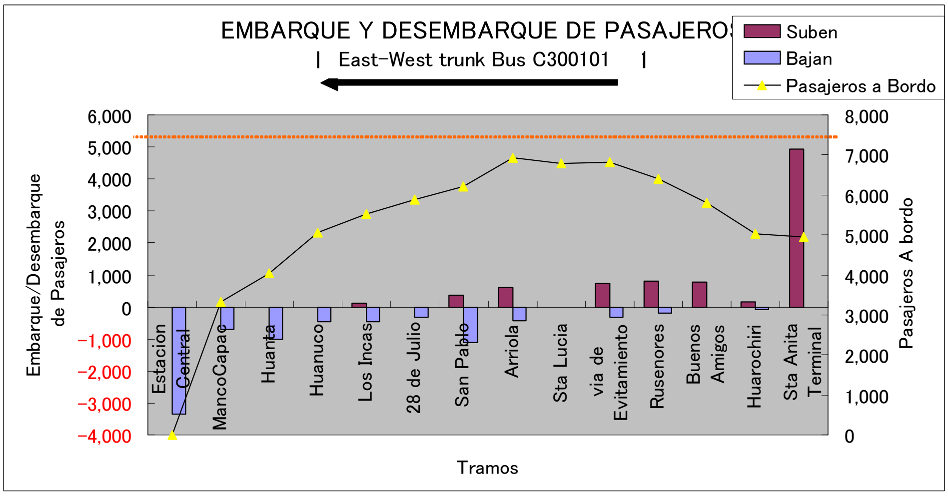


Figure 6.3-15 Boarding and Alighting Passengers at Bus Stops, and Passengers on Board (Line No. C300101)

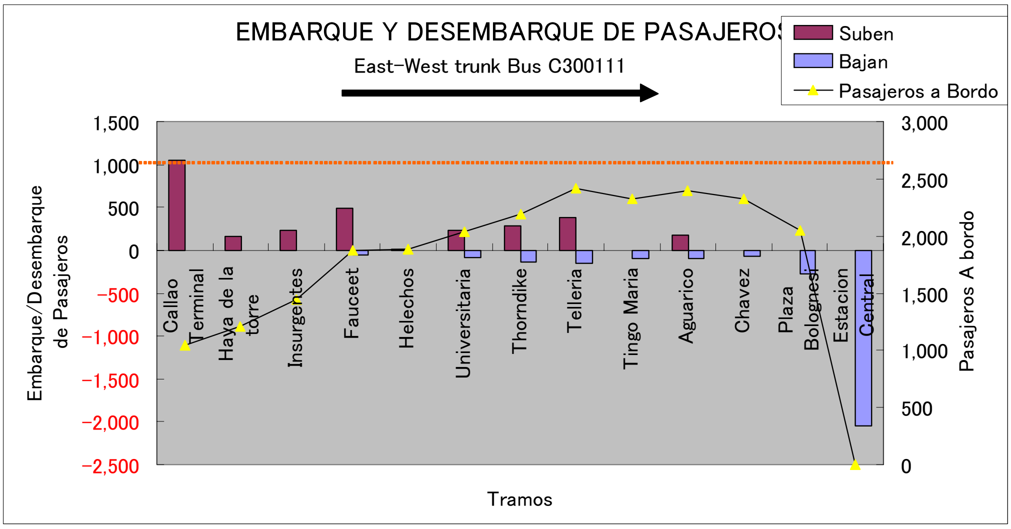


Figure 6.3-16 Boarding and Alighting Passengers at Bus Stops, and Passengers on Board (Line No. C300111)

(5) Passenger Behavior at Bus Terminals

Table 6.3-4 shows passenger behavior at the bus terminals in terms of trunk and feeder bus passengers, and service frequency. Maximum operated buses for departure or arrival of trunk and feeder bus in Santa Anita terminal are approximately 220 buses/hr, in contrast to 85 buses/hr in the Callao terminal. These values are estimated based on the passenger demand at the bus terminals. Actual number of operated buses will be estimated in the bus operation plan. Those values will be used for a necessary terminal area.

Table 6.3-4 Trunk and Feeder Bus Passengers, and Service Frequency in Both Bus Terminals

Terminal	Types	Passengers		No. of Operated Buses	
		Boarding	Alighting	Departure	Arriving
Callao	Trunk Bus	2,243	3,087	44	64
	Feeder Bus	1,419	233	41	22
	Conventional Bus	2,263	3,956	317	317
Santa Anita	Trunk Bus	10,114	4,280	82	56
	Feeder Bus	4,748	5,401	137	177
	Conventional Bus	1,240	5,631	540	540

(6) Fare Proceeds

Table 6.3-5 shows the estimated revenue from bus operation in 2010. The bus fare is assumed to be S./1.5 per trip on the trunk and feeder buses under the integrated fare system. Transfers from the feeder to the trunk bus service and vice versa at integrated bus terminals require no extra charge. The total revenue in the trunk and feeder bus system is approximately S./82,800/hour. The average revenue per bus is S./153. The average paid fare rate per passenger using the trunk bus system is S./2.1.

The detailed analysis of the fare rate system in the trunk bus system is carried out in Section 6.4 in which the relationship between total proceeds and passengers on several fare rates is analyzed in the sensitivity analysis.

Table 6.3-5 Total Revenue from Bus Operation

(Unit: S./ per hr)

	Items	With
Trunk Bus-Feeder Bus	Total Proceeds (S./)	82,836
	Proceeds/bus (S./)	153
	Proceeds/passenger (S./)	2.1

6.4. BUS FARE RATE SYSTEM PLAN

6.4.1. PROPOSED FARE SYSTEM

In the F/S study, the fare system employs the integrated fare system which allows transfer without payment of an additional fare when passengers transfer from/to feeder bus or trunk bus at terminal. The fare rate set at S./1.5 refers to the COSAC fare rate. Figure 6.4-1 shows ratio of bus fare rate to GRDP/capita in South American countries. The present fare rate at S./1.0 in Lima is equivalent to 0.012% to GRDP/capita. The fare rate of S./1.5 set in the integrated fare system is 0.018% to GRDP/capita. Its figures are somewhat low in comparison to the other countries. It will be possible for passengers to accept the proposed fare rate.

In the section, the detailed analysis of the fate rate system in the trunk bus system is carried out in which the relationship between total proceeds and passengers by several fare rates is analyzed in the sensitivity analysis.

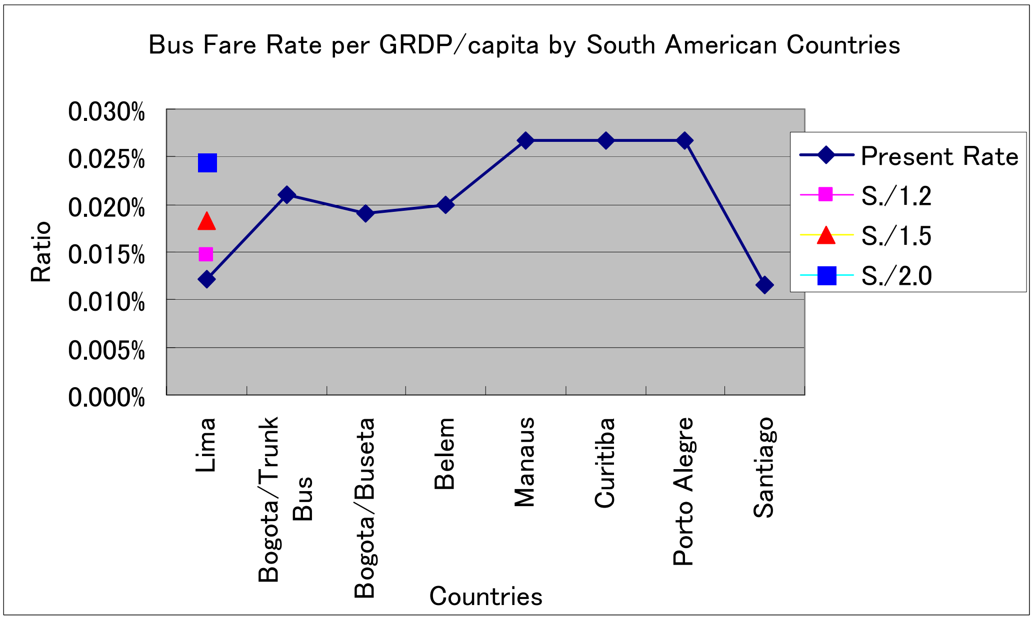


Figure 6.4-1 Bus Fare Rate per GRDP/capita in South American Countries

6.4.2. SENSITIVITY ANALYSIS

(1) Examination Cases

The following four (4) alternatives on the integrated system are examined in the sensitivity analysis.

1) Fare rate S./1.0
2) Fare rate S./1.2
3) Fare rate S./1.5 (proposed fare rate)
4) Fare rate S./2.0

On the other hand, a lower feeder bus fare rate is also set in the examination case in order to advance bus use for poor people. The following two (2) examination cases are set.

5) Trunk bus fare rate S./1.5 and feeder bus rate S./0.5

6) Trunk bus fare rate S./1.5 and feeder bus rate S./1.0

Figure 6.4-2 shows the procedure of sensitivity analysis.

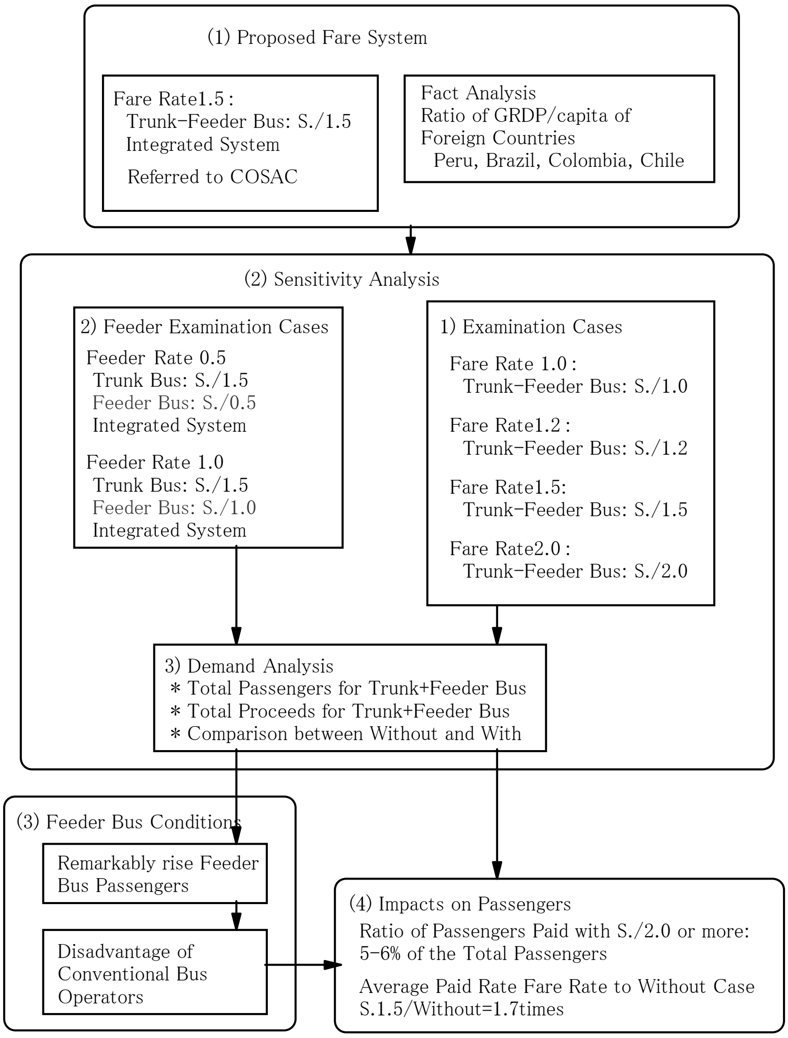


Figure 6.4-2 Procedures of Sensitivity Analysis

(2) Sensitivity Analysis

1) Total Passengers by Trunk and Feeder Buses

Table 6.4-1 shows the total number of hourly bus passengers and proceeds by fare rate cases. Figure 6.4-3 shows the relationship between total proceeds, passengers and paid rate per passenger. The line graphs of both the passengers and total proceeds show decrease with increasing the fare rate. Since these lines do not show the maximum or minimum point of inflection of a curve, it is difficult to find out an optimum fare rate.

The ratios of total passengers to the fare rate S./1.5 are at 2.0 times in the rate S./1.0, in contrast to 0.7 times in the rate S./2.0. On the other hand, the ratios of total proceeds are at 1.6 times in the rate S./1.0 and 0.8 times in the rate S./2.0. The proceeds per passenger is S./2.0 in the fare rate S./1.5, in contrast to S./1.6 in “Without” case. From the viewpoint of revenue, the fare rates S./1.0 or 1.2 are rational.

Figure 6.4-4 shows relationship between operated buses and proceeds/bus in the examination cases. The proceeds per bus rises with increasing the fare rate. On the other hand, the number of operated buses reduces with increasing the fare rate. From the viewpoint of bus operation, the fare rates S./1.5 or 2.0 are reasonable.

Table 6.4-1 Total Number of Hourly Bus Passengers and Proceeds by Fare Rate Cases

Items	Fare Rate 1.0	Fare Rate 1.2	Fare Rate 1.5	Fare Rate 2.0
Trunk and Feeder Bus Passengers (pax/hr)	79,931	53,809	40,428	27,786
Total Proceeds of Trunk Bus System (S./hr)	135,526	97,890	82,836	66,764
Proceeds/passenger of Trunk Bus System	1.7	1.8	2.0	2.4
Proceeds/bus of Trunk Bus Sytem	134.5	134.7	153.1	191.3
Ratio of Bus Passengers to Fare Rate 1.5	2.0	1.3	1.0	0.7
Ratio of Total Proceeds to Fare Rate 1.5	1.6	1.2	1.0	0.8

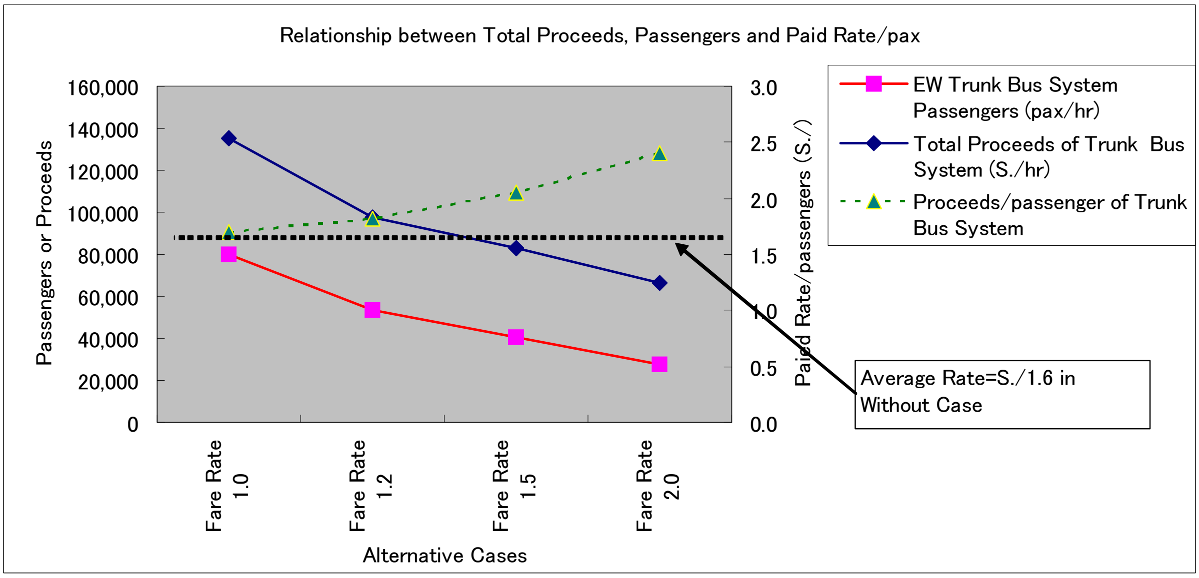


Figure 6.4-3 Relationship between Total Proceeds, Passengers and Paid Rate/passenger

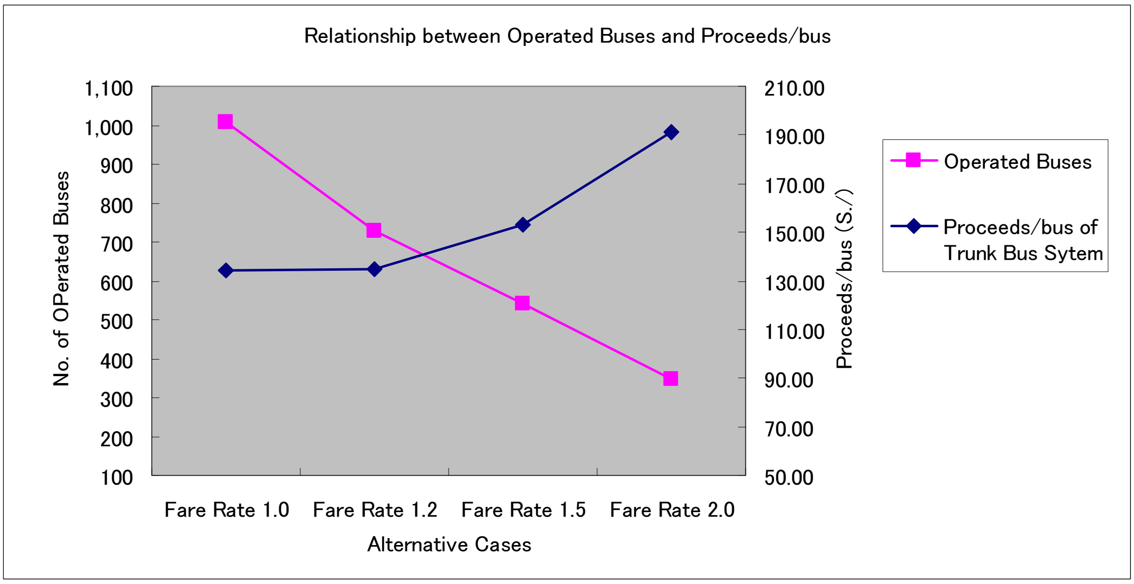


Figure 6.4-4 Relationship between Operated Buses and Proceeds/bus

(3) Feeder Bus Conditions

Table 6.4-2 shows the passengers by bus transferred modes and total proceeds in the feeder fare rates S./0.5 and S./1.0. As it can be seen, the feeder bus related passengers who pay S./0.5 remarkably rise at 6.4 times for "the feeder bus only" and 9.6 times for "the feeder and conventional buses". As for the feeder rate S./1.0, the increase ratios of the passengers are 2.4 times for "the feeder bus only" and 3.1 times for "the feeder and conventional buses" (see Figure 6.4-5).

From above discussion, when the feeder bus fare rate sets on S./0.5 or S./1.0, the conventional bus passengers are too many to operate a feeder bus. These conditions remarkably affect on the conventional bus operation and the conventional bus loses passengers to the feeder bus due to the lower fare rate. Therefore, the lower fare rate of the feeder bus is not acceptable in not only the conventional bus system but also trunk bus system.

Table 6.4-2 Passengers by Bus Transferred Modes and Total proceeds

	(1) T=S/1.5, F=S/0.5	(2) T=S/1.5, F=S/1.0	(3) Fare Rate 1.5	(1)/(3)	(2)/(3)
EW Trunk Bus only	12,500	13,124	13,332	0.94	0.98
EW Feeder Bus only	11,292	4,255	1,775	6.36	2.40
EW Trunk Bus <-> EW Feeder Bus	17,349	14,070	10,255	1.69	1.37
EW Trunk Bus <-> Conventional Bus	8,755	10,983	12,244	0.72	0.90
EW Feeder Bus <-> Conventional Bus	26,978	8,782	2,822	9.56	3.11
Total Passengers	76,874	51,214	40,428	1.90	1.27
Total Proceeds of Trunk Bus System	131,614	100,937	82,836	1.59	1.22
Proceeds/bus of Trunk Bus Sytem	114.5	127.1	153.1	0.75	0.83
Proceeds/passenger of Trunk Bus System	1.71	1.97	2.05	0.83	0.96

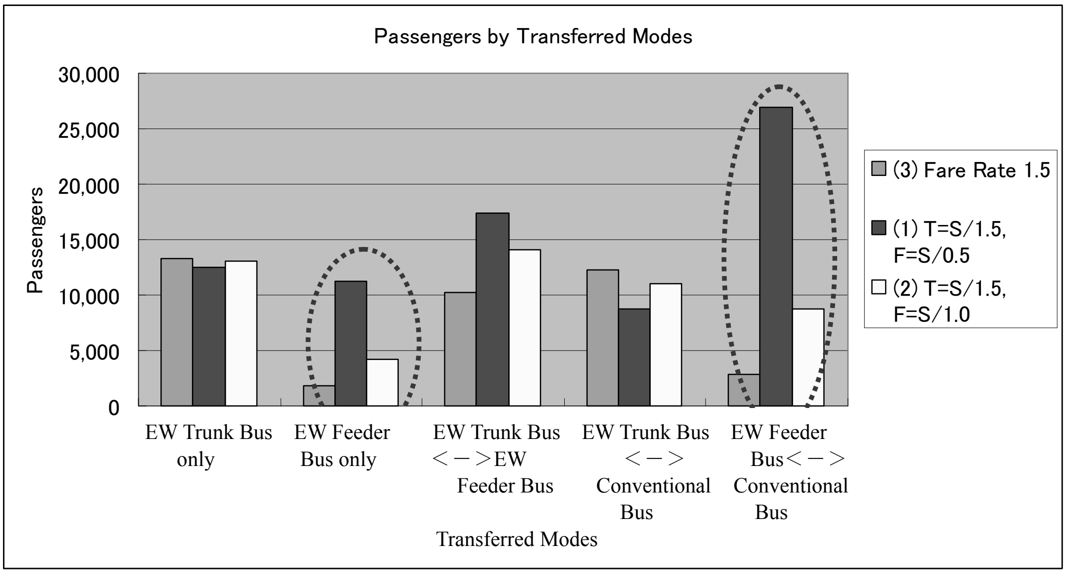


Figure 6.4-5 Passengers by Transferred Modes

(4) Impacts on passengers

The proposed fare rate S./1.5 is reasonable in consideration of bus passenger volume and the operated buses. And the low fare rate of feeder bus is difficult to propose in the system. When this fare system is employed, the passengers who pay at a rate of S./2.0 or more inclusive of the conventional bus use are as few as 7% of the total trunk bus users.

6.5. TRUNK BUS OPERATION PLAN

6.5.1. PLANNING

(1) Service Frequency

1) Trunk and Feeder Bus Service Frequencies

In Section 6.1, the trunk bus operation frequency and headway are shown based on the transit assignment model. The peak-hour operation frequency per trunk bus line, however, is obtainable by dividing the largest route-segment passenger demand of a given line by the articulated bus capacity. Passengers on a given line vary constantly throughout the route from origin to destination, and the largest demand concentrates on certain route segments or between certain bus stops. From the viewpoint of operating efficiency and economy, the bus capacity is set at 110% of the standard capacity in consideration of the passenger characteristics on board. The results of calculation are shown in Table 6.5-1. Salient characteristics of operation frequency are summarized as follows.

1) In 2010, the headway of trunk bus lines is about 1.7 and 2.5 minutes in Lines C300101 and C300102. In Lines C300111 and C300121, the headway is about 4.6 and 3.0 minutes. The Lines C300121 and C300122 are operated by the headway of 1.7 and 2.3 minutes.
2) Four (4) feeder bus lines in Callao are in operation, each with the minimum headway of about 5 minutes and their passengers transfer to the trunk bus lines at the Callao terminal.
3) In Santa Anita, three feeder bus lines respectively depart the terminal every 3-10 minutes or so in exclusive of Line F420111.
4) Three feeder bus lines in Huaycan depart the terminal every 3 minutes.

Table 6.5-1 Bus Service Frequency and Fleet Requirement for Trunk and Feeder Buses

Seq.No.	Area	Mode	Line No.	Distance (km)	Direction	Operation Speed (km/h)	Operation Time (min)	Passengers	Maximum Line Passengers	Modefied Frequency	Modefied Headway (min)	No. of Needed Operation Buses	Sub-total /Area	Total Buses /Type
1	EW Line	Trunk Bus	C300101	11.7	E→W	35	20.0	8508	6970	36	1.7			
2			C300102	11.7	W→E	35	20.0	5728	4590	24	2.5	30		
3			C300111	9.6	W→E	35	16.4	3025	2550	13	4.6			
4			C300112	9.6	E→W	35	16.4	4739	3910	20	3.0	16		
5			C300121	21.3	E→W	35	36.4	11539	6970	36	1.7			
6			C300122	21.3	W→E	35	36.4	7525	4930	26	2.3	50	96	96
7	Callao	Feeder Bus	F219211	5.6		25	13.3	185	222	5	12.0			
8			F219212	6.5		25	15.6	514	518	12	5.0	10		
9			F219221	17.4		25	41.7	0	0	0	0.0			
10			F219222	17.5		25	42.1	305	333	8	7.5	14		
11			F219231	18.9		25	45.2	186	148	3	20.0			
12			F219232	18.7		25	44.9	300	222	5	12.0	10		
13			F219251	7.6		25	18.1	118	148	3	20.0			
14			F219252	7.6		25	18.3	272	296	7	8.6	6	40	
15	Santa Clara	Feeder Bus	F420111	9.5		25	22.9	124	111	2	30.0			
16			F420112	9.5		25	22.9	457	296	7	8.6	8		
17			F420121	11.0		25	26.3	953	962	23	2.6			
18			F420122	11.0		25	26.3	1079	962	23	2.6	24		
19			F420131	15.7		25	37.7	2863	2812	68	0.9			
20			F420132	15.7		25	37.7	1232	962	23	2.6	98	130	
21	Huaycan	Feeder Bus	F410111	18.6	E→W	25	44.7	780	703	17	3.5			
22			F410112	18.6	W→E	25	44.7	1153	925	22	2.7	38		
23			F410121	19.1	E→W	25	45.8	843	814	19	3.2			
24			F410122	19.1	W→E	25	45.8	1208	962	23	2.6	40		
25			F410131	21.5	E→W	25	51.5	1190	1147	27	2.2			
26			F410132	21.5	W→E	25	51.5	1152	962	23	2.6	52	130	300

(2) Operating Bus Fleets

The trunk bus system requires articulated buses (double-body unit with capacity of 170 passengers) and feeder buses (capacity of 37 passengers). The fleet size is obtainable basically from the largest peak-hour passengers per line, with some adjustments by the respective line length, the operating speed and the turn-around frequency. The number of bus fleet required is tentatively calculated from the largest peak-hour passengers per trunk bus terminal and the feeder bus capacity. The following assumptions are made to estimate the necessary trunk and feeder bus fleets.

1) The value of the largest bus passengers used to calculate the number of trunk and feeder bus fleets is taken from the assignment results per trunk bus line.
2) The route length is the distance of each trunk and feeder bus lines from origin to destination.

Table 6.5-1 shows the results of calculation for each trunk and feeder bus lines. The conclusion from the calculation can be summarized as follows.

1) A total of 100 articulated buses with capacity of 170 passengers will be necessary for 2010 when the trunk bus system starts its operation.
2) 300 feeder buses with capacity of 37 passengers will be necessary in 2010 of which 40 buses need in Callao, 130 in Santa Clara and 130 in Huaycan.

6.5.2. PROCUREMENT PLAN OF TRUNK BUS AND FEEDER BUS

In Lima, since the bus company does not possess the articulated bus with capacity of 170 passengers, the trunk bus system proposes procurement of new trunk buses. As for the feeder bus, new feeder bus fleet with capacity of 37 passengers is proposed to purchase instead of diverting Microbus to a feeder bus.

The total procurement of the trunk and feeder bus fleets is about 100 articulated buses and 300 feeder buses.

6.5.3. VEHICULAR REQUIREMENT OF TRUNK BUS SYSTEM

(1) Structural Requirement

The trunk bus system operates a fleet of articulated double-body buses. Figure 6.5-1 shows the side and upper views of an articulated bus referred to COSAC project. Major specifications are as follows.

1) Articulation of two bodies with compressed natural gas (CNG) engine
2) Standard capacity of about 170 passengers
3) Because the peak-hour passengers are expected to increase to 110-120%, or 180-200 passengers, of the capacity, the body structure must be strong enough to carry the heavy load.
4) Four doors, or two per body, are available for passenger boarding and alighting.
5) The doors are provided on the left side of the bodies in which the height of floor is 90cm from the ground.
6) The standard seating arrangement is four seats per row, or two seats on both sides of the center aisle. In order to meet the peak-hour demand, however, the number of seats will be reduced with widened center aisle.

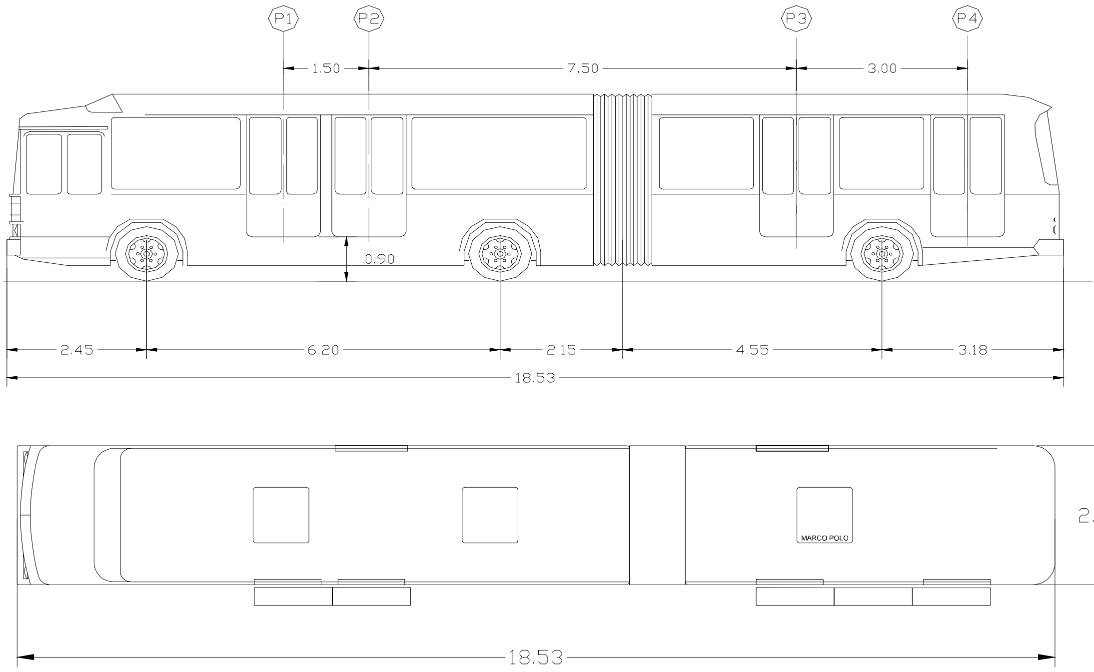


Figure 6.5-1 Standard Cross-Section Views of Four-Door Articulated Bus

(2) Environmental Requirement

The volume of emission is sure to increase apace with the expected growth of motorized traffic in the foreseeable future. To counteract the global warming, an increasing number of governments in the world are trying to develop and disseminate low-emission cars. European countries are now considering the raising of the emission standard from the current EURO-4 with effect from January 2005. Japan has been promoting the increased use of buses fueled by compressed natural gas (CNG) and developing new low-emission hybrid buses.

The growing global trend is the use of CNG-fueled buses, although various attempts are underway to develop new low-emission engines. CNG engines are mechanically the same as diesel engines but use compressed natural gas instead of diesel oil. The emission of nitrogen oxides (NO_x) by CNG-fueled engines is 60 to 80% lower than diesel-fueled engines. The emission of hydrogen monoxide (HC) and carbon monoxide (CO) is also lower by 80% and 70% respectively.

Therefore, the trunk bus fleet proposes to introduce the CNG-fueled one in the trunk bus system. It must be pointed out, however, that the CNG-fueled buses have a few disadvantages. Firstly, they are more expensive, costing 20 to 30% more than diesel-fueled buses. Secondly, they have shorter driving distance of 200 to 250km per one filling which is the same distance as conventional bus at the present. Thirdly, there are a very limited number of CNG filling stations in Peru. In Japan, the Environmental Protection Agency of the national government has established a financial facility to subsidize private bus companies that are willing to change their fleets from diesel- to CNG-fueled buses. Regarding the study area, it is proposed to establish a CNG filling station at each trunk bus terminal. (Proposed trunk bus lines range from 15 to 20 kilometers in length. This means that trunk buses have to refill after 10 to 15 round trips.)

(3) Suggestion of Bus Fleet Conditions

The major objectives for introduction of the trunk bus system are i) to decrease the number of the existing bus traffic volume for mitigation of heavy traffic congestion, ii) to ensure smooth and safety bus operation system, and iii) to keep good environmental aspects especially decrease the air pollution.

To achieve the objectives of introduction of the trunk bus system, the numbers of parson who use a passenger car should be transferred to the trunk bus system. Considering this changing the transportation mode from passenger car to trunk bus system, as well as increasing the trunk bus passengers, the following matters are suggested based on the trunk bus fleet. The benefits of the introduction of the trunk bus system are described in section 6.6 and economic and financial analysis in this report.

a) The bus fleet should be ensured the safety and comfort inside the bus room. (The driver should be educated by the cooperative bus company for ensuring the traffic safety and comfort)

b) The bus fleet should be maintained the clean and a well lighted room.

c) The bus fleet should be conducted a daily maintenance after operation.

d) The bus fleet should be installed the air-condition inside the bus room

For instance, before introduction of the trunk bus system in Bogota city, the security of inside of bus fleet was very wrong. However, after introduction of the trunk bus system, the security of inside bus room were improved by using high quality bus fleet such as the above mentioned bus fleet.

6.5.4. FARE SYSTEM

(1) Fare Collection

The bus fare is currently paid in cash at the time of boarding. Passengers board the bus by the front door and pay the fare to the conductor and move to the back door to get off the bus. Passengers have to pay the fare anew when they transfer from one line to another.

The fare system proposed for the trunk bus operation is integrated at the terminals between trunk bus lines and between trunk and feeder bus lines. Transfers between trunk and conventional bus lines are not integrated: passengers have to pay the fare anew when they transfer from one to the other. Because all trunk bus lines are in the range of 15 to 20km in total length, the fare will be uniformly fixed.

It is estimated that trunk bus lines operate with the respective headway of 2 to 5 minutes from each of the terminals during peak hours. This implies that the trunk bus traffic on av. Grau is one bus every 40 sec. With the current fare system, a passenger needs 1.5 to 2.0 seconds to board the bus. At bus stops where 10 passengers are waiting, their boarding takes 15 to 20 seconds. In order to operate trunk buses every 40 seconds, it is crucial to reduce the time needed for boarding. Accordingly, the trunk bus operation will introduce the fare sale system as shown in the next section.

(2) Sale of Tickets, Coupons and Term Passes

Tickets, coupons and term passes may be sold at shops, kiosks, bus terminals, or shopping centers. Passengers must buy tickets or coupons before boarding a trunk bus and before entering an integrated bus terminal. This will substantially shorten the time needed for passenger boarding.

Therefore, the conductor is not necessary because of the pre-buying.

Since the passenger who has free of charge is supposed, it is necessary to inspect the passenger to board at bus stop. Therefore, the inspector is stationed at the bus stop to watch a boarding passenger who does not pay a bus fare through a pedestrian crossing.

To avoid the expected initial confusion, it might be necessary to allow the payment in cash for the first few months.

(3) Restructuring of Manpower

The proposed trunk bus system introduces a fleet of larger articulated buses and the more efficient bus operation. Therefore, it is likely to necessitate the sizable restructuring of the currently employed drivers, conductors and other personnel. During the initial stage of the trunk bus operation, it might be necessary to ease the inevitable pain of restructuring by letting the redundant workers tend the bus terminal that operates and maintains the bus terminal.

(4) Future Direction of Fare Collection System

Future means of the fare collection system will be followings.

1) Electronic card system will be gradually introduced.
2) Several types of cards are used in various cities of the world, such as prepaid cards, smart cards, contactless IC cards, credit cards and magnetic cards used per ride. Since the proposed trunk bus system is expected to start its operation in 2010, there is enough time to examine the available options and make the final decision. The future socio-economic prospects of the study area, opinions and attitudes of bus passengers and the management capability of bus companies will have to be closely analyzed to select the most suitable card type.

As for electronic fare media, recently, the electronic media offers even more convenience to current and potential transit users. At present, there are various types of programs developed in oversea, but even many of those examples are still in trial of pilot phases. In the USA, European countries and Japan, development of several multipurpose programs has begun, but in-service applications are of limited scope to date.

6.5.5. TRAFFIC SIGNAL SYSTEM

The trunk bus system, which operates on the segregated busway, serves increasing public transport demand together with securing the punctuality and increasing the convenience of public transport. Although the segregated busway has its own traffic space, it does not have priority operation space at intersections, unlike the rail transit system. Therefore, the trunk bus has to be obliged with to follow traffic signals at intersections. The installation of bus priority traffic signals at intersections on trunk busways aims to maximize the merit of the trunk busway and to realize the coexistence between trunk bus operation and ordinary road traffic.

The following sections show the traffic flow control at intersection and bus priority Signal control system.

(1) Traffic Flow Control at Intersection

1) Traffic Flow Control

The proposed bus stop locates immediately downstream from a traffic signal controlled intersection. In this type of bus stop, the trunk bus is sometime waited at red signal at intersection. Substantial bus delay occurs at the intersection. The bus is obliged to wait in the intersection until the signal turns to green.

In the Study, in order to minimize the bus delay at intersection, the left-turn traffic flow of vehicles on the mixed traffic lanes is prohibited at the intersection on East-West trunk busway. Traffic turning across the busway into or out of side roads is prevented at all intersections. In such cases, side road traffic is not restricted to right and left-turns.

2) Signal Control

A traffic signal control is generally done in order to effectively manage the trunk bus and ordinary road traffic, without excessive delays. The signal control is also required to control pedestrian crossing safely. The signal control at the intersection on East-West trunk busway is composed of two phases under the restriction of left-turn flow. The waiting time at red signal reduces due to the two phases. When three phases are set on the condition of the permission of the left-turn traffic flow, a green split for the trunk bus reduces.

- Phase-1: a green split for the trunk bus on the busway and ordinary road traffic which flows out straight and right-turn
- Phase-2: a green split for side road without restriction.

In case of cycle time of 90-100 seconds, the green time of a main stream on the busway will be 55 seconds in exclusive of loss time. Accordingly, maximum two trunk buses will pass through an intersection in consideration of a minimum headway of 44 seconds in the morning peak hour. Therefore, buses queuing to enter the bus stop don't block the intersection.

As for the conventional bus, the total 55 conventional bus lines are operated on the East-West roads, eliminating the 22 conventional bus lines overlapped with the trunk busway. There are some lines to take a left-turn at intersections on the mixed traffic lanes on the East-West roads. Since the conventional bus operated on those lines must weaves a right-lane to center line near intersection, this causes traffic conflict between the conventional bus and ordinary traffic and traffic congestion. Since the left-turn movement of conventional bus on the mixed traffic lanes at the intersection is also prohibited, it is necessary to further study for these conventional bus lines.

(2) Public Transport Priority System (PTPS)

1) Introduction

The signal priority has been a promising method to improve bus, or in general, bus operations and service quality.

The expected benefits of bus signal priority (BSP) are as follows.

- Improved mobility and transportation and transit efficiency through the optimization of traffic control signals.
- Increased operational and regulatory efficiencies for system users and public agencies.
- Reduced environmental impacts by reducing emissions from vehicular use.
- Improved travel times and schedule adherence for the bus fleet.

2) Bus Priority Traffic Signal proposed in the Trunk Bus System

It is important to introduce the bus priority traffic signals for the effective operation of the busway. The introduction of bus priority traffic signals on the trunk busway is more effective.

In the study, as a low cost solution, the bus priority signal light system for the trunk busway is introduced using the method of the independent traffic-actuated control system. Figure 6.5-2 shows the system function and control concept of bus priority signal control system. An ultra sonic vehicle detector is installed on the segregated trunk busway, in order to detect buses, and the detector transfers bus information to the signal control unit at the local facilities. The signal control unit decides whether it should change the timing of the signal on the basis of preset timing and received information about the bus.

Accordingly, the traffic signal lights are regulated by extending the green light, shortening the red light, or quickly changing the green light in the opposite direction, according to the time in which such bus arrives at the intersection. This means that buses do not have to stop or the waiting time is shortened at intersections as much as possible.

Since this bus priority control system detects only the trunk bus at upstream side from an intersection, the bus stop location is proper downstream from an intersection. In case of that bus stop locates immediately upstream from an intersection, the trunk bus starts and passes through an intersection after completing loading of passengers. Since the loading time is not estimated with precision, it is difficult to extend the green light or short the red light in the priority system. Therefore, the trunk bus is sometime waited at red signal at a bus stop. In consideration of the bus priority signal system, the proposed bus stop locates downstream from an intersection.

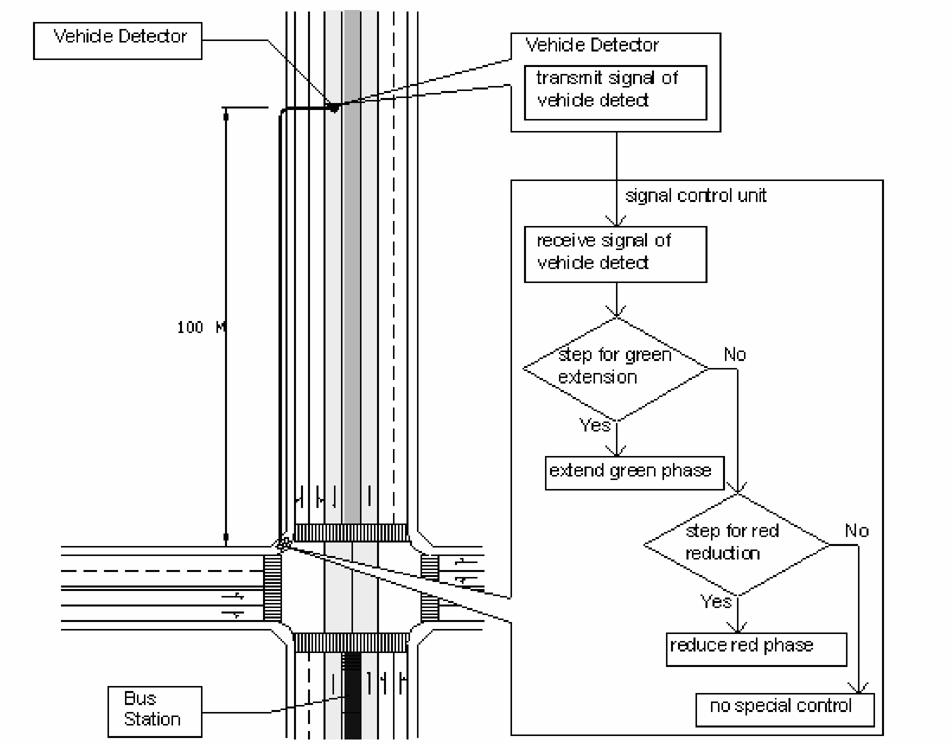


Figure 6.5-2 Proposed Bus Priority Traffic Signal System

(3) Automated Vehicle Location System (AVL System)

Bus transportation agencies are turning to advanced technologies to improve service, increase safety, and attract ridership. Specially, automatic vehicle monitoring (AVM) systems are being developed on bus transport to achieve operational system benefits. Although AVM systems were deployed in the 1970s and 1980s, only recently have transit agencies embraced the concept. The core technology, the automatic vehicle location (AVL) system, offers detailed status information previously absent from the bus operations, customer support, maintenance, and service planning areas.

The AVL system tracks vehicle movement. This capability, integrated with other functions, enables transit agencies to provide new and improved services, such as reduced emergency response time, real-time bus status information, automated passenger counting information, and improved mobile communications.

On the East-West trunk busway, the trunk bus is operated at operation headway of 40 seconds in the morning peak hour in 2010. This means that passengers are possible to take on the trunk bus without waiting at a bus stop. Therefore, the necessary of AVL system service is low from the viewpoint of passenger.

From the viewpoint of bus operator, the cost of AVL system is expensive. The maintenance cost is also huge. Although the introduction of the system contributes improvement of bus operation service, the increment of bus users does not directly link. In future, it will be necessary to introduce the AVL technology to improve bus operation services. However, in this study the AVL technology proposes as a next challenge.