CHAPTER 4
Current Transport and Traffic Issues and Planning Considerations

4. CURRENT TRANSPORT AND TRAFFIC ISSUES AND PLANNING CONSIDERATIONS

4.1 CURRENT ISSUES AND MEASURES IN THE STUDY

The current transport and traffic problems and issues are examined in the previous section based on the results of various transport and traffic surveys conducted by the JICA Study Team in 2006. In this section, the identified transport and traffic problems and issues are summarized, and Table 4.1-1 presents the measures that need to be taken.

Table 4.1-1 Relationship Between Current Issues and Measures in the Study

View Points	Problems and Issues	Measurement Policy in the Study
(1) Bus Passengers inside urbanized area	1) Operation speed is very slow	Exclusive busway is examined
	2) Long travel time is needed	Trunk and feeder bus system are examined
	3) Bus fleet is very old	New articulated bus is examined
	4) Dangerous inside the buses	New bus is examined
	5) Bus facilities are poor	Functional new bus stop and terminal are examined
(2) Poor Persons who live outside of the urbanized area	1) High bus fare	Bus fare of S/0.5 on feeder bus is examined
	2) Shortage of bus routes	Functional feeder bus route network is examined
	3) Long travel time is needed	Trunk and feeder bus system are examined
(3) Citizen who use private cars	1) Very congested traffic	Articulated bus is examined
	2) Travel speed is very low	Re-routing of conventional bus route is examined
	3) Bus driving manner is bad	Traffic education program is examined
	4) Many bus routes are concentrated	Re-routing of conventional bus route is examined
	5) Too many buses are operated	Re-routing of conventional bus route is examined
(4) Bus Operation Company	1) Bus fare is very low	Fare system is examined
	2) Many bus routes are concentrated	Re-routing of conventional bus route is examined
	3) Operation speed is low	Re-routing of conventional bus route is examined
	4) Bus system is not functional	Trunk and feeder bus system are examined
	5) Bus facilities are poor	Functional new bus stop and terminal are examined
	6) Bus organization is weak	New bus operation organization is examined
(5) Environmental Aspects	1) Air pollution has increased	CNG bus fleet and decreasing conventional bus volume are examined
	2) Noisy conditions have increased	Decreasing conventional bus volume is examined
	3) Traffic Accidents are occurring	Traffic safety and education manual are examined
(6) Traffic Management Aspects	1) Driving Manner is poor	Traffic safety and education manual are examined
	2) Intersection Facilities are weak	Intersection manual is examined

	3) Traffic signal system is weak	Traffic signal control system manual is examined
	4) On-road parking allowed	Parking system manual is examined
	5) Heavy congestion on trunk roads	TDM manual is examined
	6) Heavy traffic congestion in peak hours	TDM manual is examined
	7) Many traffic accidents are occurring	Traffic safety and education manual are examined
(7) Para-transit	1) No functional operation in the future	Functional Para-transit system is examined.
(8) Cargo Traffic	1) Increased truck traffic in the future	Alternative truck route network is examined

4.2 HIERARCHY OF TRANSPORT MODE IN THE STUDY AREA

According to the Urban Transport Master Plan of the Lima and Callao metropolitan area, which was conducted by JICA in 2005, the population of the metropolitan area in 2004 and 2025 was estimated at about 8 million and 11 million people, respectively. Additionally, the introduction of the railway system and trunk bus system was recommended from the short term plan to the long term plan in the Master Plan.

Considering the transport mode of other highly populated cities in the world, the introduction of railway systems in the Lima and Callao metropolitan area will be required as a Mass Rapid Transit System to decrease the air pollution and the traffic congestion in the Lima and Callao metropolitan area

At present, the detailed design of the Extension of the Railway Project has already been completed and the procurement of this project is under negotiation. In addition, the Feasibility study of the East-West Railway Project has also been completed. On the other hand, the detailed design of the COSAC trunk bus project has also been completed and the construction of this project will be initiated soon.

Considering the transport development situation, the size of the population and the traffic characteristics in the Lima and Callao metropolitan area, the following transport mode should be developed as shown in Figure 4.2-1 and Figure 4.2-2.

1) The railway transport system should be developed as the principal transport mode in the Lima and Callao Metropolitan Area.
2) The trunk bus system should be developed as the supplementary transport mode for the railway system to connect to the railway stations.
3) The conventional bus system should be developed as the supplementary transport mode for the railway and trunk bus systems to connect to the railway and trunk bus stations.
4) The para-transit systems, such as moto-taxi or taxi, should be developed as the supplementary transport mode for the previously mentioned transport system.

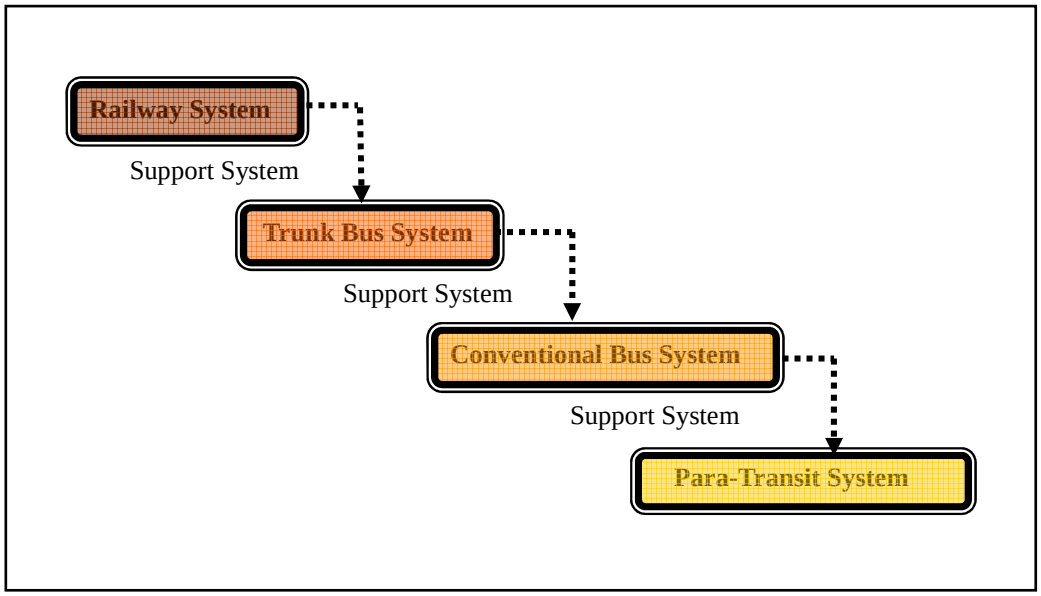


Figure 4.2-1 Hierarchy of Transport Mode in the Study Area

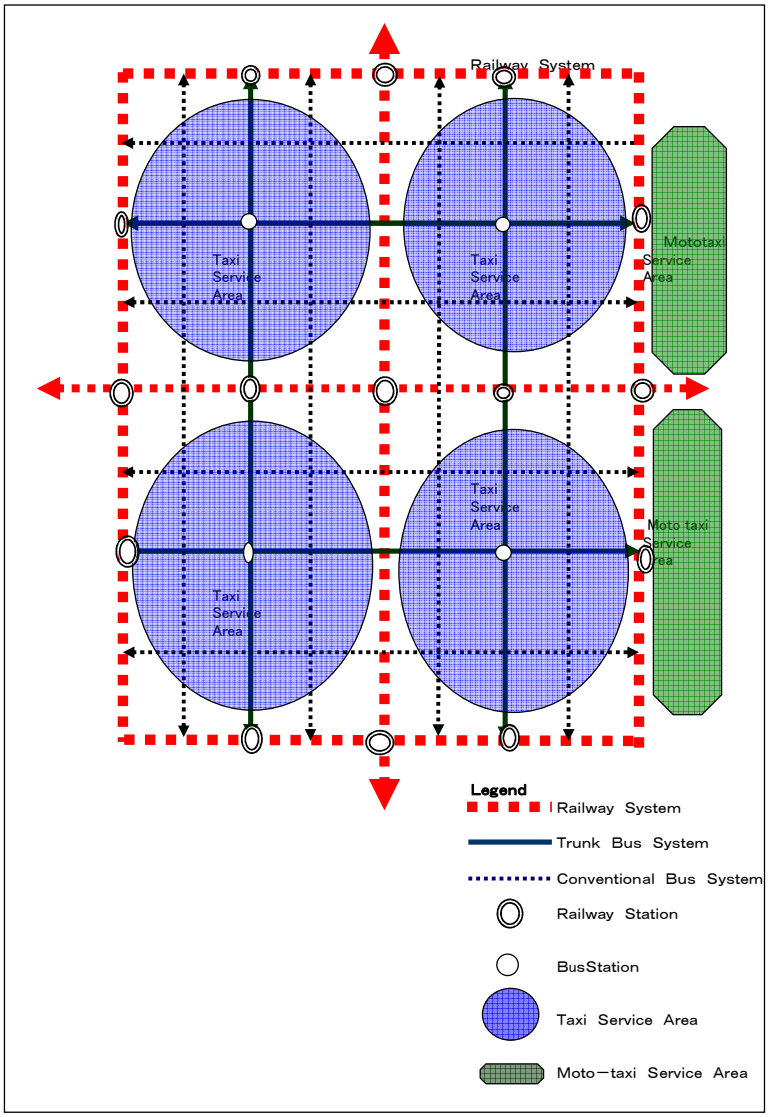


Figure 4.2-2 Concept of Hierarchy of Transport Mode in the Study Area

4.3 BASIC PLANNING CONSIDERATIONS AND PLANNING OBJECTIVE

4.3.1. BASIC PLANNING CONSIDERATION

Considering the transport hierarchy of the Study area, and the current and future traffic characteristics, the following basic planning considerations are identified.

(1) Basic Planning Consideration from the Viewpoint of the Hierarchy of Transport Mode

According to the realization of the railway transport mode, the future passenger demand situations, passenger trip characteristics, and the future number of passenger demand will change. In this case, the trunk bus system (operation system, route location) should be reviewed based on the progress of the construction schedule of the railway transport mode. In addition, the trunk bus system is classified as the supporting transport mode of railway transport. Considering the above mentioned matters, the following planning policies of the Study are identified:

1) The trunk bus system should be developed as a flexible plan.
2) The facilities of the trunk bus system should be temporary constructions. Therefore, the construction of permanent facilities, such as grade-separated intersections and large scale bridges, should be avoided.

(2) Basic Planning Consideration from the Viewpoint of Environmental Aspects

In 1995, the final design of the improvement project on Av. Venezuela and Av. Arica was conducted by Municipality of Lima, and the right of way width required was frozen by Municipal Ordinance No.-0018-05 of October 1995 based on the results of this final design.

At present, however, some parts of the frozen area on the existing Av. Venezuela in the cities of Callao and Lima have been used by some private factories and other authorities. When the East-West trunk busway is constructed, according to the right of way width which was decided by Municipal Ordinance No.-0018-05 of October 1995, the acquisition and compensation of additional land is required. Therefore, both municipalities should initiate the required land acquisition and compensation procedures.

(3) Basic Planning Consideration from the Viewpoint of the Realization of Project

For the smooth and early realization of the East-West trunk busway project, a consensus from the stakeholders of the project should be taken. Considering the stakeholder aspects, the planning of East-West trunk busway will be conducted based on the following four (4) viewpoints.

1) From the viewpoint of citizens in the cities of Lima and Callao
2) From the viewpoint of bus passengers
3) From the viewpoint of bus operating companies
4) From the viewpoint of environmental aspects

4.3.2. PLANNING OBJECTIVE OF THE STUDY

As mentioned previously, there are many transport and traffic problems along the existing Av. Venezuela, Av. Arica, Av. Ayllon, and Carretera Central. The purpose of this Feasibility Study is to mitigate the transport and traffic problems on the existing roads and keep smooth traffic flows and maintain good environmental aspects in the Study area.

Considering the purposes of this Feasibility Study, the planning objective of the Study is to carry out the East-West trunk busway project as soon as possible.

CHAPTER 5
Future Traffic and Transportation Demand Forecast

5. FUTURE TRAFFIC AND TRANSPORTATION DEMAND FORECAST

5.1. GENERAL

The future travel demand forecast was made in the Master Plan Study, in which the target years are 2010 and 2025. The demand forecast was carried out in the daily and peak hour units.

In the feasibility study, the trunk bus operation system plan is proposed for 2010, based on the travel conditions in the morning peak hour, but a daily basis is used for the economic analysis. This is because the public transport planning of a bus operation system, such as service frequency, bus lines, and number of buses, is critical in the peak hour. Therefore, the future morning peak hour OD trip data in 2010 and 2025 forecasted in the Master Plan Study is used.

In this chapter, the outline of the socio-economic frame is summarized first, estimated in the Master Plan Study. The second subject of this chapter is the forecasting of results for the daily travel demand. The last subject is focused on the travel demand characteristics on the East-West corridor in terms of trip generation and attraction and trip distribution.

5.2. SOCIO-ECONOMIC FRAMEWORK

Table 5.2-1 shows summary table of socioeconomic indexes and travel demand in 2004, 2010 and 2025 estimated in the Master Plan Study. The total number of trips per day in the Study Area in 2010 is approximately 13.42 million. The trip increase ratio from the year 2004 to 2010 is approximately 1.11. The trip production rate in terms of number of trips per person aging 6 years or above rises from 1.64 to 1.65. This indicates that in 2010, the share of the higher Stratum household ratio to the total contributes to the increase of the production rate.

Table 5.2-1 Summary of Socioeconomic Indexes and Travel Demand

Items	2004	2010	2025	2010/2004	2025/2004
Population (Persons)	7,371,385	8,146,392	10,078,272	1.11	1.37
GRDP/capita	7,563	8,575	13,467	1.13	1.78
Number of Trips by Motorized modes (trip/day)	12,118,571	13,417,548	17,950,737	1.11	1.48
Trip Production Rate /pop (6 years or more) (Car, Taxi and Public Transport)	1.64	1.65	1.78	1.00	1.08

Note: Population indicates 6 years or more

5.3. TRAVEL DEMAND IN THE STUDY AREA

(1) Trip Generation and Attraction

The daily trip generation and attraction in 2010 estimated in the Master Plan Study according to the integrated zone are shown in Table 5.3-1 and Figure 5.3-1, in which those projections are for all purposes and "to home" trips are excluded to clearly show the characteristics of generation and attraction. As it can be seen, trip generation and attraction in zone No. 1 (Lima) has a large volume of trips, especially trip attraction is the largest. The second largest generation and attraction zone is No. 4 (Miraflores). In 2010, traffic and transport demands concentrate in those zones. This is because work-place/school-place based population (employment) is substantially concentrated in the central area in comparison to the distribution of the nighttime population.

Since zone Nos. 1, 2, 3, and 11 on the East-West corridor have a large volume of trips the trunk bus system plays an important role in the study area.

Table 5.3-1 Trip Generation and Attraction by Integrated Zones in 2010 (Exclusive of "to home" purpose)

zone	Name of District	2010	
		Gen	Att
1	Lima	1,139,363	2,130,335
2	Callao	461,211	491,961
3	Los Olivos	979,498	717,598
4	Miraflores	1,021,654	1,292,378
5	La Molina	185,567	127,603
6	Chorrillos	235,504	183,728
7	Villa El Salvador	794,963	509,448
8	Ancon	351,918	256,408
9	Carabayllo	524,251	305,970
10	San Juan de Lurigancho	610,162	386,705
11	Lurigancho	709,366	639,418
12	Cieneguilla	17,433	4,488
13	Lurin	67,245	60,109
14	San Bartolo	24,352	8,107
15	Outside of the Study Area	333	8,564
Total		7,122,820	7,122,820

Gen: Generation, Att: Attraction (from Master Plan Study)

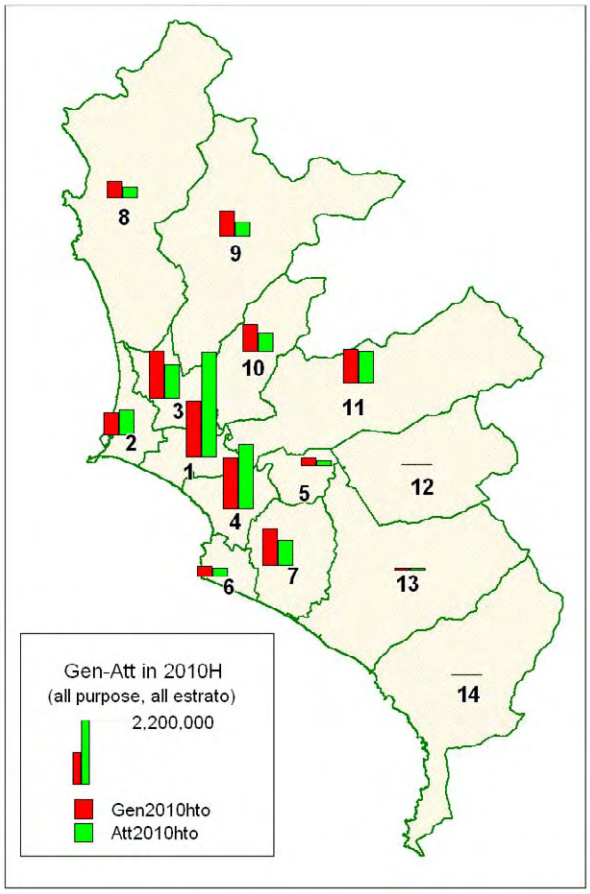


Figure 5.3-1 Trip Generation and Attraction in 2010 (All Purposes exclusive of To home)

(2) Modal Split

The number of trips by three modes in 2010, car, taxi and public transport, is shown in Table 5.3-2. In 2010, the modal shares of car, taxi and public transport are 18%, 7% and 75%, respectively. The increase ratios of each mode between 2004 and 2010 are 1.27 for car, 1.04 for taxi and 1.08 times for public transport. In 2010, car trips per person increase approximately 1.3 times, while public transport trips are somewhat low in increase ratio, compared to car trips.

The desire lines by public mode are shown in Figure 5.3-2. In 2010, the desire lines by the public mode strongly cover the entire Study Area, especially along the East-West corridor (Zone Nos. 1-2, 1-3, and 1-11).

Table 5.3-2 Modal Share of Person Trips (persons/day) in 2010 and 2025

Trips by Modes		Car	Taxi	Public	Total
Trips (Trips/day)	2004	1,853,295	900,138	9,365,138	12,118,571
	2010	2,358,750	934,139	10,124,659	13,417,548
	2025	4,041,689	1,261,286	12,647,761	17,950,737
	2010/2004	1.27	1.04	1.08	1.11
	2025/2004	2.18	1.40	1.35	1.48
Composition	2004	15.3%	7.4%	77.3%	100.0%
	2010	17.6%	7.0%	75.5%	100.0%
	2025	22.5%	7.0%	70.5%	100.0%

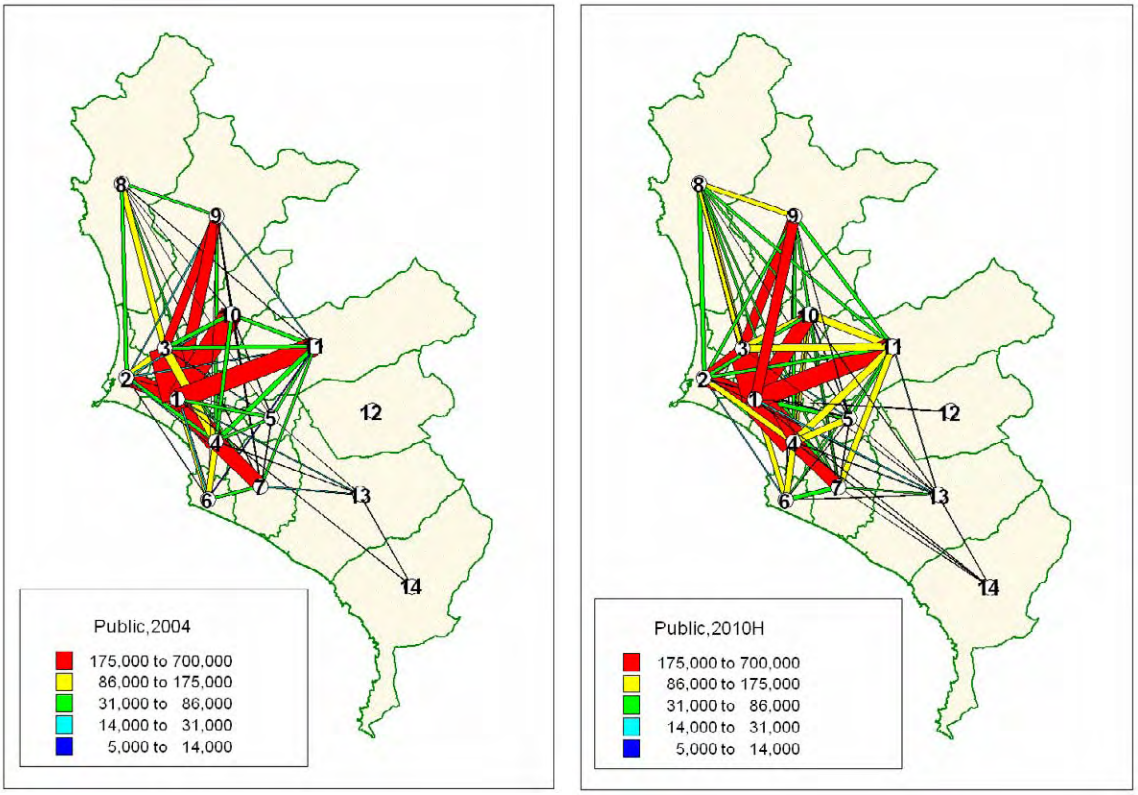


Figure 5.3-2 Daily Trip Desire Line by Public Modes in 2004 and 2010

5.4. TRAVEL DEMAND IN THE PEAK HOUR ON THE EAST-WEST CORRIDOR

(1) Zoning in Huaycan and Santa Clara

In the study, the feeder bus system is planned in Callao, Huaycan and Santa Clara. The feeder system operates in these areas around a trunk bus terminal to carry passengers to and from the terminal. Its service area will be limited to those areas, with relatively short line length and smaller numbers of passengers per bus.

In order to forecast the feeder bus demand in those areas, it is necessary to subdivide the traffic zones provided in the Master Plan study. Figure 5.4-1 shows the zoning system in Huaycan and Santa Clara where 6 traffic zones are subdivided into 30 zones. In Callao, since the zoning system balances with the proposed feeder bus line network, the sub zone system is not provided.

The trip OD tables in 2010 and 2025 are converted to this zoning system. The total trip generation and attraction in each traffic zone are unchangeable.

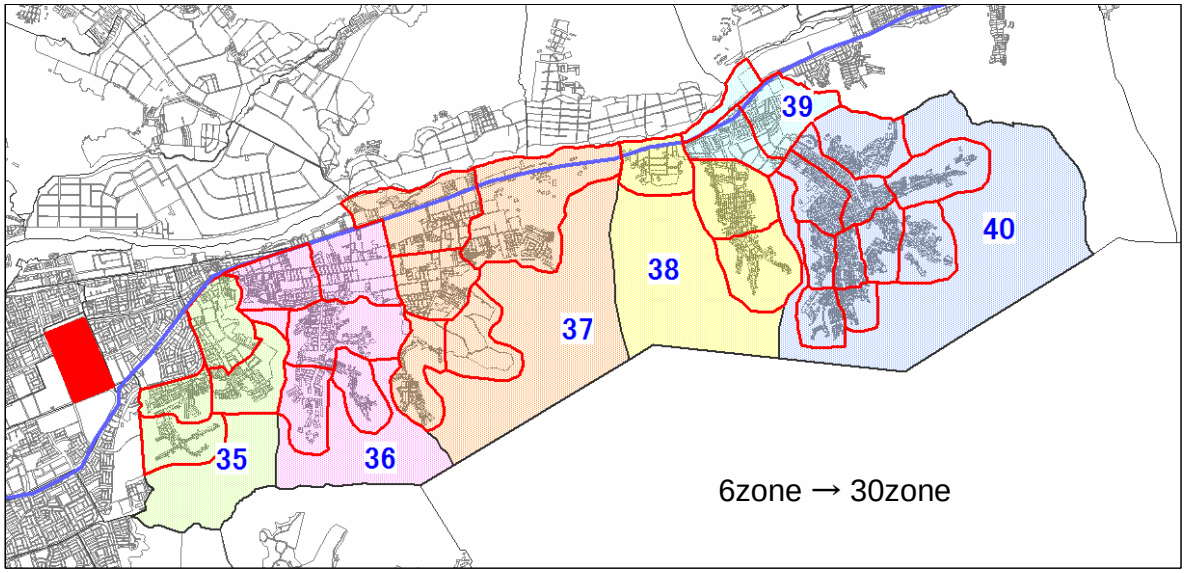


Figure 5.4-1 Zoning in Huaycan and Santa Clara

(2) Trip Generation and Attraction

Figure 5.4-2 shows trip generation and attraction in the morning peak hour in 2010 by public mode on zone blocks along the East-West corridor, in which the red and yellow colors show the trip generation and attraction, respectively, and the blue line shows the location of the East-West trunk busway. As it can be seen, the trip generation and attraction are higher in zone block Nos. 2, 7, 8 (Centro) and 12 (San Isidro and Miraflores), which are the areas near the corridor.

On the other hand, Callao (Nos. 1 and 6), Santa Clara (No. 10) and Huaycan (No. 11), where the feeder bus service is examined in the study, are somewhat lower in trip generation and attraction than that in the above areas.

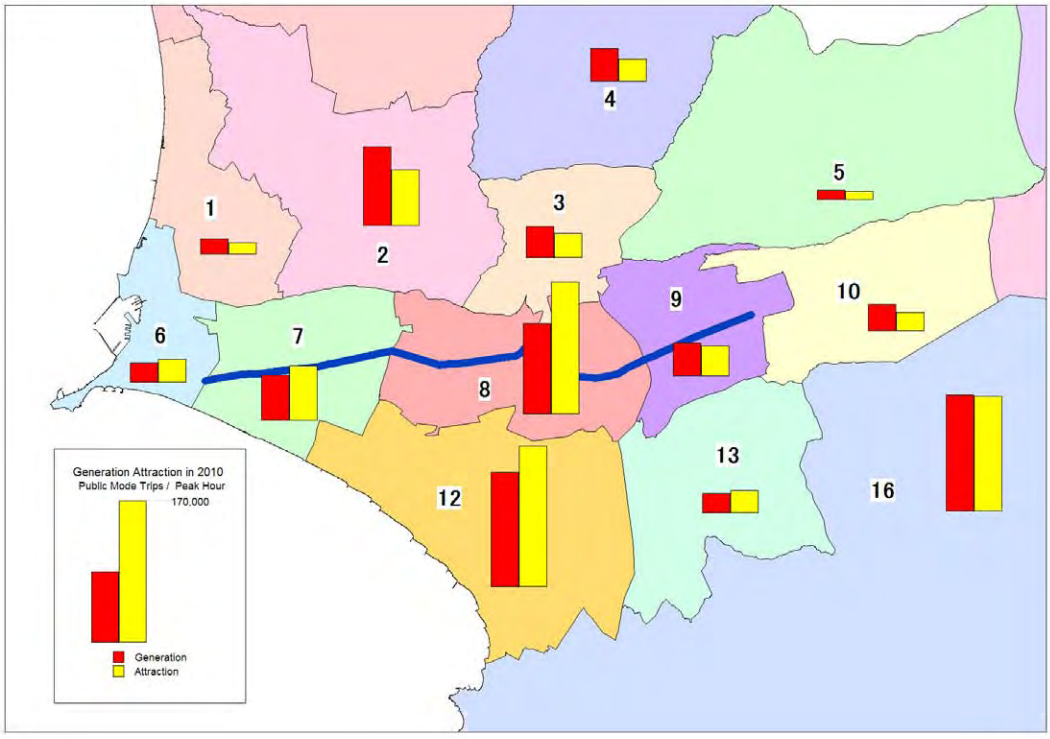


Figure 5.4-2 Trip Generation and Attraction in 2010 along the East- West Corridor

(3) Trip Distribution

Figure 5.4-3 and Figure 5.4-4 show the desire line charts in zone block Nos. 7, 8 and 9 in the inbound and outbound directions, respectively, which are the public transportation mode in the morning peak hour. These figures show the trip desire lines in the area along the East-West corridor. The heavy desire lines concentrate into zone block No. 8 (Centro).

Figure 5.4-5 and Figure 5.4-6 show the desire line charts in the Callao area (No. 1 and 6) where the feeder bus network is proposed. The heavy desire lines connect to zone block Nos. 8, 12 and 16. Since those areas are parallel with the East-West corridor, the trips have a potential of demand in the trunk bus system.

The desire lines in Santa Clara and Huaycan are shown in Figure 5.4-7 to Figure 5.4-10 in the same manner as that in Callao. Since the heavy desire lines from those areas distribute the areas which are parallel to the East-West corridor, those trips became the potential of demand in the trunk bus system.

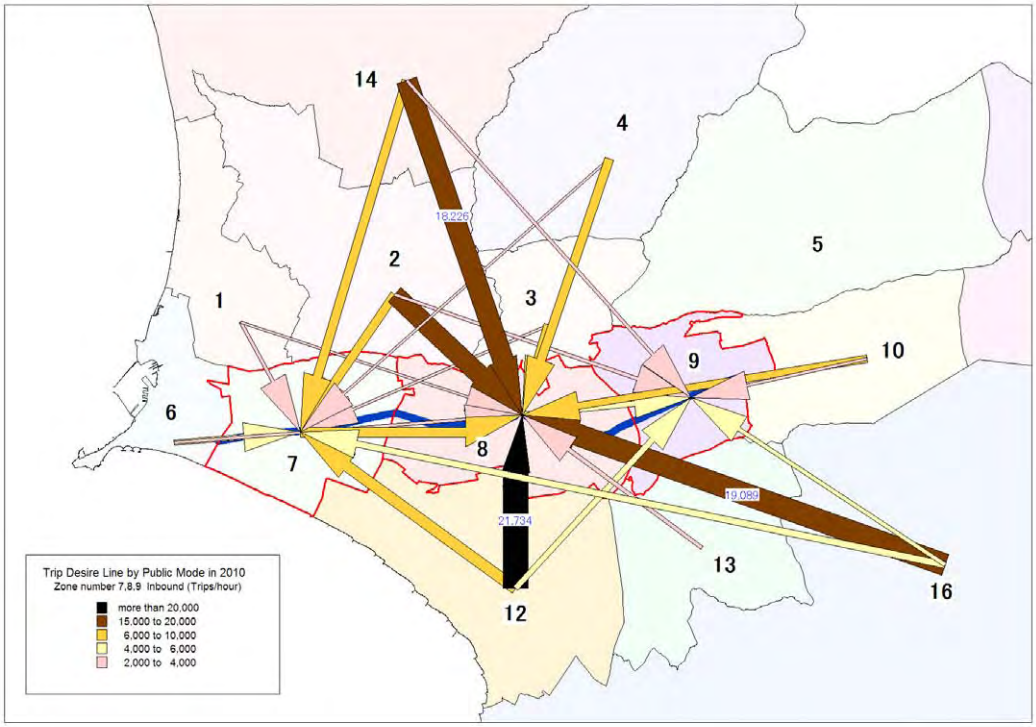


Figure 5.4-3 Desire Lines in Zone Block Nos. 7, 8, and 9 in Inbound Direction

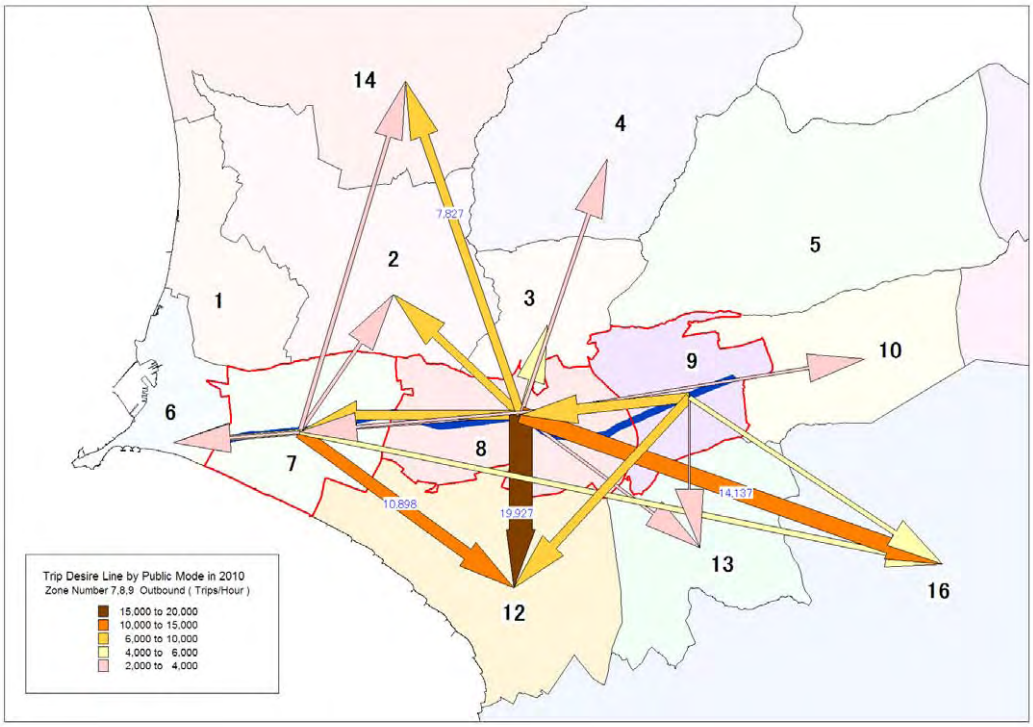


Figure 5.4-4 Desire Lines in Zone Block Nos. 7, 8, and 9 in Outbound Direction

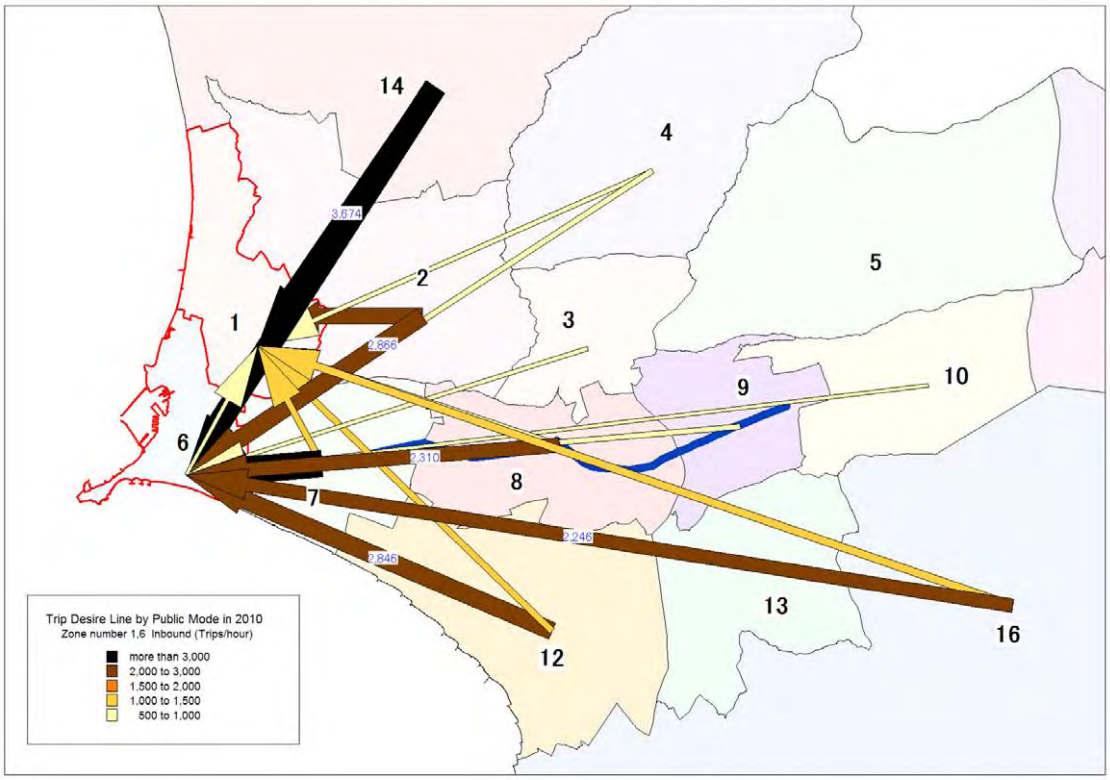


Figure 5.4-5 Desire Lines in Zone Block Nos. 1 and 6 (Callao) in Inbound Direction

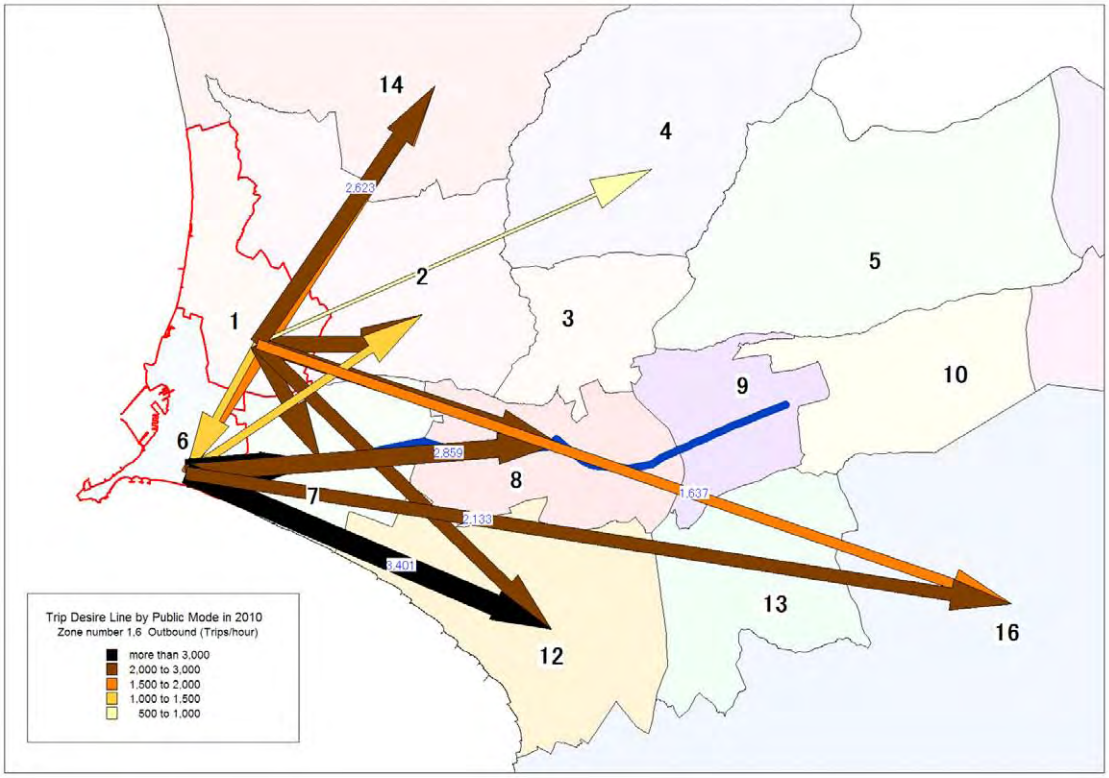


Figure 5.4-6 Desire Lines in Zone Block Nos. 1 and 6 (Callao) in Outbound Direction

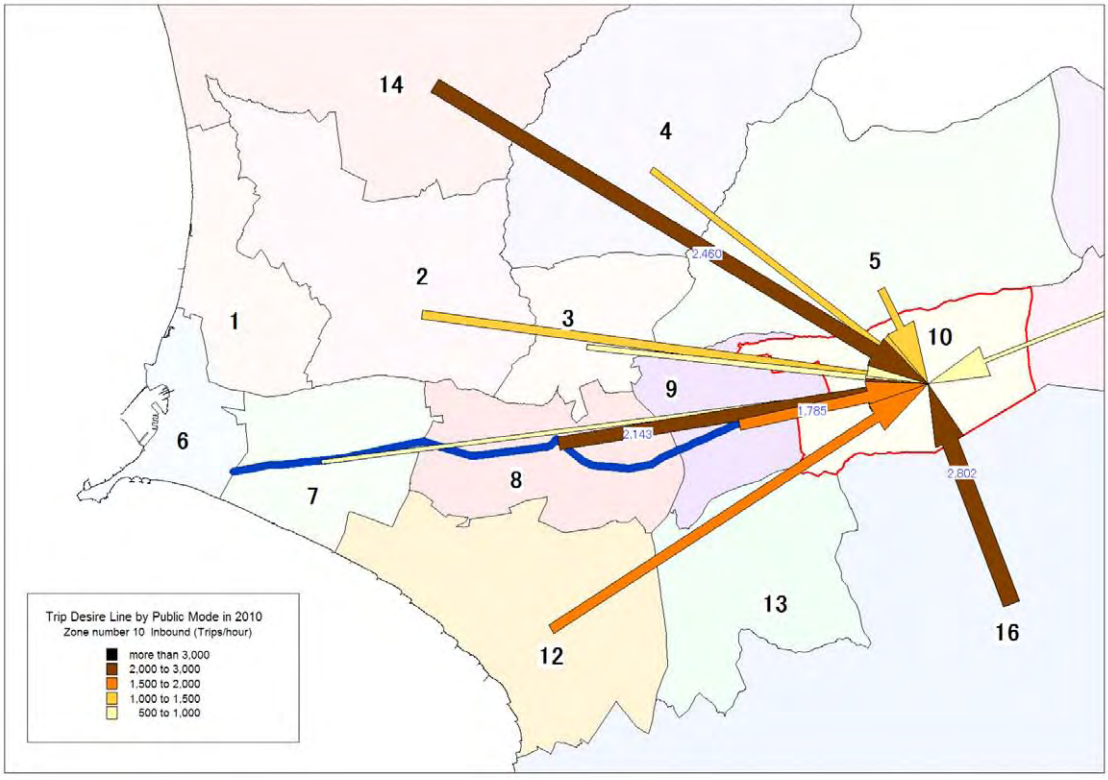


Figure 5.4-7 Desire Lines in Zone Block No. 10 (Santa Clara) in Inbound Direction

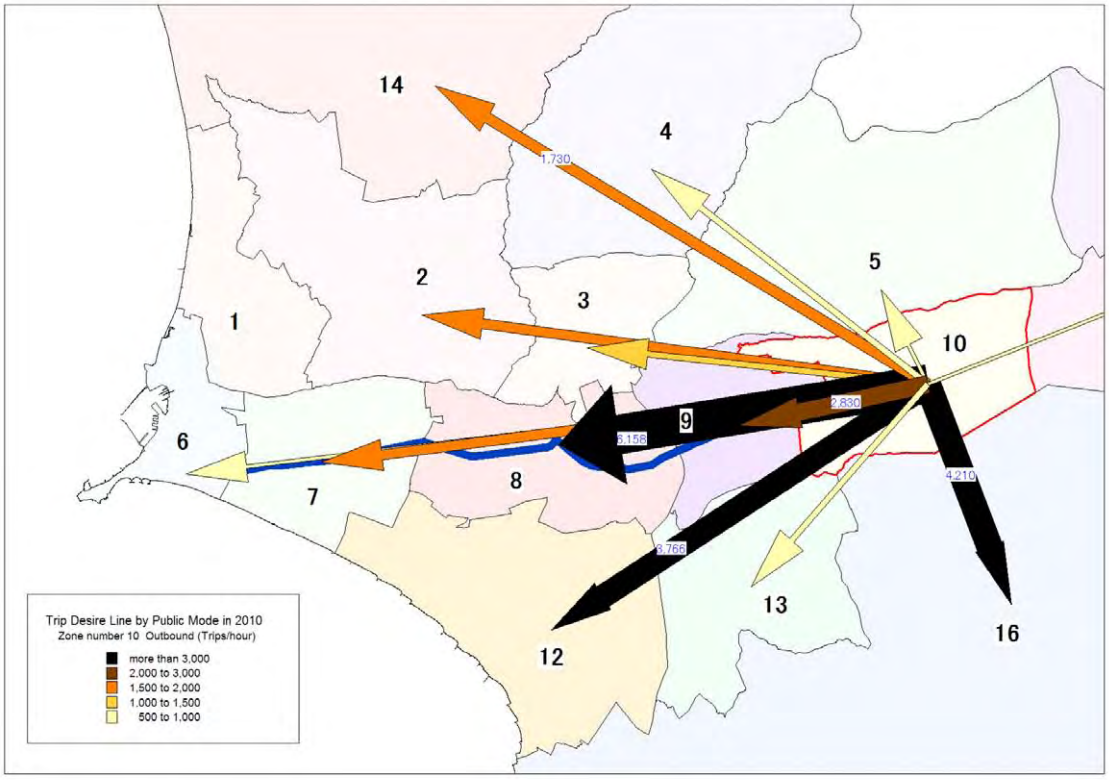


Figure 5.4-8 Desire Lines in Zone Block No. 10 (Santa Clara) in Outbound Direction

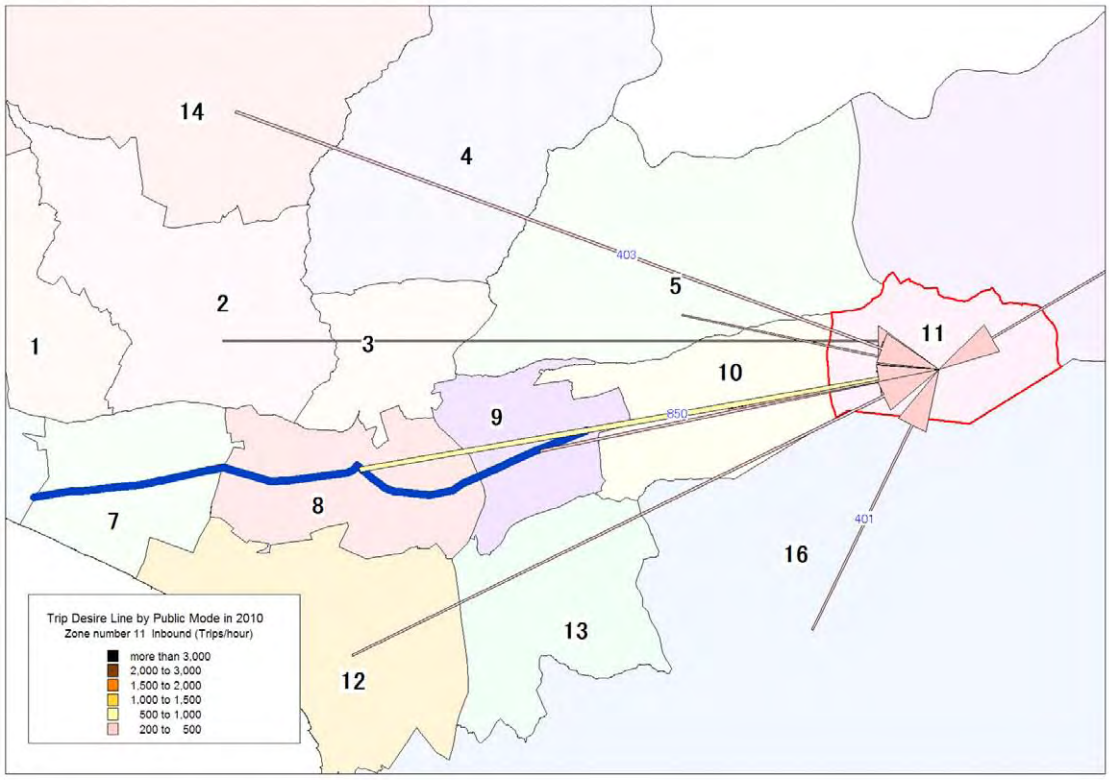


Figure 5.4-9 Desire Lines in Zone Block No. 11 (Huaycan) in Inbound Direction

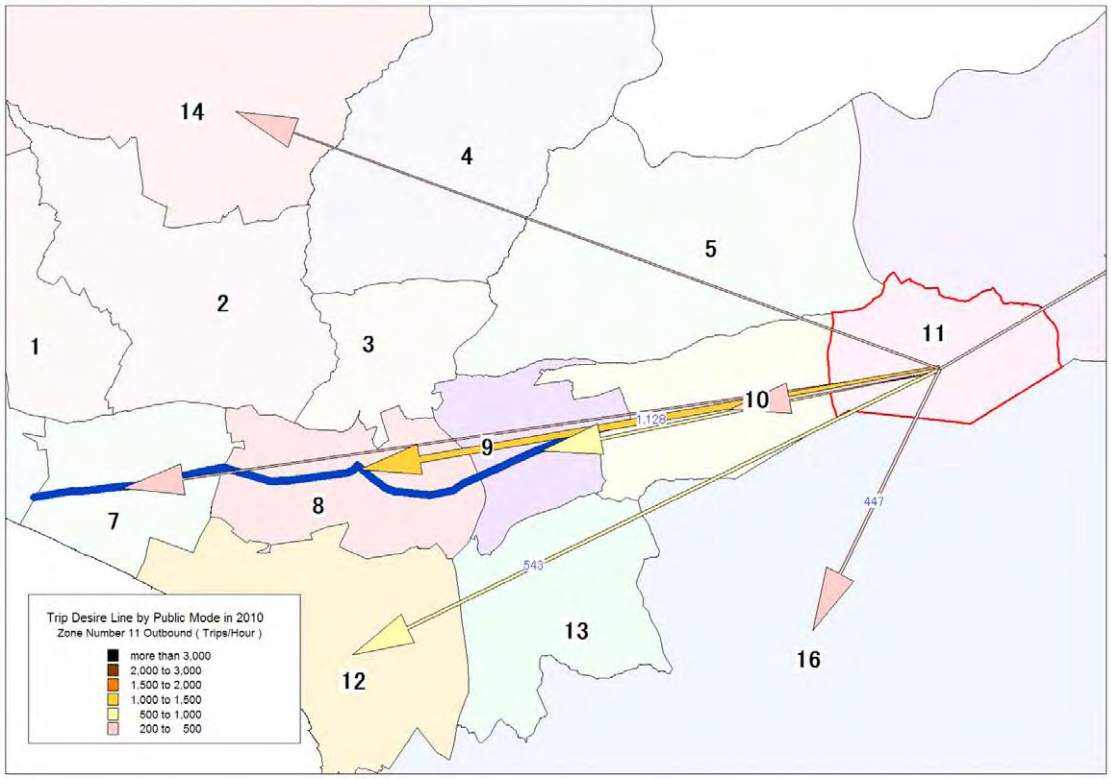


Figure 5.4-10 Desire Lines in Zone Block No. 11 (Huaycan) in Outbound Direction

CHAPTER 6
Traffic Bus System Plan

6. TRUNK BUS SYSTEM PLAN

6.1. PROPOSED TRUNK BUS SYSTEM

6.1.1. OUTLINE OF THE PROPOSED TRUNK BUS SYSTEM

The present conventional bus system has several problems in the Lima and Callao metropolitan area, in terms of bus operation, including competition between buses, taxis and Colectivos, bus facility, bus company organization, and administration. Those issues are discussed with the counterparts as well as several public transportation plans proposed in the Master Plan Study.

Of the projects proposed in the Master Plan Study, the east-west trunk bus project is proposed as a high priority project in 2010. The east-west trunk bus system develops busway infrastructure and special operation measures on the east-west corridor on Av. Venezuela and Carretera Central.

In the proposed trunk bus operation system, the trunk bus operates shuttle services on the segregated busway with a rapid operating speed, and feeder buses collect passengers and bring them to a transfer terminal, where they transfer to trunk buses. The proposed trunk bus line system is composed of trunk bus, conventional bus and feeder bus lines, in which trunk buses run on the exclusive busway and the others on mixed traffic lanes.

In this section, the following major items are studied.

1) Trunk bus operating line plan
2) Rerouting of conventional bus lines
3) Bus fare rate system plan
4) Trunk bus operating system plan
5) Feeder bus operating system plan
6) Effectiveness of the system

6.1.2. PLANNING POLICY AND STRATEGY

(1) Trunk Bus System

The type of bus service in the trunk bus system consists of a trunk bus, conventional bus and feeder bus. The outline of the bus services is shown below.

1) Trunk Bus Service

The trunk bus service is operated with higher operating speed on the busway, which may be partially segregated from other traffic or fully segregated from other traffic by curbs or fences to secure operating conditions such as speed, punctuality and safety. The trunk bus system results in higher volumes of bus passenger flows.

In the study, the east-west trunk busway is planned on Av. Venezuela, Av. Grau and Carretera Central and its roads run through the high-density populated area. The trunk bus operates shuttle services between the Callao and Santa Anita bus terminal.

2) Feeder Bus Service

The function of feeder buses is to supplement a trunk bus service. The feeder buses serve within some areas where no trunk buses operate. The feeder bus system operates in an area

around a trunk bus terminal to carry passengers to and from the terminal. Its service area is limited to a relatively small area in the suburbs, with relatively short route length and a smaller number of passengers per bus. Because feeder buses probably run on narrower roads, the fleet consists of smaller buses with 30-40 passenger capacity, like a microbus or Camioneta.

In the study, the feeder bus lines are prepared within the Callao area where the feeder bus terminates in the Callao terminal, and Santa Clara and Huaycan areas where the feeder bus connects into the Santa Anita terminal.

3) Conventional Bus Service

The conventional bus system operates the bus lines other than the trunk bus and the feeder bus lines. The conventional buses will be operated outside of the segregated busway on roads. In the study, the conventional bus system uses the bus line system on the Study of the Concession of Lines on 9 Metropolitan Roadway Axes by GTU in which two route scenarios were defined, one for 202 lines in 2007 and the other for 213 lines in 2012.

In the study, the 202 line system is employed as the conventional bus system in 2010. However, some conventional bus lines are eliminated by the degree of competition from the east-west trunk bus line.

(2) Busway Facility

1) Trunk Busway

The trunk busway is segregated by a concrete structure from the through traffic lane in order to ensure that the regular trunk bus service complies with schedule and traffic safety requirements. The busway is closed to pedestrians, bicycles, taxis and other motor vehicles throughout the day. The east-west corridor that introduces the trunk busway has two to three one way lanes on both sides of the busway for regular motorized traffic.

In the study, the busway on these roads is located in the center of the road (median). The fully segregated busway and/or bus priority lane are planned, depending on the road width and roadside environment.

2) Bus Stop Spacing

The main physical determinations of average commercial bus speed appear to be bus stop and intersection spacing. Bus stop capacity is an important determinant of overall bus system performance. Bus stop spacing also influences performance. The longer the stop spacing, the higher the commercial speed will be. Bus stop spacing in the east-west trunk bus system provides for a distance of 0.8km or 1km to ensure operating speed and line-haul capacity.

Two trunk bus terminals are planned in the Study, one in Callao and the other in Santa Anita. The detailed locations of the terminals are shown in Chapter 7, Preliminary Engineering of East-West Trunk Busway.

3) Busway Capacity

In the bus passenger flow survey in 2006, the maximum passenger flows on the east-west corridor are approximately 25,000 passengers in the westerly direction in the morning peak hour. The maximum numbers of buses are approximately 1,200 fleets passing in the westerly direction and 900 buses heading east on the corridor.

Table 6.1-1 shows the trunk line capacity per hour by different service frequency (headway). This capacity is calculated on the assumption of the number of bus operation

frequencies derived from headway and bus passenger capacity as an index of performance. This does not show the actual performance. This shows one measure of the performance of transport capacity in the trunk bus system. The trunk bus operation plan refers to those values. On actual bus operation, since this transport capacity depends on the conditions of passenger demand, bus stop spacing, intersection, bus stop capacity, operation speed, etc., an actual capacity is different under those conditions. In the event that the passenger demand on the trunk busway becomes large enough to require a headway shorter than 30 seconds, it would be more appropriate to introduce the articulated bus linking three vehicles (capacity of 200 or 240 passengers).

Table 6.1-1 Service Frequency and Transport Capacity of Trunk Bus Line

Service Frequency (Headway)	No. of Buses operated (units/hour) (A)	Capacity per Articulated Bus(B)	Transport Capacity per hour/lane (persons/direction/lane) (A x B)	Remarks
20 seconds	180	150	27,000	Difficult to operate
30 seconds	120	150	18,000	
45 seconds	80	150	12,000	
60 seconds	60	150	9,000	
90 seconds	40	150	6,000	
120 seconds	30	150	4,500	

(3) Bus Operating System

1) Integrated Bus Operating System

The feasibility study proposes two new bus terminals for trunk bus operation. The terminals provide integrated transfers between trunk and feeder bus lines in which passengers are allowed to transfer between buses without fare payment. In this study, the conventional bus lines will not be integrated with the trunk bus system. Accordingly, the bus terminals are structured so as to segregate the integrated trunk and feeder bus services from the conventional bus lines and other private transport means. Passengers of conventional bus lines can transfer to trunk bus lines at trunk bus stops but they have to pay the fare again.

2) Bus Fare Rate System

The following two types of tariff system are considered for the trunk bus system:

a) A flat rate system, which is the same rate regardless of travel length.
b) A zone fare system in which the fare rises according to trip length

In the Study, alternative cases are set on the flat rate system because the zone fare system is difficult in the actual application, especially ticket sale, fare collection and ticket validation. It is difficult to verify the ticket under the zone fare system without any fare collecting equipment.

Two alternative cases are considered as follows:

1. Alternative-A: a flat rate system with an additional fare at every transfer point
2. Alternative-B: a flat rate system without payment of an additional fare when transferring

Alternative-B allows transfer without payment of an additional fare when passengers transfer from/to feeder bus or trunk bus at terminal or bus stop. However, it is also difficult to verify the passengers who transfer or not by the validation of tickets only. If such a

system is actually introduced, some segregated structures like railway stations need to validate the passengers.

In the feasibility study, alternative-B is proposed in the trunk bus system under the integrated operation system mentioned above.

A. Integrated System for Intelligent Ticket

In order to accomplish high performance in the trunk and feeder bus system, an efficient ticketing system is needed. Boarding times per passenger in a fare collection system, in which entry to a bus is unobstructed by fare collection or ticket validation, are lower than that of the current system in which entry is restricted.

The off-board ticketing system is an intelligent ticketing system. It offers the possibility to reduce passenger service time and thereby to reduce bus waiting time and increase commercial speed. Such a system will not be effective on only a few busways. The integrated system to be applied in the whole city will enhance the performance of the trunk and feeder bus system, if no attention is paid to the cost.

The proposed integrated system is considered as follows:

a) Trunk bus – trunk bus: applied integrated system
b) Trunk bus – feeder bus: applied integrated system
c) Trunk and feeder buses – conventional bus: no applied integrated system
d) Trunk bus and feeder buses – railway: no applied integrated system

B. Proposed Integrated System in 2010

There will be only two trunk bus lines in 2010 in the feasibility study: COSAC and the East-West trunk bus line. Therefore, in the feasibility study, the integrated fare system in 2010 is independently applied by each project as a period of transition to the fully integrated fare system. That is, the COSAC project applies COSAC's integrated system and the East-West trunk bus project initially examines the following fare rates which will be proposed. The detailed bus fare rate is analyzed in Section 6.4, Bus Fare Rate System Plan.

a) East-West trunk bus system: S./1.5- 2.0
b) Conventional bus: S./1.0
c) A fare rate of each public transport mode for transfer between public transport will be applied.

At the moment, COSAC is examining the optimum fare rate system in advance of this F/S Study. The several alternative fare systems are proposed in the course of the study. This F/S study analyzes under the above conditions and proposes the bus fare rate system in the East-West trunk bus system. Therefore, on the implementation schedule of both the projects, it will be necessary to further study in the Detailed Design Stage whether full integrated system is applied to both the projects, or not, when the system is applied.

3) Bus Fleet

In Lima, bus transport is the main mode of public transport and public transport demand is heavy, especially in the peak hours. When the trunk bus system is introduced in the Lima metropolitan area, larger buses on the trunk busway will offer both lower operating cost and higher service reliability.

The general merits of large buses are as follows.

- Operating costs per unit of offered capacity decrease as bus fleet size increases.

- Line capacity increases almost linearly with bus size. With larger buses, street congestion decreases and reliability of service increases.
- Vehicle maneuverability decreases with bus size.
- Riding comfort increases with the bus size of single-body buses, but it is lower with articulated and double-decker buses.

The bus capacity proposed in the trunk bus system is shown as follows: An articulated bus with two bodies with a capacity of 150-170 is used for the trunk busway. The passenger capacities of the trunk bus are almost 2-5times, compared to the current Omnibus and Micro bus capacities.

- Trunk bus: 150 - 170 passenger / unit for articulated bus
- Feeder bus: 30 – 40 passenger / unit
- Conventional bus: 15 –100 passenger / unit

6.2. TRUNK BUS LINE AND FEEDER BUS LINE PLANS

6.2.1. PROPOSED TRUNK BUS LINE SYSTEM

The conventional bus lines on major roads are organized in accordance with passenger volumes. Figure 6.2-1 provides a diagram of the conventional bus lines on the study roads, where many bus lines overlap. The proposed trunk bus line system will be composed of trunk bus, conventional bus and feeder bus lines, in which trunk buses run on an exclusive busway and others on mixed traffic lanes. The diagram in Figure 6.2-2 illustrates the configuration of the trunk bus system.

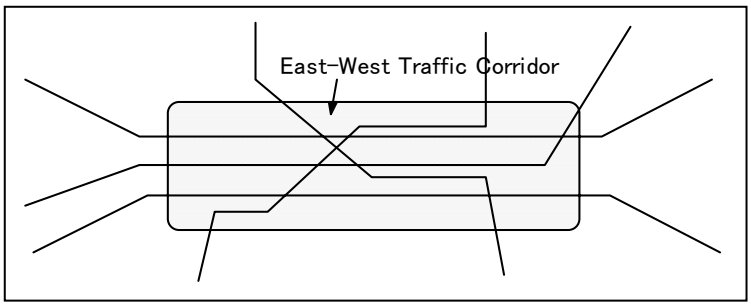


Figure 6.2-1 Conventional Bus System

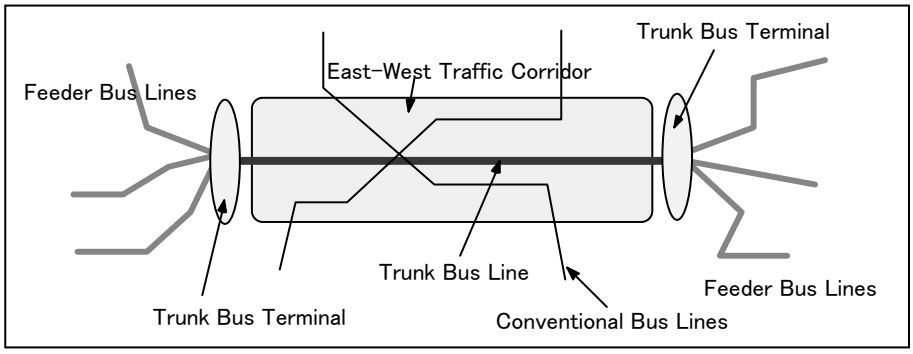


Figure 6.2-2 Trunk Bus Line System (Shuttle Service)

6.2.2. TRUNK BUS LINE

Since the passenger characteristics such as volume and flow are different between Callao-Central Lima and Central Lima-the eastern suburb (Santa Clara and Huaycan), the trunk bus line is prepared in consideration of the passenger characteristics. Figure 6.2-3 shows the trunk bus line configuration on the east-west trunk bus system. Three trunk bus lines are proposed as followings.

1) Line-1: Av. Grau- Santa Anita Trunk Bus Terminal
2) Line-2: Callao Trunk Bus Terminal- Av. Grau
3) Line-3: Callao Trunk Bus Terminal- Santa Anita Trunk Bus Terminal

The trunk bus operates a shuttle service on those lines between the terminals in accordance with the passenger demand

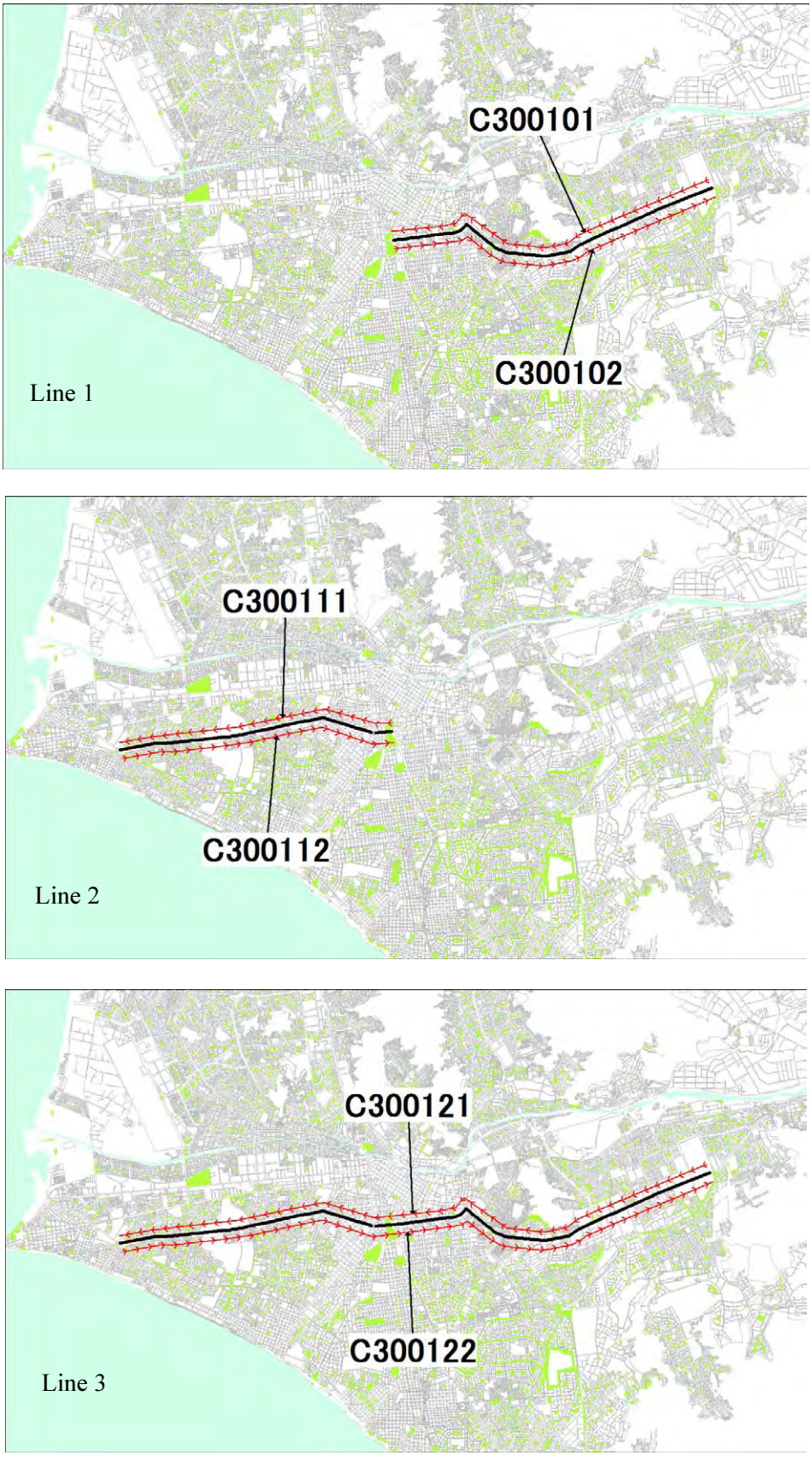


Figure 6.2-3 Trunk Bus Line Configuration

6.2.3. CONVENTIONAL BUS LINES

(1) Conventional Bus Lines on the East-West Trunk Line

When the trunk busway is constructed on the east-west trunk bus line, the conventional bus lines operated on those roads must be rerouted by eliminating those that overlap with trunk bus lines. Figure 6.2-4 shows the number of bus lines passing on the EW trunk bus line by segment in the 2007 line system. The maximum number of bus lines is 23 lines/one-way. Figure 6.2-5 shows the conventional bus line configuration overlapping with the trunk bus line, which total 73 lines/one-way. On the other hand, the number of conventional bus lines not overlapping with the trunk bus line is 331 lines/one-way.

The conventional bus lines among the 73 lines/one-way are eliminated by the criteria shown in the next section.

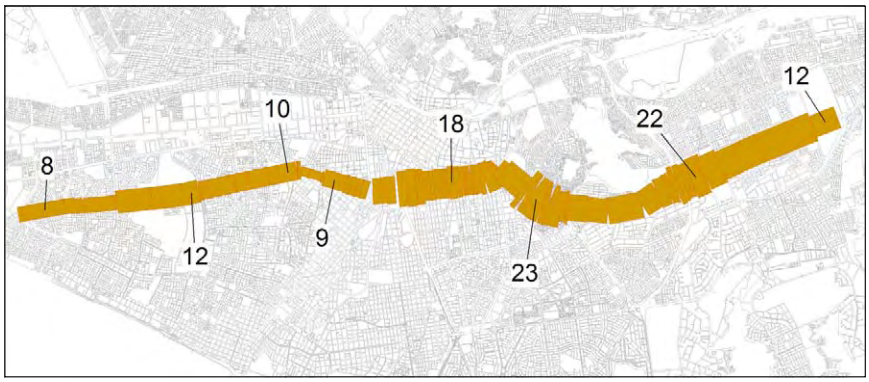
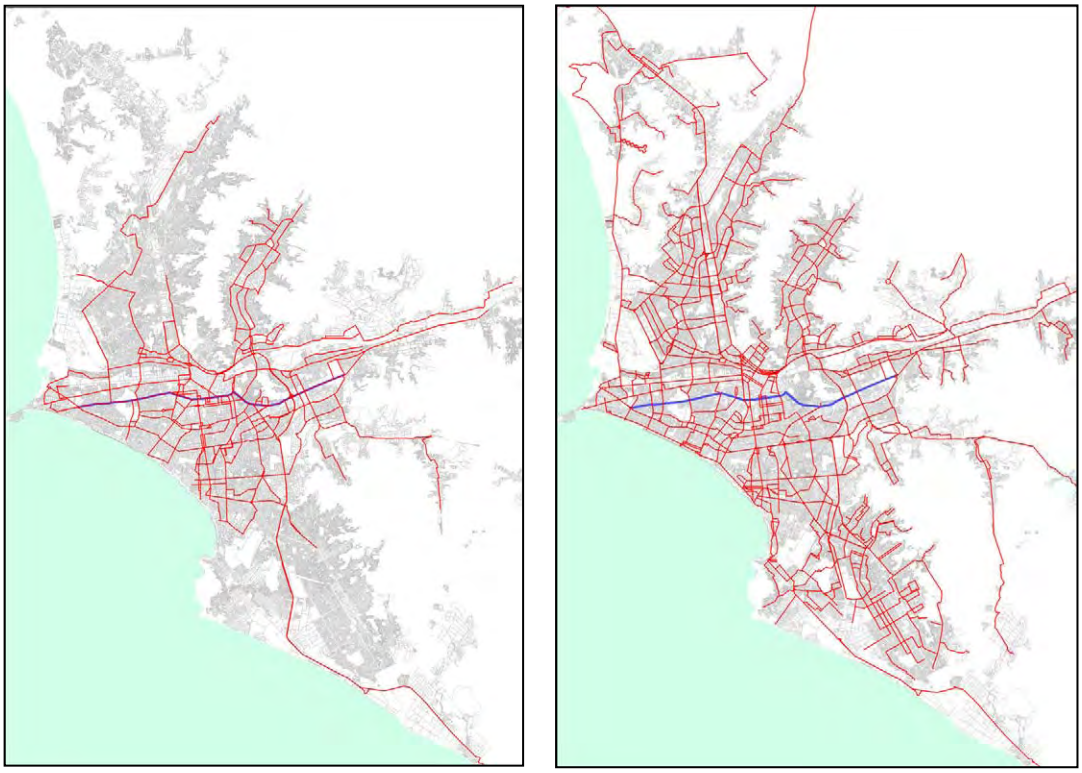


Figure 6.2-4 Number of Conventional Bus Lines on the East-West Trunk Bus Line/one-way



73 Overlapped Bus Lines/one-way

331 Not Overlapped Bus Lines/one-way

Figure 6.2-5 Conventional Bus Lines overlapping and not overlapped with the Trunk Bus Line

(2) Elimination of Conventional Bus Lines

The elimination of the conventional bus lines is examined based on the following considerations:

1) Degree of similarity of line configuration between conventional and trunk bus lines
2) Line distance overlapped with the trunk bus line

Table 6.2-1 and Figure 6.2-6 show the relationship between the overlapped ratio and the number of conventional lines. In consideration of the degree of similarity of line configuration, an overlapped ratio of 20% or more to the total line distance is optimum in the elimination of a line. In the case of the ratio of 20% or more, 22 lines/one-way, equivalent to 30% of the total bus lines, are eliminated from the conventional bus lines overlapped with the east-west trunk bus line.

Table 6.2-1 Relationship between Overlapped Ratio and Number of Lines

Duplicated Ratio (%)	Acccumulated No. of Lines	Ratio of Elimination	Overlapped Ratio (%)	No. of Lines
>0	73	100.0%	>0	73
10 or more	32	43.8%	0–10	41
20 or more	22	30.1%	11–20	10
30 or more	18	24.7%	21–30	4
40 or more	11	15.1%	31–40	7
50 or more	7	9.6%	41–50	4
60 or more	6	8.2%	51–60	1
70 or more	6	8.2%	61–70	0
80 or more	0	0.0%	71–80	6
90 or more	0	0.0%	81–90	0
100	0	0.0%	100	0

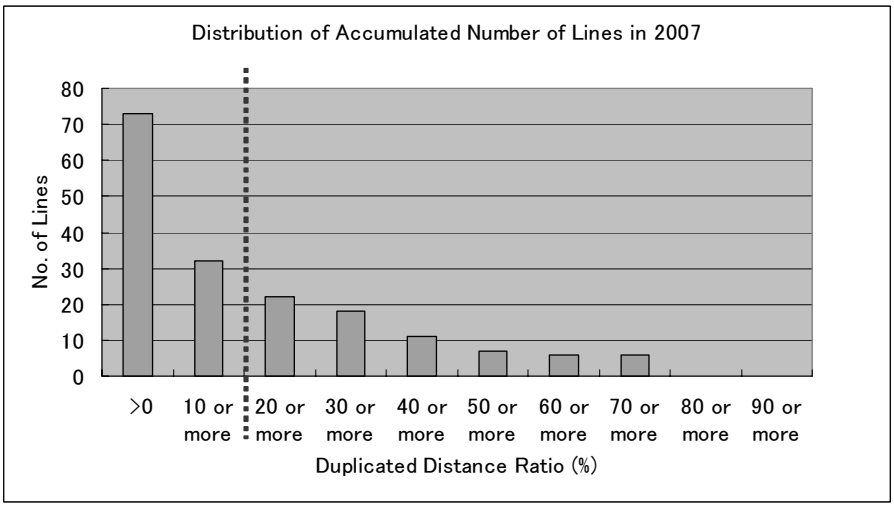


Figure 6.2-6 Distribution of Accumulated Number of Bus Lines against Overlapped Distance Ratio

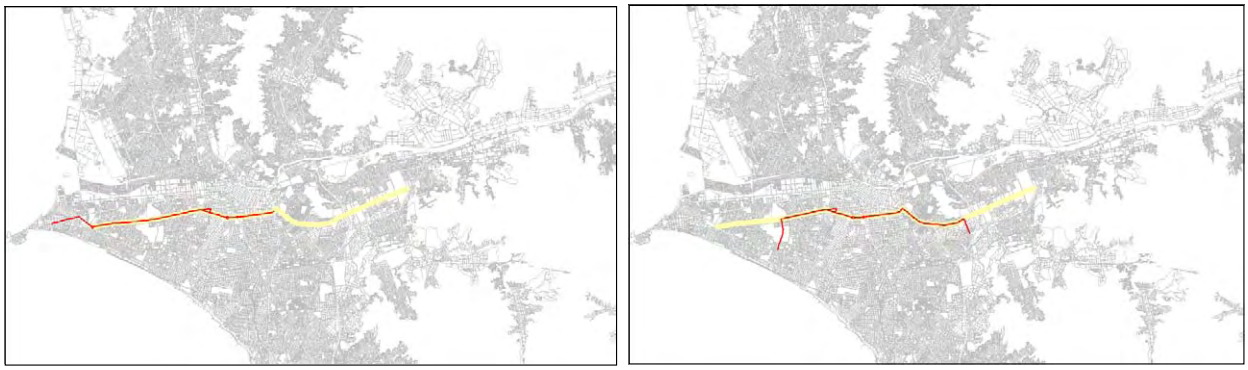
Figure 6.2-7 and Figure 6.2-8 show typical bus lines eliminated by overlapping of 20% or more of the total distance with the east-west trunk bus line, in which the yellow band is the trunk bus line and the red is the eliminated conventional line. Those lines show the high degree of overlapping from the viewpoint of degree of similarity of line configuration between conventional and trunk bus lines.

Figure 6.2-9 shows the conventional line configuration which is overlapped at a ratio of 20% or more of the total line distance on the east-west trunk bus line. Table 6.2-2 shows

the eliminated conventional bus line Nos. The 22 conventional lines/one-way are eliminated in order to avoid overlapping.

Line No. M1 Line No. M2

Figure 6.2-7 Typical Bus Lines Eliminated by Overlapping with the East-West Trunk Bus Line



Line No. M11 Line No. C-T24B

Figure 6.2-8 Typical Bus Lines Eliminated by Overlapping with the East-West Trunk Bus Line

Figure 6.2-9 22 Conventional Bus Lines (Overlapped Ratio of 20% or More of the Total Line Distance)

Table 6.2-2 Eliminated 22 Conventional Bus Lines/oneway

No.	Route_Name	No.	Route_Name
1	M1-o	13	C-T6arequipa-n
2	M1-e	14	C-T7arequipa-n
3	A61-n	15	C-T24B-o
4	A61-s	16	C-T24B-e
5	M2-e	17	T6-o
6	M2-o	18	T6-e
7	M11-e	19	C-T6arequipa-s
8	M11-o	20	C-T7arequipa-s
9	M3-n	21	Ruta-1-o
10	M3-s	22	Ruta-1e
11	C-T5arequipa-n		
12	C-T5arequipa-s		

(3) Influence of Eliminating

Several problems related to the execution of the project are anticipated when the trunk bus system is introduced in the Lima and Callao metropolitan area. One of the major problems is a probable objection from employees wishing to ensure employment when the elimination of the conventional bus lines is completed. Since 22 conventional lines are eliminated in order to avoid overlapping, the related employees are affected by the elimination.

Table 6.2-3 shows the number of bus companies and bus fleets in the Metropolitan Lima and Callao. Table 6.2-4 shows the employment factors for drivers and conductors which were obtained from the managers of the 12 most representative companies in Lima from the bus company survey. The average drivers and conductors per bus is 1.68 and 1.51, respectively. The management and maintenance workers are shown in Table 6.2-5 for which information was also obtained from the bus company survey. Approximately 6,000 administrative workers are excluded because they are car owners who do not directly relate to the daily bus operation. From the above information, the number of employees influenced by the elimination of 22 bus lines/oneway is approximately 1,000 people in consideration of the 2010 travel conditions on the assumption of the total employees on the 2004 line network (see Table 6.2-6). The figures estimate only employees who directly work in the daily bus operation.

Table 6.2-3 Number of Bus Companies and Bus Fleets in Metropolitan Lima and Callao

	Callao	Lima	Total
Bus Companies	146	336	482
Number of Bus Fleets	7,863	24,507	32,370

(Source: GTU-MML)

Table 6.2-4 Employment Factors for Driver and Conductor

	Total	Ratio
Total Bus Fleets	1,898	
Drivers/bus	3,184	1.68
Conductors/bus	2,862	1.51

(Source: Study Team)

Table 6.2-5 Workers for Management and Maintenance

Position	Ratio of Companies which has Related Position 1)	Average Number of Workers per Company 2)	Total Administrative workers
Manager	100%	1	482
Secretary	86%	1	415
Accountant	93%	1	450
Advisor	87%	1	419
Analyst	18%	1	88
Dispatcher	83%	4	1600
Controller	61%	1	296
Marketing	12%	2	120
Fuel dispenser	34%	2	330
mechanics	19%	4	372
Security agent	40%	4	780
Doorman	13%	1	65
Cleaning	48%	2	460
Solicitor	11%	1	53
Others	16%	1	77
Total Workers			6007

Note: 1): from the Company Survey
2): Study Team

Table 6.2-6 Employees Influenced by Eliminated Bus Lines in 2010

Items		Volumes
(1) Bus Operating Conditions		
	Kilometer /vehicles/day *	250
	Vehicle-Kilimeter/day in 2010	2,840,274
	Total Number of Operated Vehicles/day	11,361
	Number of Cycles/ vehicle/day *	3.0
(2) Employees		
	Drivers	6,353
	Conductors	5,710
	Office Workers	6,000
	Total Operated Persons	18,063
(3) Line Condition		
	No. of Lines in 2004/loop	625
	No. of Lines in 2007/loop	202
(4) Condition of Operated Workers		
	Average Operated Workers/line in 2004 Line Network	28.9
	Average Operated Workers/line in 2007 Line Network	89.4
	No. of Eliminating Lines/loop in the 2007 Line Network	11
	Effected Workers	1,000

Note: * Company Survey

6.2.4. FEEDER BUS LINES

(1) Line Planning Policy

The function of feeder buses is to complement the trunk bus service. The feeder system operates in an area around a trunk bus terminal to carry passengers to and from the terminal. Its service area is limited to a relatively small area in the suburbs, with relatively short line length and smaller numbers of passengers per bus. Also, feeder buses run on narrower roads.

The Master Plan Study disclosed that the trunk bus system is required for a mass and rapid transportation system, and the feeder bus service is required to prepare the feeder bus line within the residential areas. Therefore, the following function and policy are requested in the feeder bus system.

1) The function of the feeder bus service is the following:
   - Support public activity for work, school, shopping, etc.
   - Support activity of lower income people
   - Support commercial activity in shopping centers
2) The policy of line preparation is the following:
   - Connection between residential area and commercial area, hospital, school, public facilities, etc.
   - Connection of residential areas without bus service but with narrow roads in which Camioneta (bus) cannot operate.
3) The policy of feeder bus operation is the following:
   - Feeder bus operates in accordance with passenger demand.
   - Feeder bus fare rate is as low as possible.

The feeder bus lines are prepared in Callao, Santa Clara and Huaycan in the study in consideration of the above planning policies. The feeder bus lines within Callao connect to the Callao trunk bus terminal, while in Santa Clara and Huaycan the bus lines connect to the Santa Anita terminal.

(2) Line Plans

1) Callao

The feeder bus line configuration is prepared in consideration of the following policy.

- Connect to major transport facilities such as the international airport, the port of Callao, La Punta (promontory) and Callao trunk bus terminal.
- Prepare the feeder network on wider roads with 4 lanes or more to easily operate a feeder bus fleet.
- Prepare the feeder bus network in the direction of heavy desire lines of travel demand.

Alternative Feeder Line Case-1

Callao has 31 conventional bus lines/loop operating inside of Callao in 2006. At present, Callao plans the rerouting and integration of conventional bus lines and 15 new conventional lines /loop are proposed instead of the 31 lines. The feeder network case-1 prepares 4 feeder lines based on the above policy (see Figure 6.2-12 and Table 6.2-7). From among the new conventional lines, of the feeder bus lines, remain only the lines connected to major transport facilities such as the international airport, the port of Callao, La Punta (promontory) and the Callao trunk bus terminal remain. These lines coincide with the direction of heavy travel demand. The feeder bus operates round trips on the feeder lines (see Figure 6.2-14)

Alternative Feeder Line Case-2

The Callao feeder bus line refers to the new 15 conventional lines based on the above policy. Since the new conventional bus line configuration coincides with the above policy, the feeder bus line prepares the same line as the new line in Callao, but the feeder bus line connects with the Callao trunk bus terminal. The 15 lines/loop are prepared as the feeder bus line case-2 (see Figure 6.2-13 and Table 6.2-7). The feeder bus operates round trips on the feeder lines.

2) Santa Clara and Huaycan

The feeder bus line configuration within Santa Clara and Huaycan is prepared in consideration of the following policy.

- Connect to important facilities such as hospital, school, market, and sport facilities. Figure 6.2-10 and Figure 6.2-11 show the locations of major facilities in Huaycan and Santa Clara.
- Refer to the conventional bus lines operated within those areas.
- Partly overlap with the conventional bus line. This is because the conventional bus lines are already provided in zones which have heavier passenger demand and connect between residential area and commercial area, hospital, school, public facilities, etc. The feeder line, however, connects to the Santa Anita trunk bus terminal and those areas, while the conventional bus line from/to Santa Clara and Huaycan has a different destination by each line. The destination of each bus line on the conventional and feeder bus lines does not overlap.

Alternative Feeder Line Case-1

Table 6.2-7 shows number of feeder bus lines in the feeder line case-1. The feeder line case-1 prepares 3 lines in each area as shown in Figure 6.2-12 Feeder. The number of lines is a few, but the operation route connects many facilities in one travel (see Figure 6.2-14). Therefore, route distance between origin and destination is longer than the case-2.

Alternative Feeder Line Case-2

The feeder line case-2 prepares 5 lines in each area as shown in Figure 6.2-13 and Table 6.2-7. The number of lines is more than that of the case-1. The operation route directly connects between origin and Santa Anita terminal. Therefore, the route distance is shorter than that in the case-1. Figure 6.2-15 shows the operation route in the case-2.

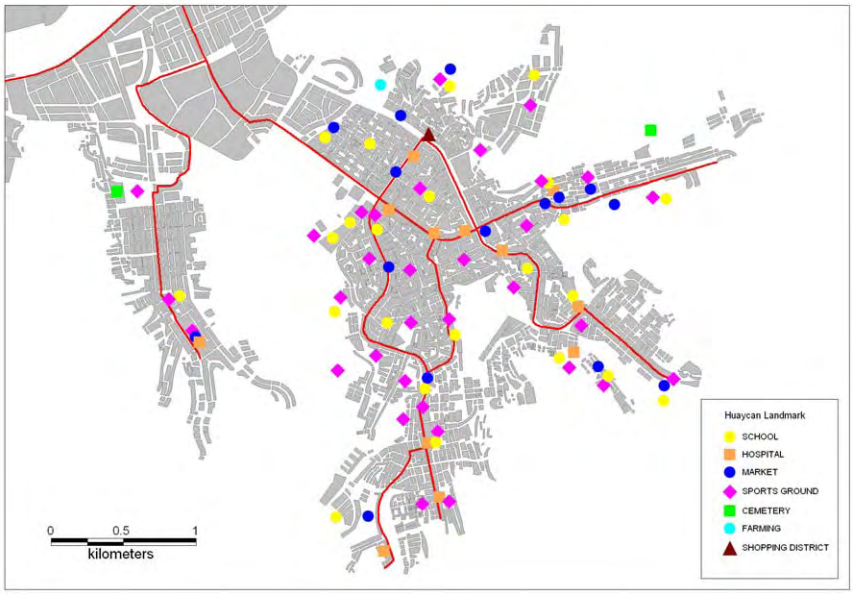


Figure 6.2-10 Major Facilities in Huaycan

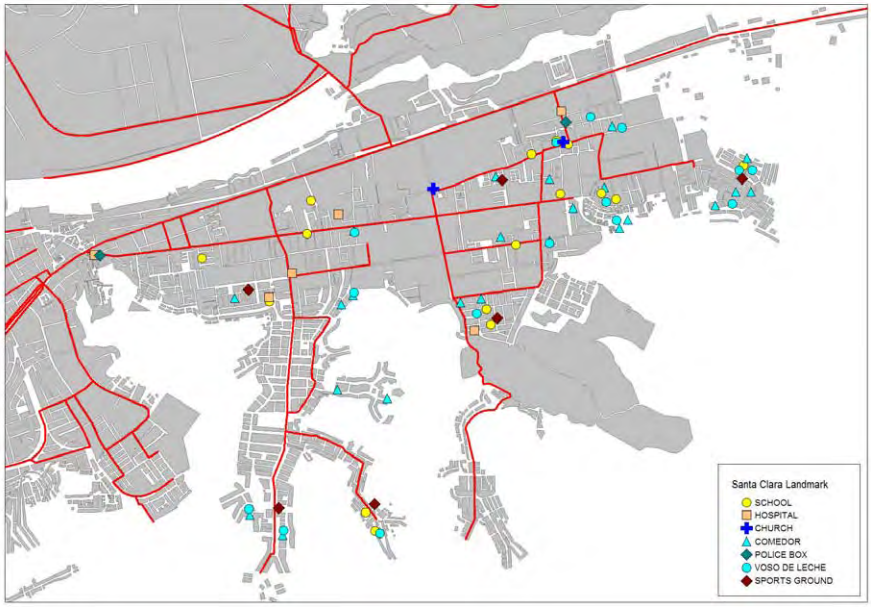


Figure 6.2-11 Major Facilities in Santa Clara

Table 6.2-7 Number of Feeder Bus Lines

(Unit: Number of feeder bus lines/loop)

	Feeder Case-1	Feeder Case-2
Callao	4	15
Santa Clara	3	5
Huaycan	3	5

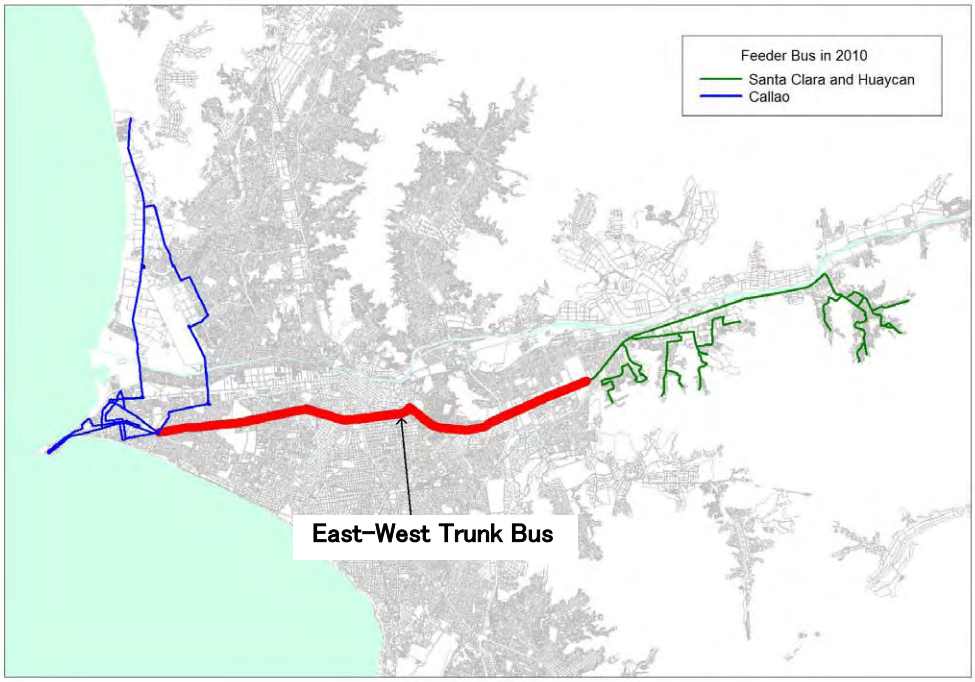


Figure 6.2-12 Feeder Bus Line Network Case-1

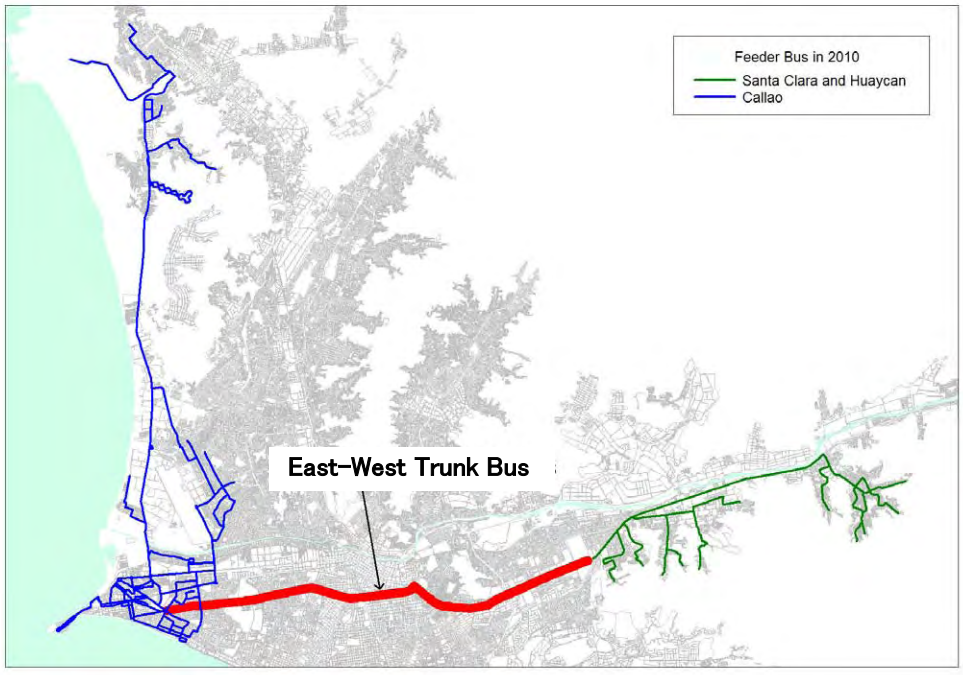
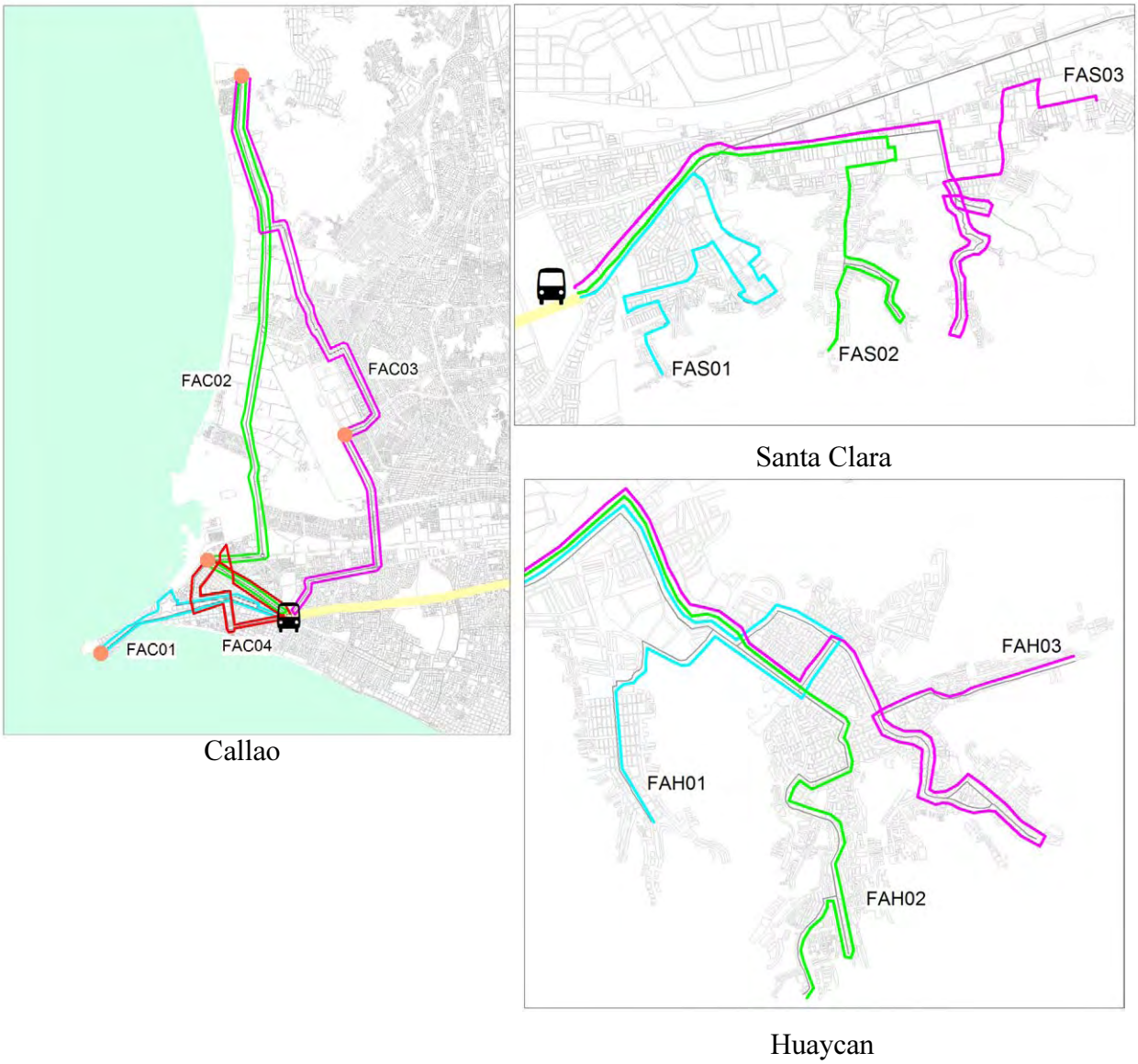


Figure 6.2-13 Feeder Bus Line Network Case-2



Callao

Santa Clara

Huaycan

Figure 6.2-14 Feeder Bus Operation Case-1

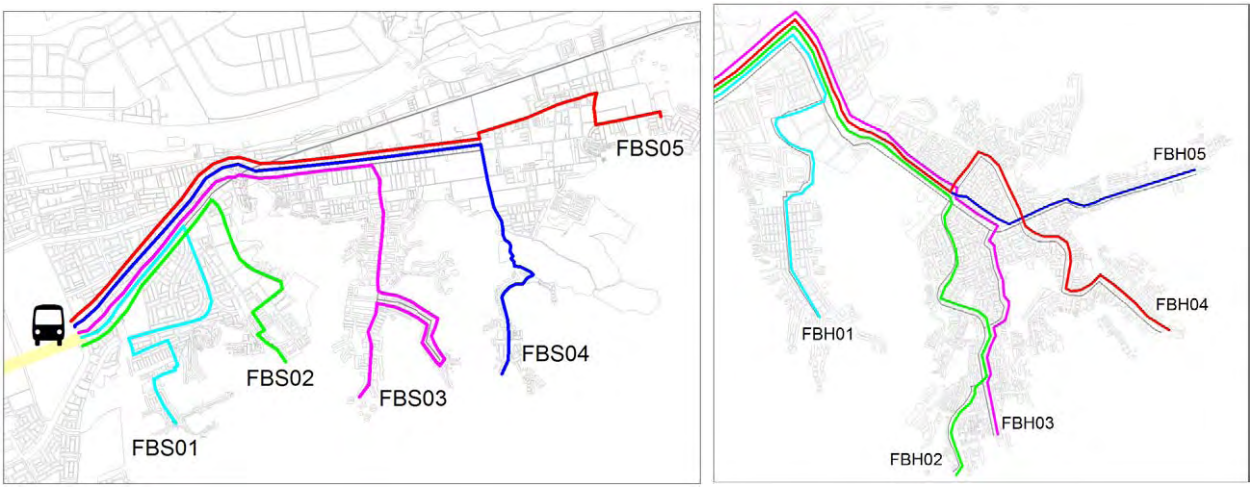


Figure 6.2-15 Feeder Bus Operation Case-2

3) Covered Population

The covered areas and population in the feeder bus line network case-1 and case-2 are shown in Table 6.2-8 and Table 6.2-9 in which the covered area in Callao is counted only southern part because the northern part does not directly affect in the trunk bus system. The analysis of the bus network system in Section 13.4.3 shows that minimum bus network service needs to prepare the covered population ratio of 70% or more. Since the ratio of the covered area in those areas in the case-1 is 75%, the feeder networks in those areas fill the need for the limited network density. The case-2 also exceeds the limited density.

Table 6.2-8 Covered Area and Population in the Feeder Bus Network Case-1

	Zone Area (km2)	Covered Area (km2)	Covered Ratio (%)	Total Population	Covered Population
Huaycan	16.4	12.1	74%	72,000	53,300
Santa Clara	21.6	18.5	86%	105,700	90,500
Callao (excluding Airport Area)	43.9	33.1	75%	589,100	443,700

Table 6.2-9 Covered Area and Population in the Feeder Bus Network Case-2

	Zone Area (km2)	Covered Area(km2)	Covered Ratio(%)	Total Population	Covered Population
Huayca	16.4	12.5	77%	72,000	55,100
Santa Clara	21.6	17.8	82%	105,700	87,000
Callao (excluding Airport Area)	43.9	42.0	96%	589,100	564,000

Callao　　Santa Clara and Huaycan

Figure 6.2-16 Covered Area by the Feeder Bus Line Network Case-1

6.2.5. FEEDER BUS NETWORK ANALYSIS

(1) Procedure of Feeder Bus Network Analysis

Two feeder bus operation cases are proposed in Section 6.2.4. Those cases are examined and a better feeder bus network system is proposed in this section. The procedure of the feeder bus operation analysis is shown in Figure 6.2-17, in which at first the demand on the feeder network lines is forecasted and the second analyzed the line operation conditions, the last proposed a better feeder bus line system.

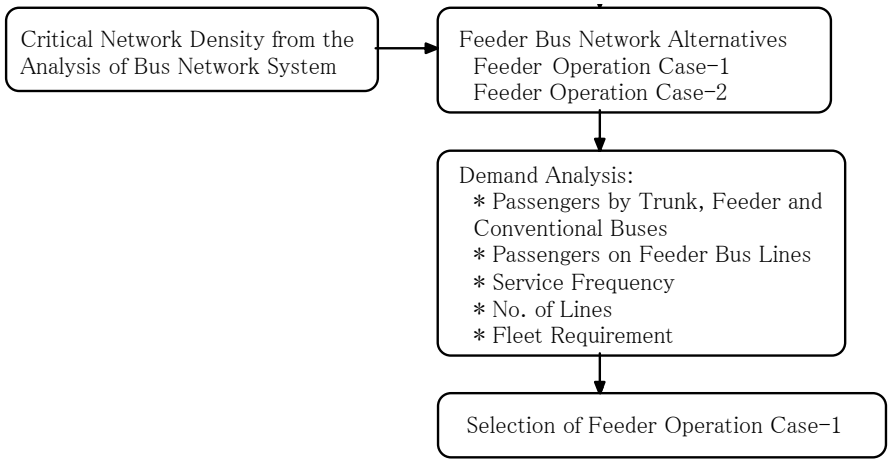


Figure 6.2-17 Procedure of Feeder Bus Line Analysis

(2) Demand on Feeder Bus Networks

1) Total Passengers by Trunk and Feeder Buses

Table 6.2-10 shows the total trunk and feeder bus passengers by the areas in the feeder case-1 and the case-2. In the case-2, the passengers in the trunk bus system increase 1.1 times in comparison with the case-1. The feeder bus passengers in Callao increase to approximately 30% of the case-1 and in Santa Clara and Huaycan the feeder bus passengers also increase by approximately 20% and 40%. It is obvious from this that the total passenger volumes are closely related with the number of feeder bus lines.

Table 6.2-10 Total Number of Hourly Bus Passengers in Feeder Case-1 and Case-2

(Unit: passengers/hr)

Area	Mode	Feeder Case-1	Feeder Case-2	Feeder Case-2 /Case-1
EW Line	Trunk Bus	41,064	43,647	1.06
Callao	Feeder Bus	1,880	2,385	1.27
Santa Clara	Feeder Bus	6,708	9,679	1.44
Huaycan	Feeder Bus	6,326	7,399	1.17
Total		55,978	63,110	1.13

2) Line Characteristics

Table 6.2-11 shows number of passengers classified into 5 transferred groups; EW-trunk bus only, feeder bus only and its combined use in the trunk bus system. As can be seen, the feeder bus passengers who use only feeder bus and trunk- feeder bus in the case-2 increase at 1.26 and 1.31 times, respectively in comparison with the case-1. However, the trunk bus passengers who use the trunk bus only in the case-1 and case-2 do not change in number.

Table 6.2-11 Number of Passengers by Bus Transferred Modes in Feeder Case-1 and Case-2

(Unit: passengers/hr)

Transfer	Feeder Case-1	Feeder Case-2	Case-2 /Case-1
EW Trunk Bus Only	13,332	13,226	0.99
EW Feeder Bus Only	1,775	2,233	1.26
EW Trunk Bus <->EW Feeder Bus	10,255	13,448	1.31
EW Trunk Bus <->Conventional Bus	12,244	11,547	0.94
EW Feeder Bus <->Conventional Bus	2,822	3,613	1.28
Total	40,428	44,067	1.09

3) Average Line Operation Conditions

Table 6.2-12 and Table 6.2-13 show average line operating conditions in case-1 and case-2 in terms of average operating time, passengers, frequency (headway) and fleet requirement Table 6.2-14 shows ratio of average line operating conditions in case-2 to case-1. Those values indicate the average figures per line.

Those conditions by the cases are summarized as followings.

- The average operation time in case-1 is longer than that in case-2 due to the loop operation.
- In case of Callao where the feeder line network is covered in the whole area by many feeder lines, the average passengers per line decrease.
- That is, the average passengers per line decrease, while the fleet requirements increase in proportion to the number of lines.

Table 6.2-12 Average Line Operation Conditions in Feeder Case-1

Bus	Area	Operation Pattern	Lines	Average Operation Time (min)	Average Passengers	Average Frequency/hr	Average Headway (min)	Fleet Requirement
Trunk Bus			3	24.3	6,844	25.8	2.3	96
Feeder Bus	Callao	A	4	29.9	235	5.4	11.2	40
	Santa Clara	B	3	28.9	1,118	24.3	2.5	130
	Huaycan	B	3	47.3	1,054	21.8	2.7	130

Table 6.2-13 Average Line Operation Conditions in Feeder Case-2

Bus	Area	Operation Pattern	Lines	Average Operation Time (min)	Average Passengers	Average Frequency/hr	Average Headway (min)	Fleet Requirement
Trunk Bus			3	24.3	7,275	27.5	2.2	110
Feeder Bus	Callao	A	15	63.0	79	2.0	30.0	110
	Santa Clara	A	5	18.0	968	22.4	2.7	138
	Huaycan	A	5	40.6	740	16.0	3.8	148

Table 6.2-14 Ratio of Average Line Operation Conditions in Feeder Case-2 to Case-1

Bus	Area	Lines	Average Operation Time (min)	Average Passengers	Average Frequency/hr	Average Headway (min)	Fleet Requirement
Trunk Bus		1.00	1.00	1.06	1.06	0.94	1.15
Feeder Bus	Callao	3.75	2.11	0.34	0.37	2.69	2.75
	Santa Clara	1.67	0.62	0.87	0.92	1.09	1.06
	Huaycan	1.67	0.86	0.70	0.73	1.36	1.14

(3) Proposed Feeder Bus Network System

From the above discussion, the summary of the line operation indices is shown in Table 6.2-15 in which circle indicates “good” and triangle is “fair” in comparison between both the cases. Case-1 is better than Case-2 in total evaluation. The feeder bus line system chooses Case-1.

Table 6.2-15 Summary of Line Operation Indices

	Operation Pattern	Lines	Passenger Demand	Travel Time	Waiting Time (Headway)	Fleet Requirement	Evaluation
Feeder Case-1	Loop Operation	Few	○	△	○	○	○
Feeder Case-2	Direct Operation	Many	△	○	△	△	△

Note: ○: good, △: fair