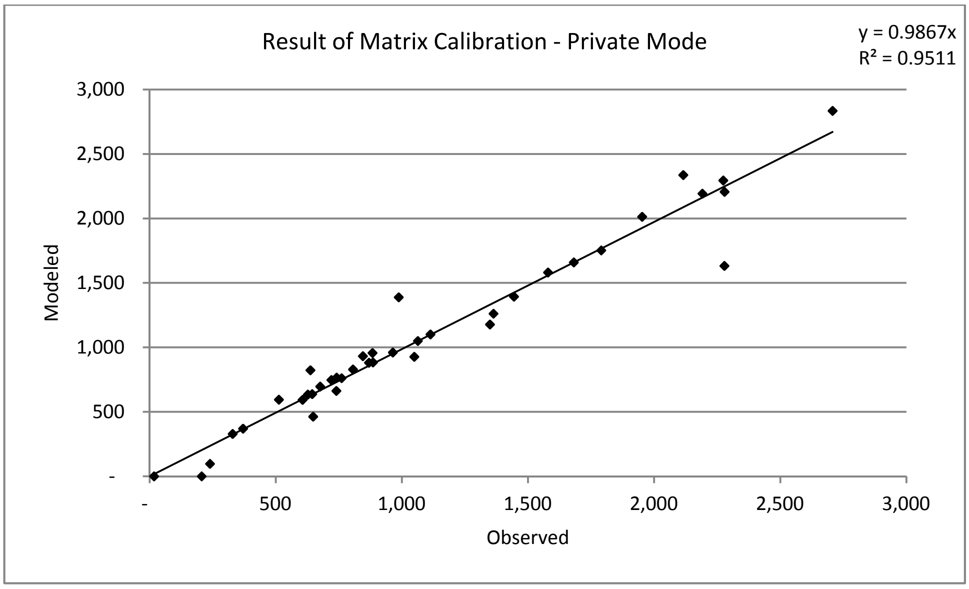
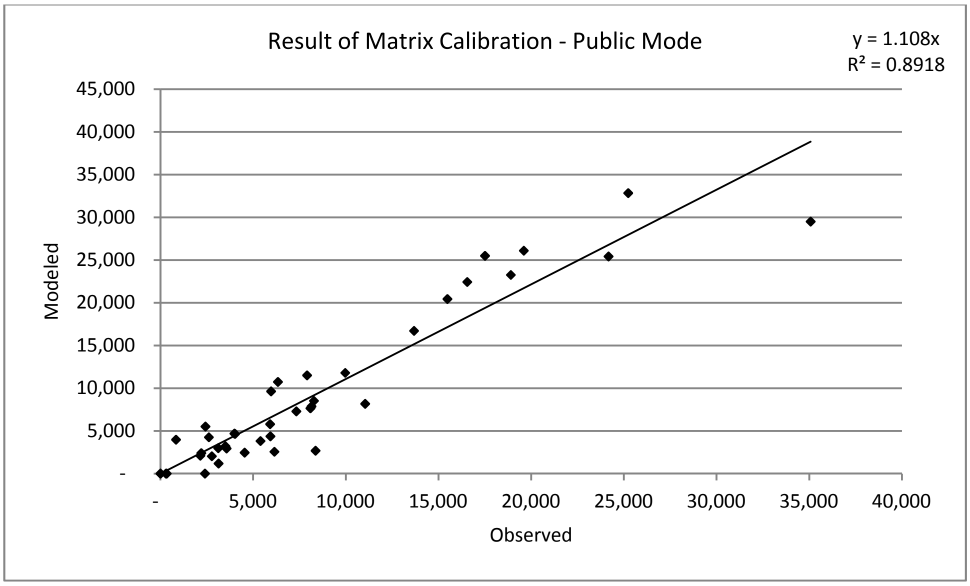


Source: JICA Study Team

Figure 5.5 Results of matrix calibration of the private mode



Source: JICA Study Team

Figure 5.6 Results of matrix calibration of the public mode

5.5 Transport Models

5.5.1 Trip Generation Model

(1) Model Structure

The total demand by traffic zone is estimated in the trip generation model. The model consists of the production model and attraction model.

The **multiple linear regression**, which estimates parameters for a linear relationship between a set of explanatory variables and dependent variables, was employed for the model.

To establish the relationship, the trips were classified in three groups:

- Home-based Work purpose trip - HBW: a work purpose trip from or to the home of the trip maker;
- Home-based School purpose trip - HBS: a study purpose trip from or to the home of the trip maker;
- Other purpose trip - OP compound by:
  - ✓ Home-based Other purpose trip - HBO: another purpose trip from or to the home of the trip maker; and
  - ✓ Non home-based trip - NHB: a trip of which the origin and destination are not the home of the trip maker.

The above groups were selected after preliminary tests by other variations of grouping. For example, the trip generation model by family income group was tested but the results were not satisfactory.

The multiple regressions are based on the determination of the coefficients associated to the dependent variables in the following type of function:

$$y_i = \alpha_1 \times v_1 + \alpha_2 \times v_2 + ... + \alpha_n \times v_n$$

Where:

y_i =dependent variable to be calculated, for example, HBW;

$\alpha_1, \alpha_2, .., \alpha_n$ =coefficients to be determined;

$v_1, v_2, ..., v_n$ =explanatory variables

The explanatory variables are selected after testing combinations from a set of variables such as population, employment, school registers, average income and motorization rates. The combination that resulted in the best fit of the regression was selected for the trip generation model.

The model considered the period of two hours in the morning peak from 7:00 am to 9:00 am with a total of 2.3 million trips considering private and public modes. These trips are distributed in 46.6% for HBW, 33.3% for HBS and 20.1% for OP.

The model was developed at district level considering the data reliability at district and traffic zone level. Once the production and attraction volumes are calculated by district, it is disaggregated at zone level proportionally to those estimated in the Person Trip Survey.

The results of the regression model for each group of trips are presented below.

(2) Production Model for HBW

For this group of trips, the model is given by the following equation:

$$PHBW_i = 0.11075697 * Pop_i$$

Where,

$PHBW_i$ = Production of HBW in district i
Pop_i= Population in district i

Table 5.3 shows the main results of the regression where R^2=0.95 indicates that the population explains 95% of the trip production for this group. The Student T and P values are also compatibles with the results.

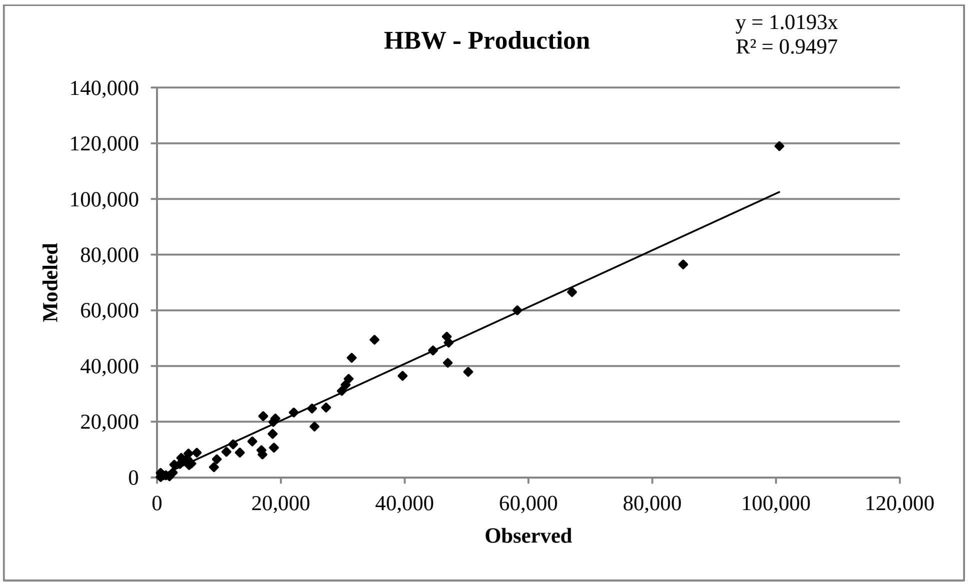
Table 5.3 Results of the Regression of Production Model for HBW

Regression statistics	
R multiple	0.986612437
R-square	0.973404101
R-adjusted squares	0.952570768
Standard error	5198,530705
Observations	49

	Coefficients	*Standard err*	*Stat t*	*value-P*
Intersection	0	#N/D	#N/D	#N/D
Population	0.110756972	0.002642477	41,91407317	1.8206E-39

Source: JICA Study Team

Figure 5.7 shows the correlation between the estimation in the Person Trip Survey and the modeled data where R^2 is as high as 0.95.



Source: JICA Study Team

Figure 5.7 Predictability of Production Model for HBW

(3) Attraction Model for HBW

For this group of trips the model is given by the following equation:

$$AHBW_i = 0.223266 * Emp_i + 38{,}578.31 * Dummy1$$

Where,
$AHBW_i$ = Production of HBW in district i
Emp_i= Employment in district i

Dummy1 = variable defined for district 37 (San Isidro) with very particular behavior in terms of trip attraction

Table 5.4 shows the main results of the regression where R^2=0.93 indicates that the employment and the dummy variable explain 93% of the trip attraction for this group. The Student T and P values are also compatibles with the results.

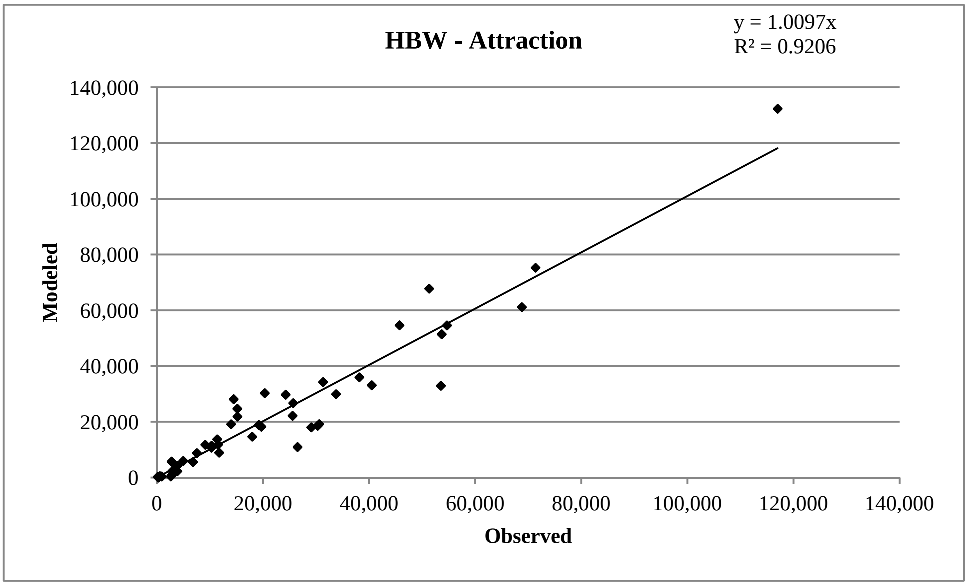
Table 5.4 Results of the regression of Attraction model for HBW

Regression statistics	
R multiple	0.97805361
R-square	0.95658887
R-adjusted squares	0.93438864
Standard error	6844,64857
Observations	49

	Coefficients	*Standard err*	*Stat t*	*value-P*
Intersection	0	#N/D	#N/D	#N/D
Employment	0.22326561	0.007333054	30,44647046	1.3714E-32
Dummy 1	38578,3135	6928,799011	5.567821119	1.2061E-06

Source: JICA Study Team

Figure 5.8 shows the correlation between the estimation in the Person Trip Survey and the modeled data where R^2 is as high as 0.92.



Source: JICA Study Team

Figure 5.8 Predictability of Attraction Model for HBW

(4) Production Model for HBS

For this group of trips the model is given by the following equation:

$$PHBS_i = 0.08424584 * Pop_i$$

Where,

$PHBS_i$ = Production of HBS in district i

Pop_i= Population in district i

Table 5.5 shows the main results of the regression where R^2=0.96 indicates that the population explains 96% of the trip production for this group. The Student T and P values are also compatibles with the results.

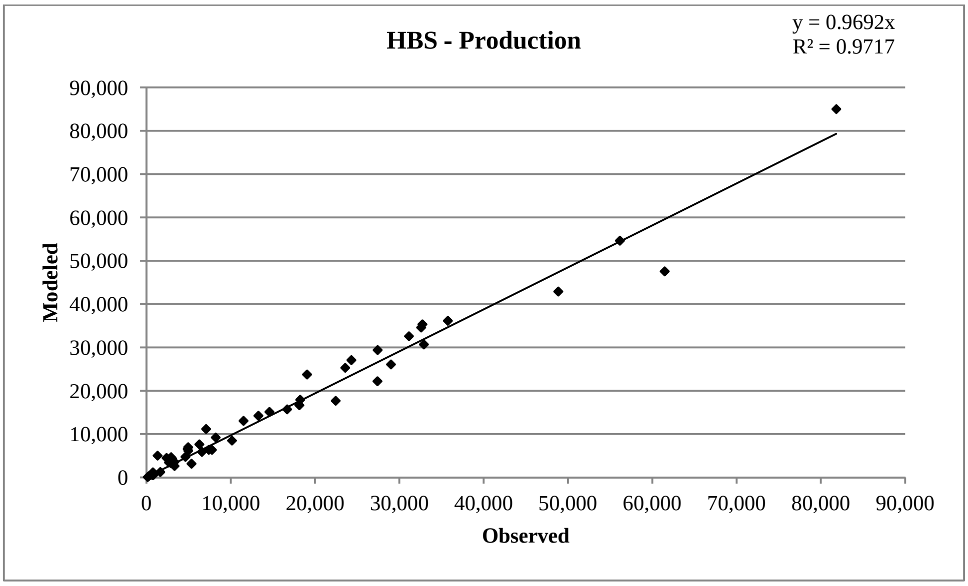
Table 5.5 Results of the Regression of Production Model for HBS

Regression statistics	
R multiple	0.99247713
R-square	0.98501085
R-adjusted squares	0.96417751
Standard error	2950,97349
Observations	49

	Coefficients	*Standard err*	*Stat t*	*value-P*
Intersection	0	#N/D	#N/D	#N/D
Population	0.08424584	0.001500016	56,16329302	1.9092E-45

Source: JICA Study Team

Figure 5.9 shows the correlation between the estimation in the Person Trip Survey and the modeled data where R^2 is as high as 0.97.



Source: JICA Study Team

Figure 5.9 Predictability of Production Model for HBS

(5) Attraction Model for HBS

For this group of trips the model is given by the following equation:

$$AHBS_i = 0.331974 * Sp_i + 25{,}485.55 * Dummy2$$

Where,

$AHBS_i$ = Production of HBS in district i

Sp_i= Student in school place in district i

Dummy2 = variable defined for district 23 (Los Olivos) with very particular behavior in terms of trip attraction

Table 5.6 shows the main results of the regression where R^2=0.94 indicates that the school registers and dummy2 explain 94% of the trip attraction for this group. The Student T and P values are also compatibles with the results.

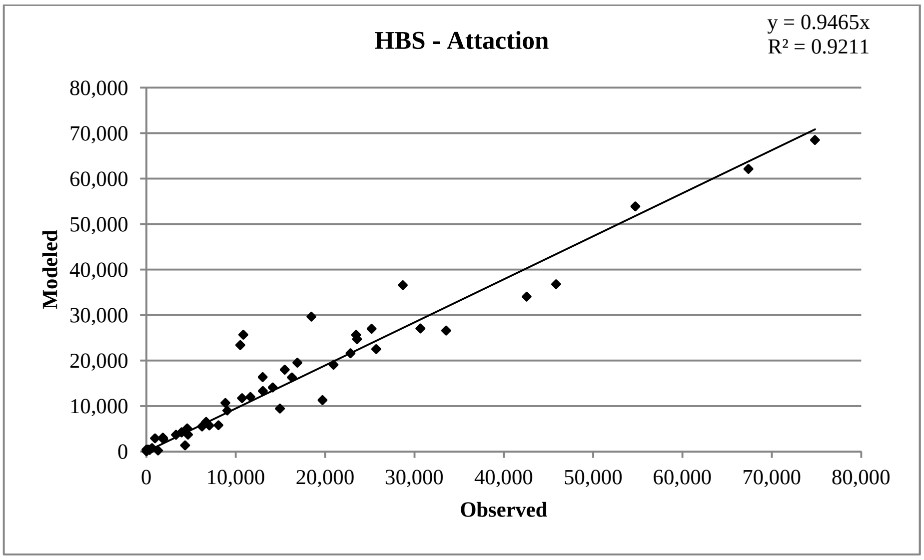
Table 5.6 Results of the Regression of Attraction model for HBS

Regression statistics	
R multiple	0.98033889
R-square	0.96106435
R-adjusted squares	0.93895933
Standard error	4687,99156
Observations	49

	Coefficients	*Standard err*	*Stat t*	*value-P*
Intersection	0	#N/D	#N/D	#N/D
Matr2012	0.33197397	0.010374911	31,9977656	1.4741E-33
Dummy 2	25485,5523	4776,213486	5,335932403	2,679E-06

Source: JICA Study Team

Figure 5.10 shows the correlation between the estimation in the Person Trip Survey and the modeled where R^2 is as high as 0.92.



Source: JICA Study Team

Figure 5.10 Predictability of Attraction Model for HBS

(6) Production Model for OP

For this group of trips the model is given by the following equation:

$$POP_i = 0.05034698 * Pop_i$$

Where,

POP_i = Production of OP in district i

Pop_i= Population in district i

Table 5.7 shows the main results of the regression where R^2=0.96 indicates that the population explains 96% of the trip production for this group. The Student T and P values are also compatibles with the results.

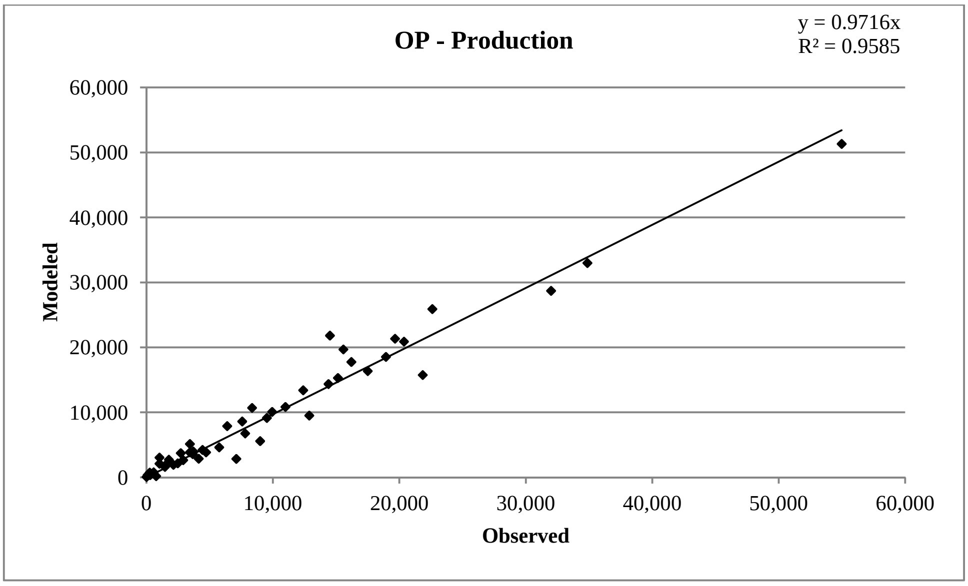
Table 5.7 Results of the Regression of Production Model for OP

Regression statistics	
R multiple	0.98897264
R-square	0.97806689
R-adjusted squares	0.95723356
Standard error	2140,8587
Observations	49

	Coefficients	*Standard err*	*Stat t*	*value-P*
Intersection	0	#N/D	#N/D	#N/D
Population	0,05034698	0,001088225	46,2652386	1,7786E-41

Source: JICA Study Team

Figure 5.11 shows the correlation between the estimate in the Person Trip Survey and the modeled data where R^2 is as high as 0.96.



Source: JICA Study Team

Figure 5.11 Predictability of Production Model for OP

(7) Attraction Model for OP

For this group of trips the model is given by the following equation:

$$AOP_i = 0.2554245 * Pop_i + 0.052002 * Emp_i$$

Where,

AOP_i = Attraction of OP in district i

Pop_i= Population in district i

Emp_i = Employment in district i

The table gives the main results of the regression where the R^2=0.95 indicates that the population and employment explain 95% of the trip attraction for this group. The Student T and P values are also compatibles with the results.

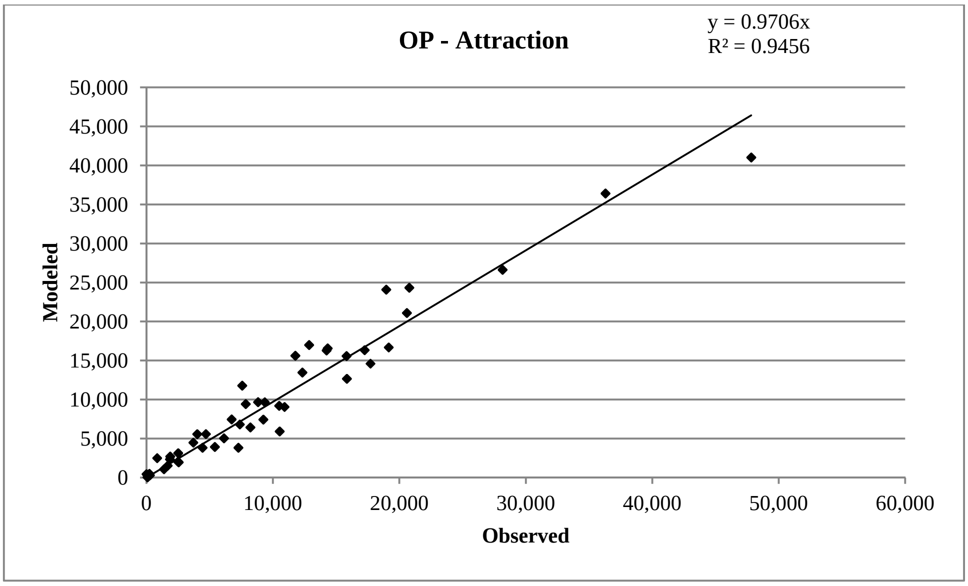
Table 5.8 Results of the Regression of Attraction Model for OP

Regression statistics	
R multiple	0.98686786
R-square	0.97390818
R-adjusted squares	0.95207644
Standard error	2241,74036
Observations	49

	Coefficients	*Standard err*	*Stat t*	*value-P*
Intersection	0	#N/D	#N/D	#N/D
Pop2012	0.02554245	0.00183989	13,8826334	3.0183E-18
Empl2012	0.05200159	0.00383078	13,5746795	7.0484E-18

Source: JICA Study Team

Figure 5.12 shows the correlation between the estimate in the Person Trip Survey and the modeled data where R^2 is as high as 0.95.



Source: JICA Study Team

Figure 5.12 Predictability of Attraction Model for OP

5.5.2 Trip Distribution Model

(1) Model Structure

The trip distribution model estimates the number of trips for every pair of origin and destination.

The models utilize the estimation of trip production and attraction by zone and some structure about the demand distribution.

The basic idea of the procedures incorporated in these models is that the demand produced in each zone is distributed between attractor zones. This step is associated to the choice of the destiny that is in function of the potential attractiveness of the zones.

A type of gravity model is used for the trip distribution model. The trip demand between zones is estimated from trip generation volume at origin, trip attraction volume at destination, and impedance between origin and destination. The composition of the impedance function in terms of time equivalence was represented by the variables below extracted from the network model.

- Public Mode:
  - ✓ In vehicle time in minutes between origin i and destination j;
  - ✓ Walking access time in minutes between origin i and destination j;
  - ✓ Total waiting time in minutes between origin i and destination j
  - ✓ Total fare paid in the trip (transformed in minutes equivalent) between origin i and destination j;

  The impedance in minutes for the public mode (Tt) is defined as:

$$Tt_{ij} = Ttv_{ij} + 2*Ttp_{ij} + 2*Ttw_{ij} + F_{ij} * 60 / VOTt$$

  Where:

  Tt_{ij} = impedance of public mode in minutes between origin i and destination j
  Ttv_{ij} = in-vehicle time in minutes between origin i and destination j
  Ttp_{ij} = walking access time in minutes between origin i and destination j
  Ttw_{ij} = waiting time in minutes between origin i and destination j
  F_{ij} = fare in Soles between origin i and destination j
  $VOTt$ = value of time for the public transport user in Soles/hour. The estimated VOT calculated from the Person Trip survey is 4.18 Soles/hour

- Private mode:
  - ✓ Total in-vehicle time in minutes between origin i and destination j
  - ✓ Operation cost (Soles/km) transformed in minutes between origin i and destination j;
  - ✓ Parking cost (Average value in Soles in destination zone) transformed in minutes in destination j.

  The impedance in minutes for de private mode (*Tp*) is defined as:

$$Tp_{ij} = 1{,}3 * Tpv_{ij} + \frac{d_{ij} * Cop * 60}{VOT_p} + \frac{Cpk_j * 60}{VOT_p} \quad (2.2)$$

  Where:
  Tp_{ij} = impedance of private mode in minutes between origin i and destination j
  Tpv_{ij} = in-vehicle time in minutes between origin i and destination j
  d_{ij} = distance in km between origin i and destination j

Cop = operational cost in Soles/km adopted as 1 Sole/km

Cpk_j = average parking cost in destination j

VOT_i = value of time for private mode users; the VOT of private users was estimated in 5.70 Soles/hour according to Person Trip survey.

The constant value of 1,3 was applied to the in-vehicle time in order to consider the time to access and egress by walking that is not accounted in the network model.

The trip distribution model is applied before the modal split model. Therefore, it is necessary to define a composition of public and private impedances. In this study, the average cost between these modes shown below was adjusted:

$$Tm_{ij}=(Tt_{ij} + Tp_{ij})/2$$

The method utilized for the trip distribution model was based on an estimation of the **gamma regression function** defined according to the equation:

$$f(v_{ij}) = \exp(k + k^m + a_i + b_j + c * Tm_{ij} + d * \ln(Tm_{ij}))$$

Where:

$f(v_{ij})$ = distribution function between i and j

Tm_{ij} = average impedance between i and j calculated as the average between public and private mode.

k = intercept

k^m = coefficient of the group to be calibrated (HBW, HBS, and OP)

a_i = coefficient of the origin zone i

b_j = coefficient of the destination zone j

c, d = coefficients to be calibrated

The coefficients are estimated by the maximum likelihood method.

The statistic software "R" was used to calculate the parameters. Table 5.9 shows the structure of input variables for the software. The trip data of the morning peak period by traffic zone was used.

Table 5.9 Input Data Structure for Software R

ORIGIN	DESTINATION	GROUP	TRIP	Tm_{ij}	$Ln(Tm_{ij})$
O-101	D-111	HBW	99	75.81	4.33
O-101	D-112	HBW	91	58.53	4.07
O-101	D-115	HBW	441	28.40	3.35
O-101	D-116	OP	120	37.32	3.62
O-101	D-117	HBS	119	40.55	3.70
O-101	D-118	HBW	91	39.93	3.69
O-101	D-122	HBS	219	85.40	4.45
O-101	D-501	OP	99	52.02	3.95
O-101	D-606	OP	121	152.88	5.03
O-101	D-1301	HBW	109	75.47	4.32
O-101	D-1302	HBS	109	79.35	4.37
O-101	D-1302	HBW	109	79.35	4.37
O-101	D-1711	HBS	148	67.17	4.21
O-101	D-2809	HBW	99	80.28	4.39
O-101	D-3106	HBW	99	91.24	4.51

Source: JICA Study Team

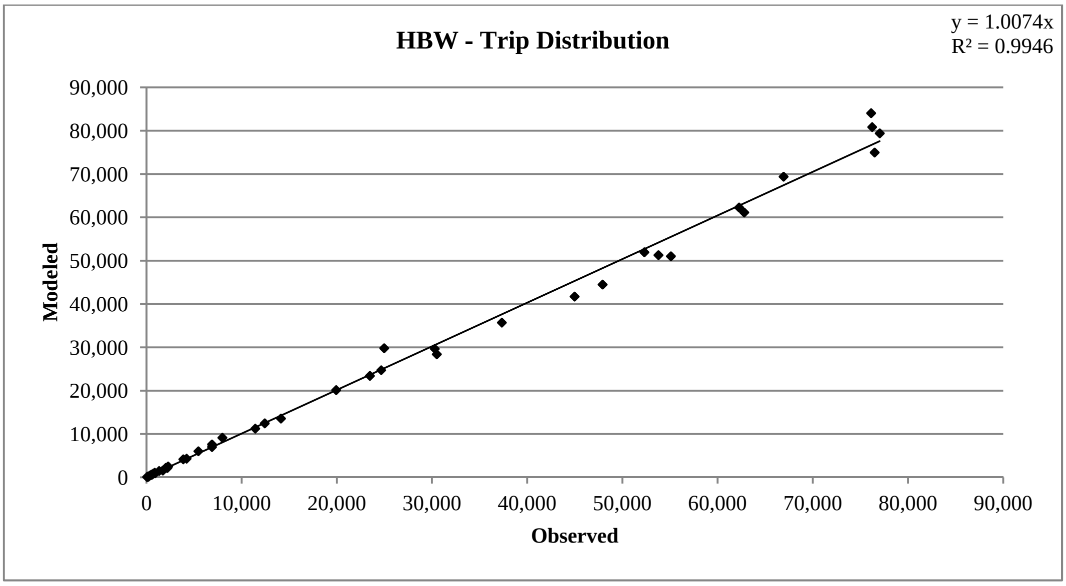
There are 841 parameters estimated by the process: 415 for origin zone a_i, 421 for destination zone b_j and parameters for k, k^m, c and d. For the origin-destination pairs with no trip, the coefficients of zero were adopted.

(2) Initial Validation of Distribution Model

1) HBW

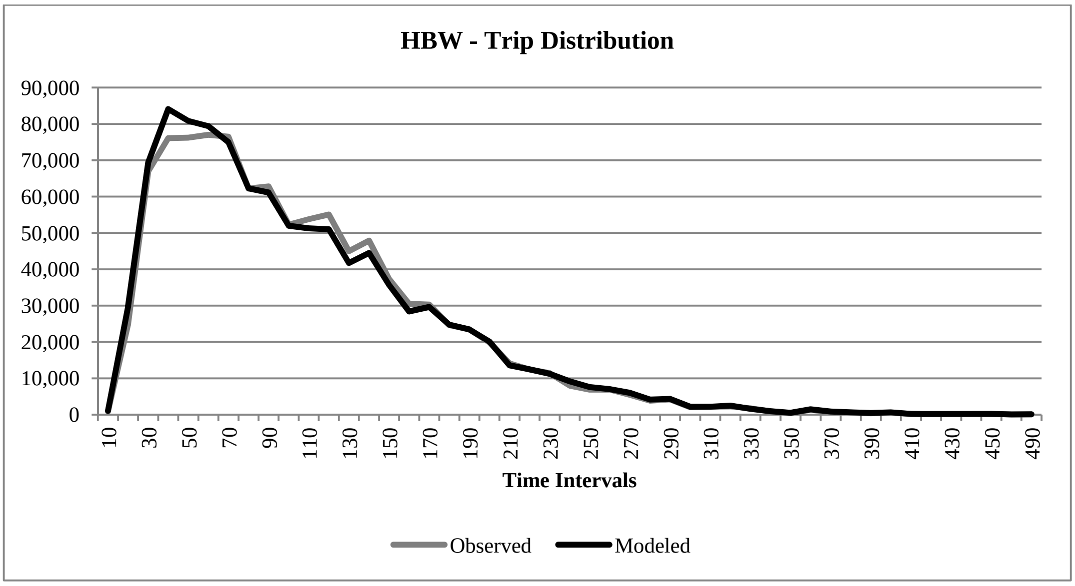
Figure 5.13 shows the comparison of the number of trips between the Person Trip Survey and the model, indicating a good result with R^2 of 0.99.

Figure 5.14 shows the comparison of number of trips by travel time, showing that the model gives a slight overestimation for short trips.



Source: JICA Study Team

Figure 5.13 Predictability of OD Traffic by Trips Distribution Model for HBW



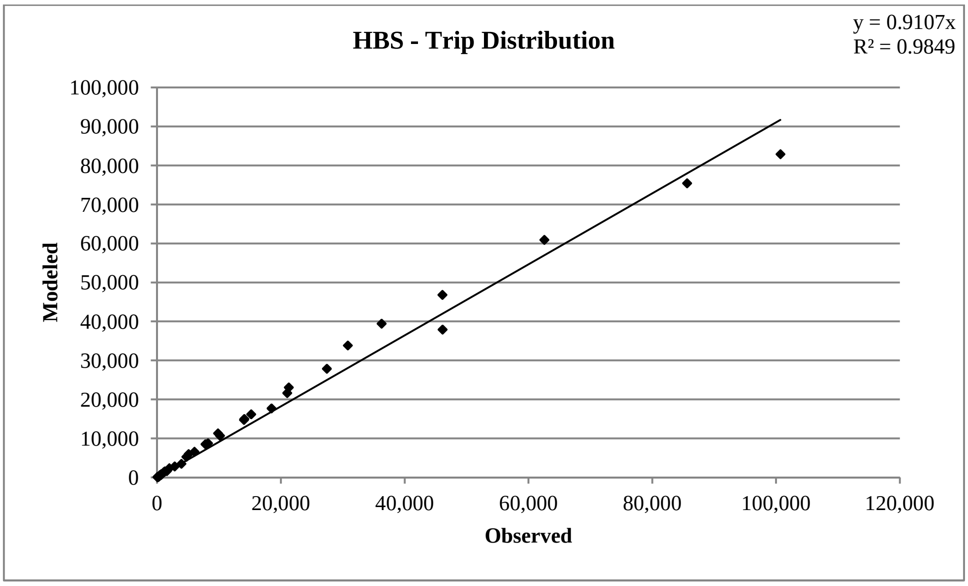
Source: JICA Study Team

Figure 5.14 Predictability of Travel Time Distribution by Trip Distribution Model for HBW

2) HBS

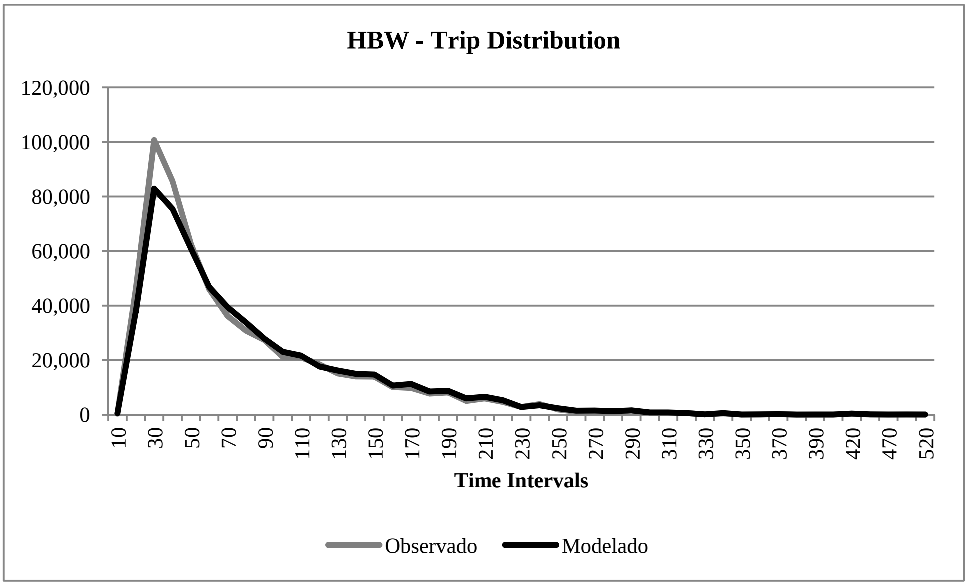
Figure 5.15 shows the comparison of the number of trips between the Person Trip Survey and the model, indicating a good result with R^2 of 0.99.

Figure 5.16 shows the comparison of number of trips by travel time, showing that the model gives a slight overestimation for short trips.



Source: JICA Study Team

Figure 5.15 Predictability of OD Traffic by Trips Distribution Model for HBS



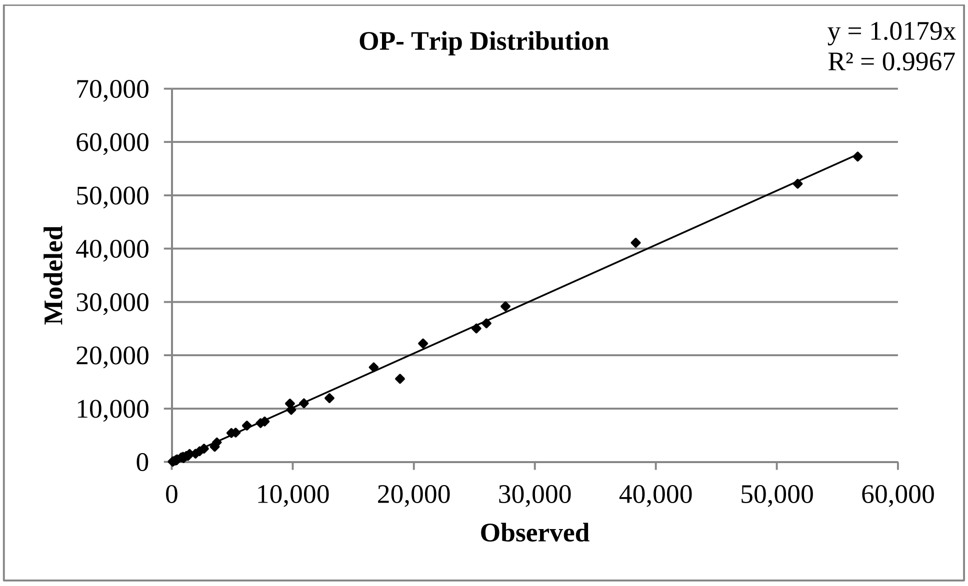
Source: JICA Study Team

Figure 5.16 Predictability of Travel Time Distribution by Trip Distribution Model for HBS

3) OP

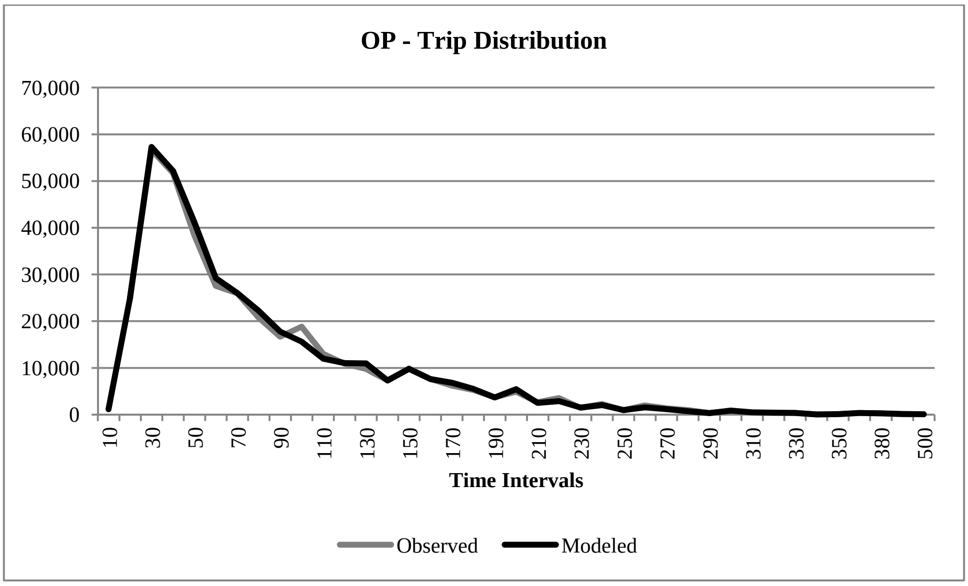
Figure 5.17 shows the comparison of the number of trips between the Person Trip Survey and the model, indicating a good result with R^2 of 0.99.

Figure 5.18 shows the comparison of number of trips by travel time, showing a good predictability.



Source: JICA Study Team

Figure 5.17 Predictability of OD Traffic by Trips Distribution Model for OP



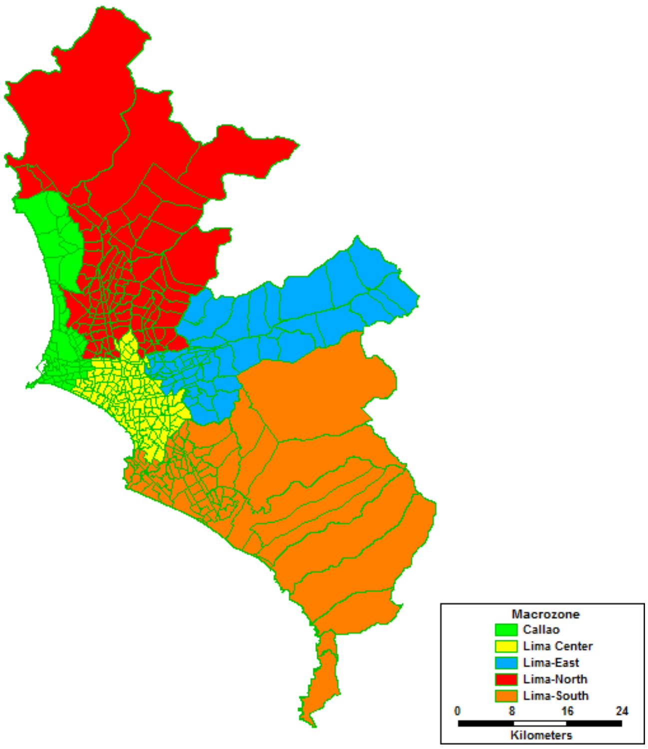
Source: JICA Study Team

Figure 5.18 Predictability of Travel Time Distribution by Trip Distribution Model for OP

(3) Final Validation of the Distribution Model

The final validation of the trip distribution model was done so that the trip production and attraction calculated by the trip distribution model meet those estimated by the trip generation model. For the origin-destination pairs with no trips in the Person Trip survey, a small number (0.0001) was given as a seed for the adjustment.

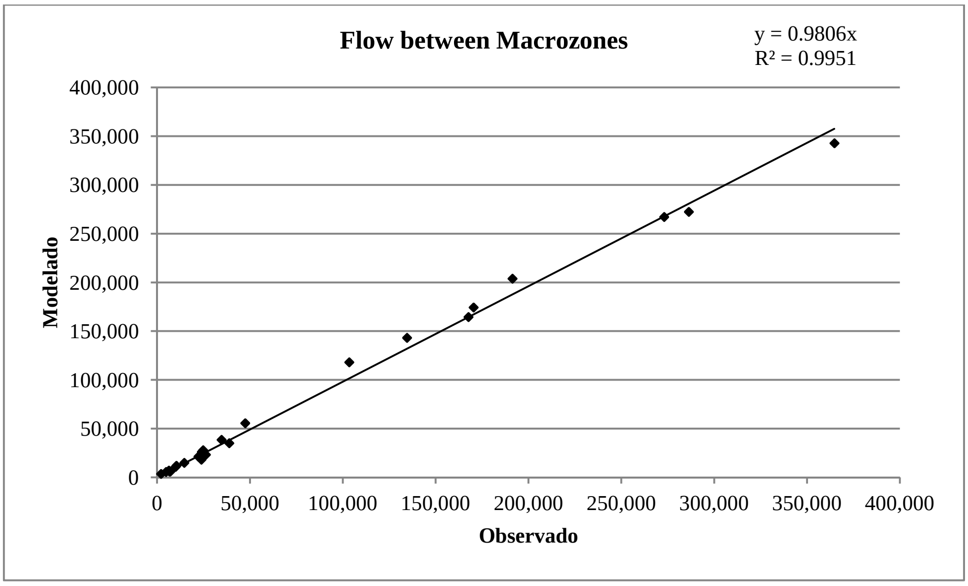
To ensure the statistical reliability of the Person Trip Survey, the number of trips by traffic zone was aggregated into five "macro zones", namely, Lima Center, Lima North, Lima South, Lima East and Callao as shown in Figure 5.19.



Source: JICA Study Team

Figure 5.19 Macrozones defined in the Study Area

Figure 5.20 shows the comparison of the number of trips between the Person Trip Survey and the model, indicating a good correlation with R^2=0.99.



Source: JICA Study Team

Figure 5.20 Correlation between observed and modeled data distributed by macrozones

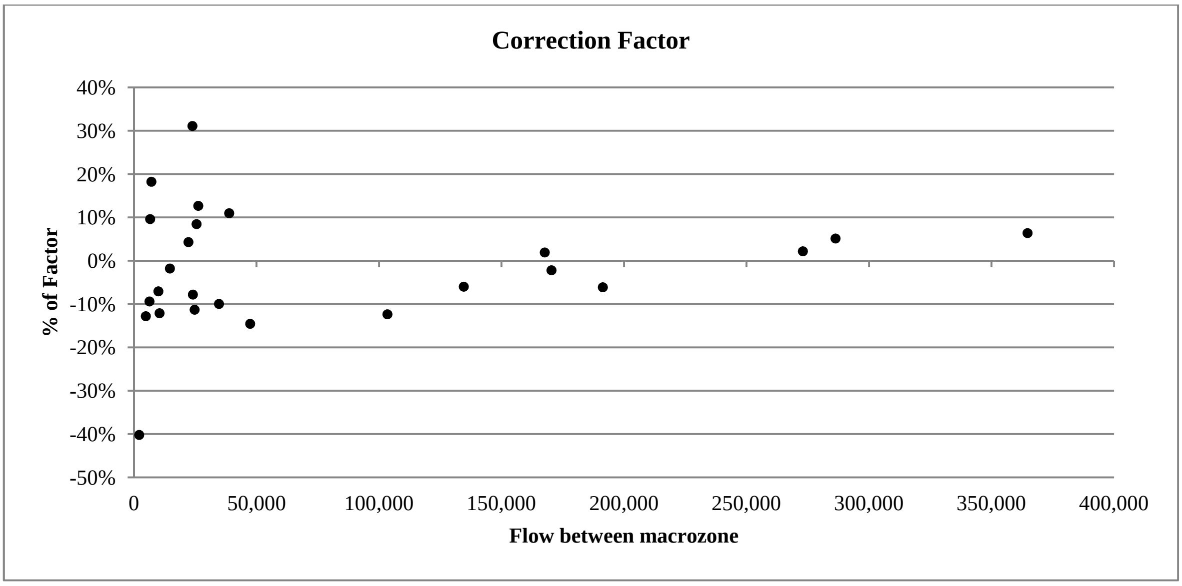
Table 5.10 shows correction factors to be applied to the number of trips for the macro zone of Lima Center, as an example. The figures show that correction factors are small except for the flow from Callao, which is small compared to trips of other pairs.

Table 5.10 Example of Correction Factors for Macrozones Flows

Origin	Destination	Observed	Modeled	Factor
Callao	Lima-Center	47,386	55.460	15%
Lima Center	Lima-Center	364,703	342.810	6%
Lima-East	Lima-Center	170,381	174.222	2%
Lima-North	Lima-Center	167,627	164.491	2%
Lima-South	Lima-Center	134,574	143.139	6%

Source: JICA Study Team

Figure 5.21 shows correction factors plotted by the number of trips. The correction factors of large traffic volumes are relatively small.



Source: JICA Study Team

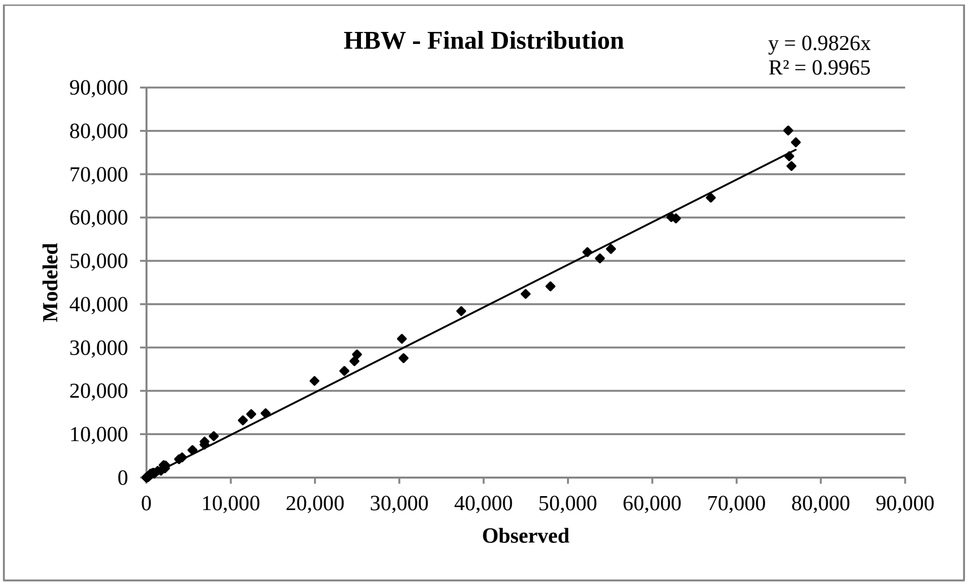
Figure 5.21 Dot Plot of Correction Factors by Trip Volume

The next items show the final results of the trip distribution model by trip group after applying the correction factors.

1) HBW

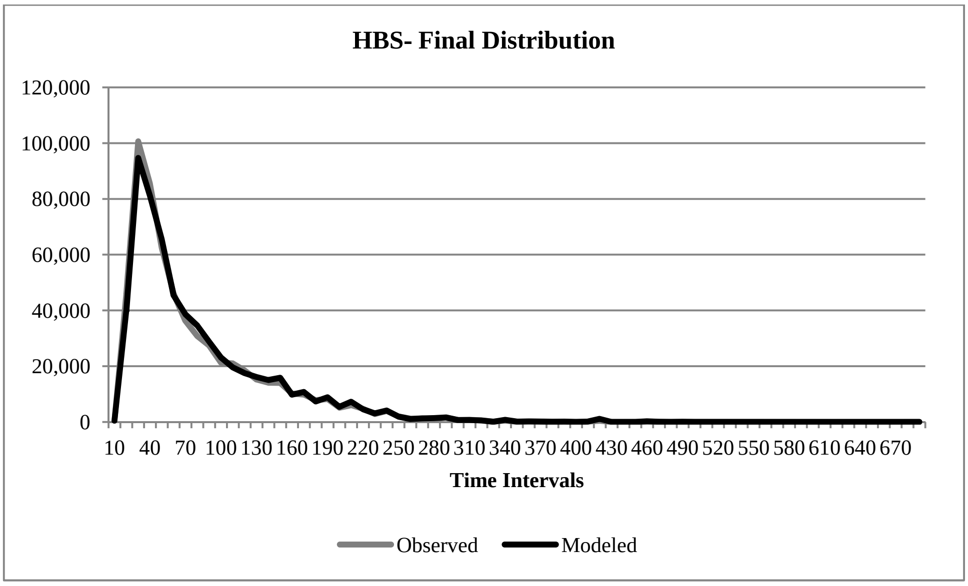
Figure 5.22 shows the comparison of the number of trips between the Person Trip Survey and the model, indicating a good result with R^2 of 0.99.

Figure 5.23 shows the comparison of number of trips by travel time, showing a good predictability.



Source: JICA Study Team

Figure 5.22 Predictability of OD Traffic by Final Adjustment for HBW



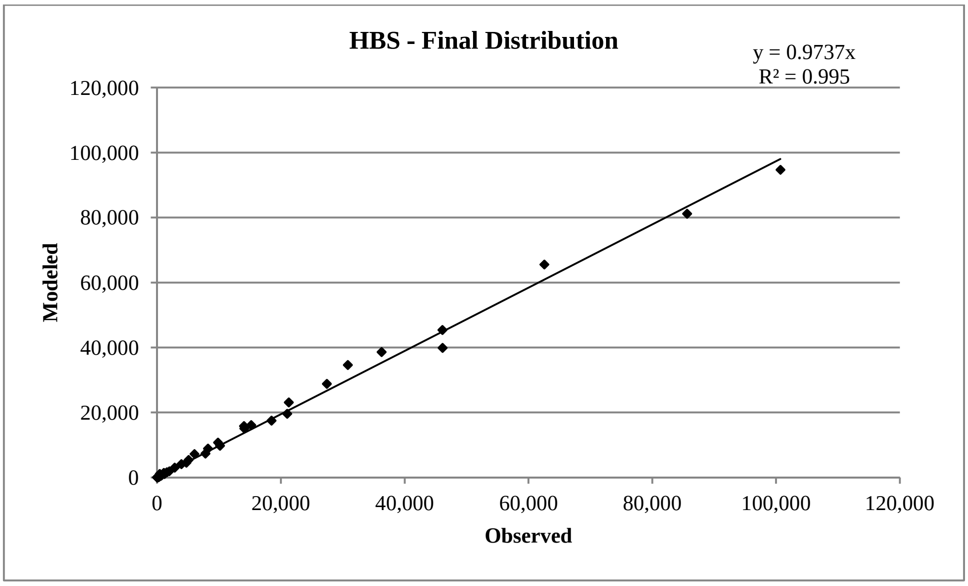
Source: JICA Study Team

Figure 5.23 Predictability of Travel Time Distribution by Final Adjustment for HBW

2) HBS

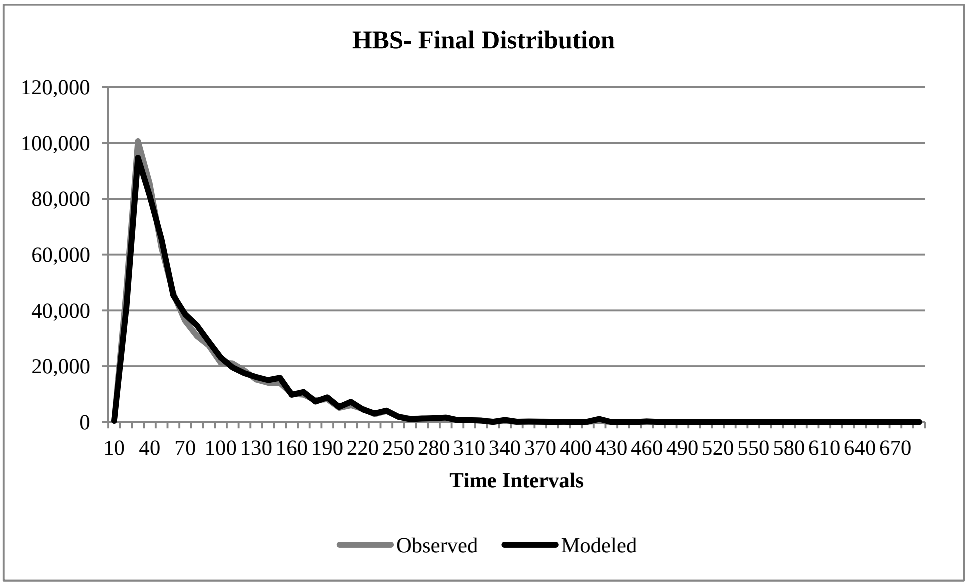
Figure 5.24 shows the comparison of the number of trips between the Person Trip Survey and the model, indicating a good result with R^2 of 0.99.

Figure 5.25 shows the comparison of number of trips by travel time, showing a good predictability.



Source: JICA Study Team

Figure 5.24 Predictability of OD Trips by Final Adjustment for HBS



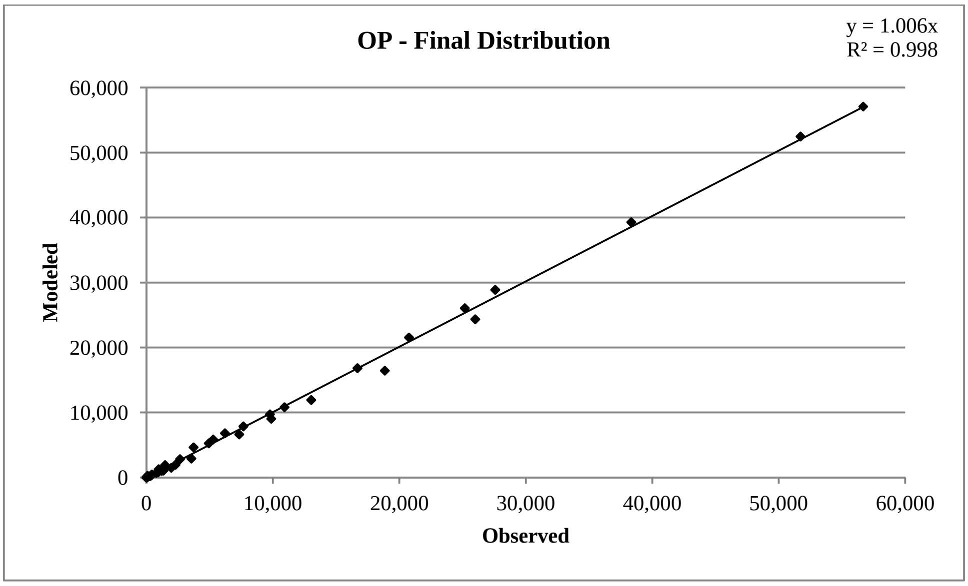
Source: JICA Study Team

Figure 5.25 Predictability of Travel Time Distribution by Final Adjustment for HBS

3) OP

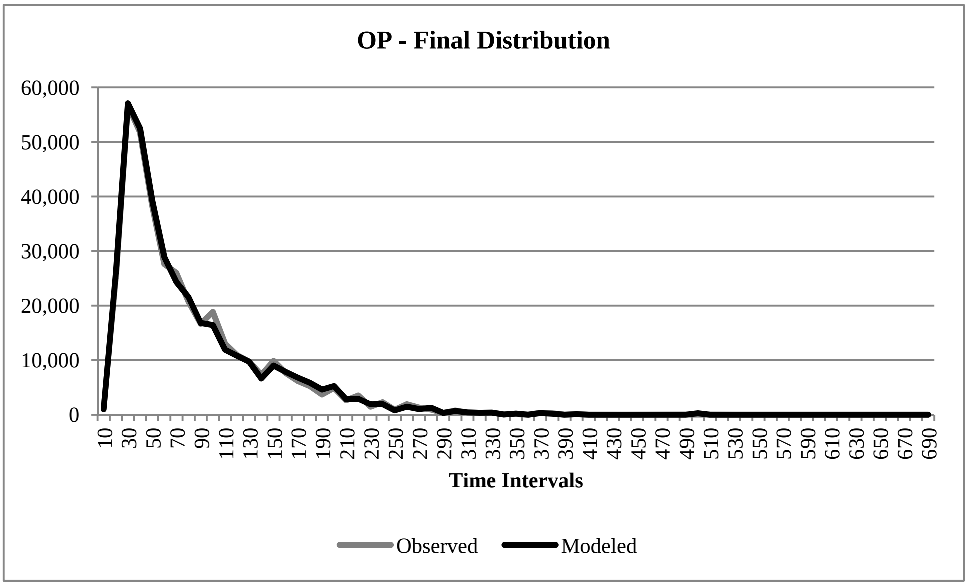
Figure 5.26 shows the comparison of the number of trips between the Person Trip Survey and the model, indicating a good result with R^2 of 0.99.

Figure 5.27 shows the comparison of number of trips by travel time, showing a good predictability.



Source: JICA Study Team

Figure 5.26 Predictability of OD Trips by Final Adjustment for OP



Source: JICA Study Team

Figure 5.27 Predictability of Travel Time Distribution by Final Adjustment for OP

5.5.3 Modal Split Model

(1) Model Structure

For the modal split model, a binary logit model was utilized. This model is represented by the following formula:

$$Pt_{ij} = \frac{e^{Ut_{ij}}}{1 + e^{Ut_{ij}}}$$

$$Pp_{ij} = 1 - Pt_{ij}$$

Where:

Pt_{ij} = Probability of public mode from zone i to j;

Ut_{ij} = Composite utility of public mode from zone i to j;

Pi_{ij} = Probability of private mode from zone i to j.

Utility, generally used in economics, represents preferences of goods or services. The popular formula of utility is:

$$U = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + ... + \alpha_n x_n$$

Where:

$x_1, x_2 ... x_n$ = variables corresponding to service attributes of all modes;

$\alpha_0, \alpha_1, \alpha_2 ... \alpha_n$ = coefficients obtained from calibration.

The transport user considers a set of variables or attributes as listed below.

(i) Variables associated to time

- Total time of trip;
- Walking time;
- Waiting time

(ii) Variables associated to cost

- Fare;
- Fuel;
- Toll;
- Parking;

(iii) Variables associated to comfort

- Walking distance;
- Number of transfer;

Besides these attributes, other variables can influence the modal split such as the average income and the motorization rate of the zone.

In this sense, the composition of the utility function for the modal split model was defined as the following formula:

$$Ut_{ij} = \alpha_0 + \alpha_1 Ttv_{ij} + \alpha_2 Ttw_{ij} + \alpha_3 .Transf_{ij} . + \alpha_4 Ttp_{ij} + \alpha_5 F_{ij} + \alpha_7 Cp_{ij} + \alpha_6 Tpv_{ij} + \alpha_8 d_{ij} + \alpha_9 Mot_i$$

Where:

Ut_{ij} = Composite utility for public mode
Ttv_{ij} = In- vehicle time between origin i and destination j;
Ttwij = Waiting time in minutes
$Transf_{ij}$ = Number of transfers
Ttp_{ij} = Walking access time in minutes from i to j;
F_{ij} = Cost of the trip represented by the total fare paid for the trip from i to j
Cp_{ij} = Cost of the trip by private mode given by the operational cost (Soles/km), and parking cost according to:

$$Cp_{ij} = (d_{ij} * Cop + Cpk_j) / x$$

Where:
Cp_{ij} = cost of private mode from i to j
d_{ij} = distance in km from i to j
Cop = operational cost Soles/km adopted as …..
Cpk_j = parking cost in zone j
x = the average occupancy rate in cars (adopted as 1.39 person/car).

Tpv_{ij} = total trip time for the private mode from i to j;
d_{ij} = distance in km from I to j;
Mot_i = number of cars by 1000 inhabitants of zone i
$\alpha_{1, \ldots\ldots,} \alpha_9$ = coefficients to be calibrate.

The software Minitab was used to calibrate the modal split model. The input file has the following elements by trip group:

Table 5.11 Input data structure for software Minitab

OD pair	Group	Public Trips	Private Trips	Total	Ttv_{ij}	*Ttwij*	$Transf_{ij}$	Ttp_{ij}	F_{ij}	Cp_{ij}	Tpv_{ij}	d_{ij}	Mot_i
101-111	HBW	99	0	99	36.68	3,76	0	8	1.5	4.48	16.67	5.73	76.89
101-112	HBW	91	0	91	15.06	0,68	0	8	1.5	4.12	15.58	5.22	76.89
101-113	HBW	209	0	209	10.65	0,99	0	8	1.5	3.00	13.40	3.67	76.89
101-115	HBW	310	131	441	2.59	0,61	0	8	1.5	1.42	9.29	1.92	76.89
101-118	HBW	91	0	91	5.89	0,68	0	8	1.5	2.58	11.26	3.09	76.89
101-1301	HBW	219	0	219	29.6	2,6	0	8	1.5	5.02	17.29	6.48	76.89
101-1302	HBW	109	0	109	28.99	2,6	0	8	1.5	5.53	17.99	7.19	76.89
101-2505	HBW	134	0	134	37.73	3,3	1	8	3	14.92	25.30	20.69	76.89

Source: JICA Study Team

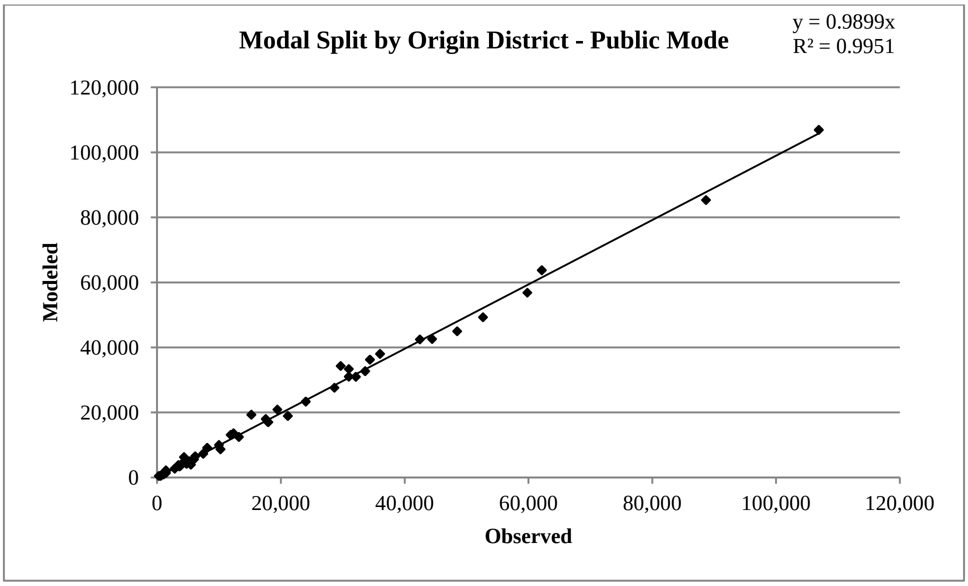
(2) HBW

The parameters of the utility function for the HBW group were estimated as shown in Table 5.12. Figure 5.28 and Figure 5.29 show the correlation between the calculated numbers of trips by the model and the estimated numbers in the Person Trip Survey for public mode and private mode, respectively.

Table 5.12 Coefficients in Modal Split for HBW

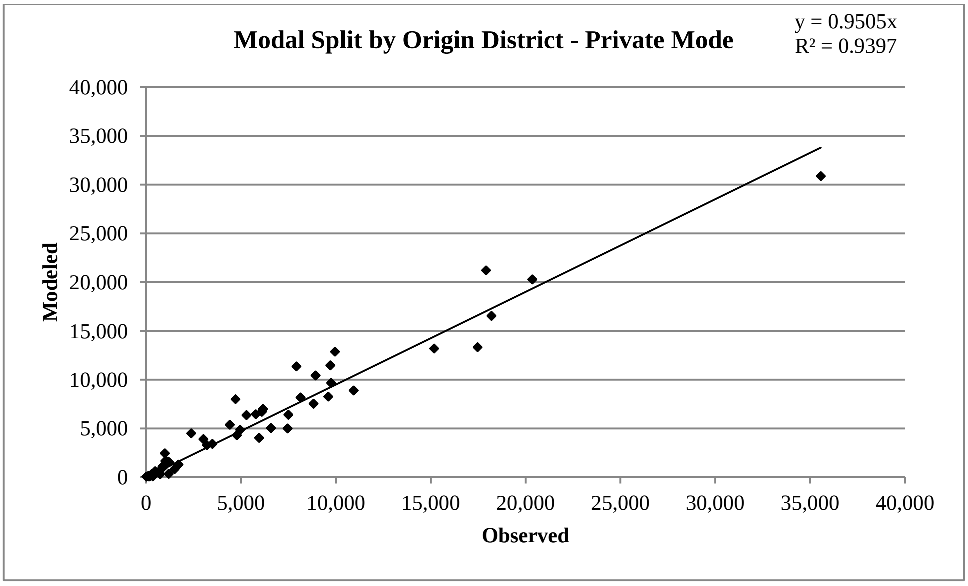
Predictor	Coefficient	P	t
Constant	1.13076	0.0049	230.79
Ttv_{ij}	-0.00284	0.000165	-17.24
$Transf_{ij}$	-0.13356	0.006107	-21.87
Cp_{ij}	0.901801	0.016345	5517
Tpv_{ij}	-0.55564	0.011762	-47.24
Mot_i	-0.00809	2.43E-05	-332.89

Source: JICA Study Team



Source: JICA Study Team

Figure 5.28 Predictability of Public Mode Trips by Modal Split Model for HBW



Source: JICA Study Team

Figure 5.29 Predictability of Private Mode Trips by Modal Split Model for HBW

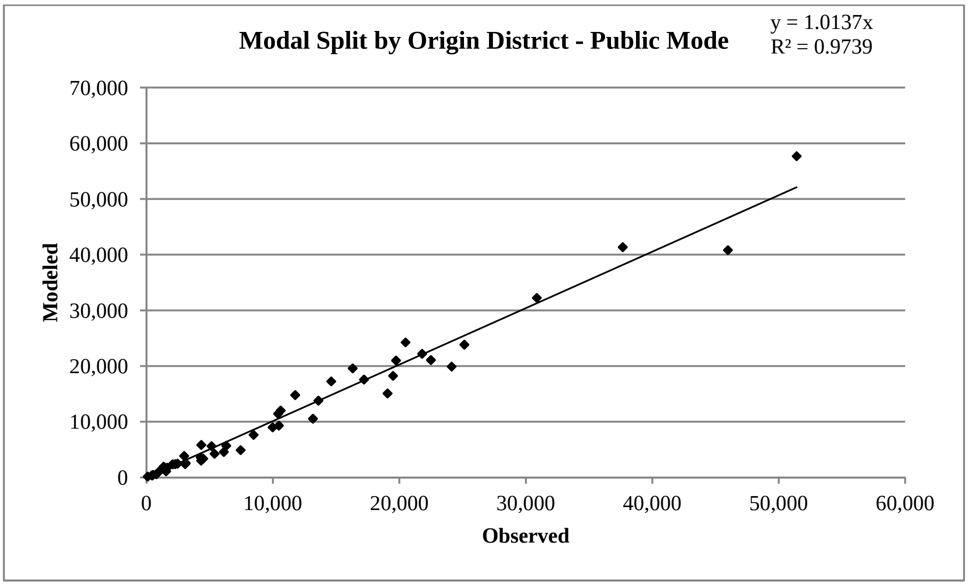
(3) HBS

The parameters of the utility function for the HBS group were estimated as shown in Table 5.13. Figure 5.30 and Figure 5.31 show the correlation between the calculated numbers of trips by the model and the estimated numbers in the Person Trip Survey for public mode and private mode, respectively.

Table 5.13 Coefficients in Modal Split for HBS

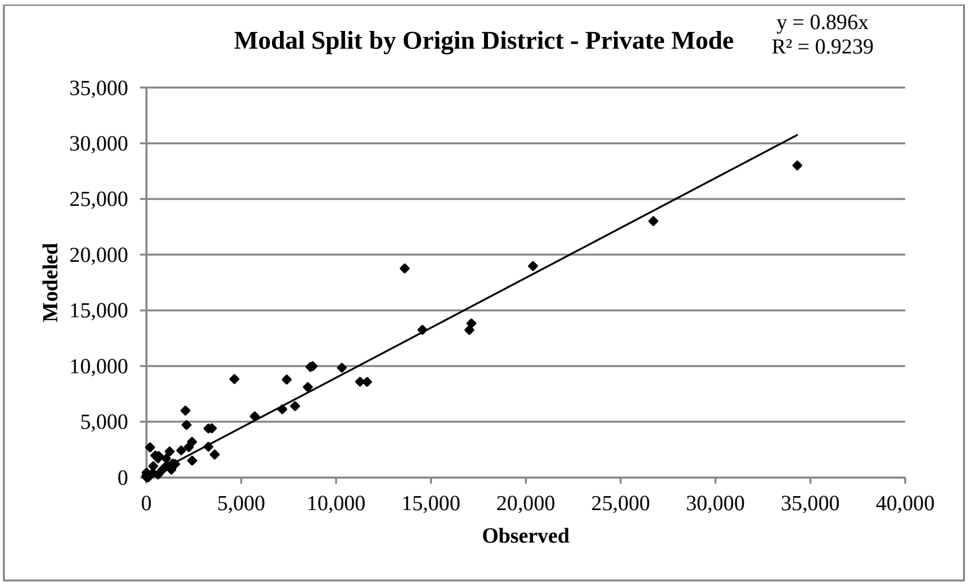
Predictor	Coefficient	P	T
Constant	-0.54289	0.005035	-107,83
$Transf_{ij}$	-0.52699	0.009796	-53.8
Cp_{ij}	0.067066	0.002342	28.64
Tpv_{ij}	0.105382	0.000856	123,06
Mot_i	-0.002	3.18E-05	-62.88

Source: JICA Study Team



Source: JICA Study Team

Figure 5.30 Predictability of Public Mode Trips by Modal Split Model for HBS



Source: JICA Study Team

Figure 5.31 Predictability of Private Mode Trips by Modal Split Model for HBS

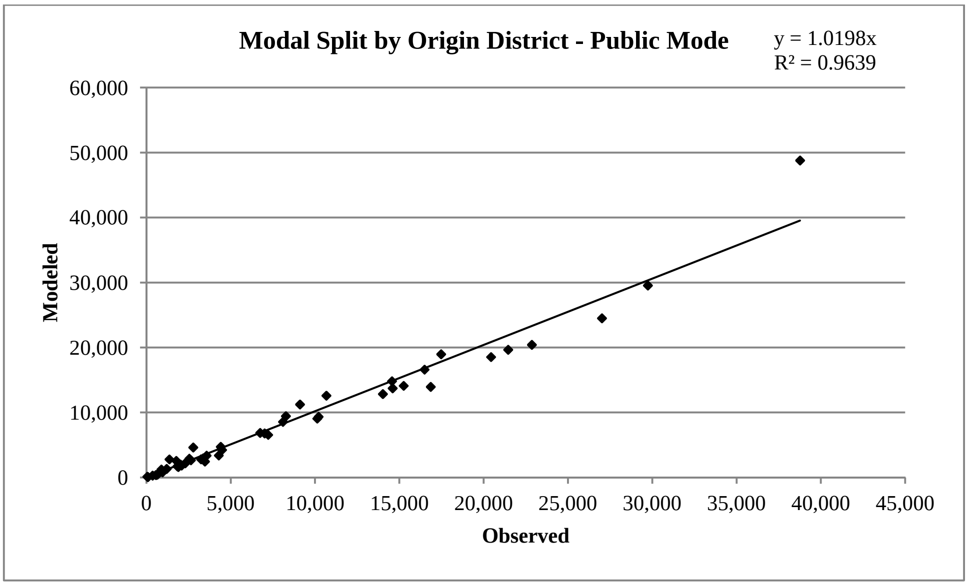
(4) OP

The parameters of the utility function for the HBS group were estimated as shown in Table 5.14. Figure 5.32 and Figure 5.33 show the correlation between the calculated numbers of trips by the model and the estimated numbers in the Person Trip Survey for public mode and private mode, respectively.

Table 5.14 Coefficients in Modal Split for OP

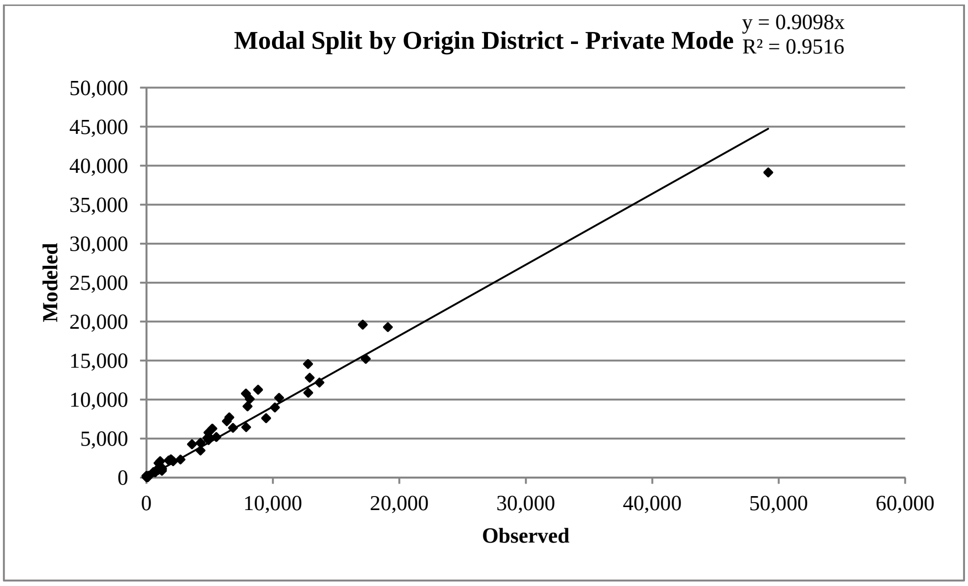
Predictor	Coefficient	P	t
Constant	-0.47848	0.005496	-87.07
Cp_{ij}	0.094299	0.020227	4.66
Tpv_{ij}	0.092662	0.000792	117.04
d_{ij}	-0.09333	0.014338	-6.51
Mot_i	-0.00473	2.97E-05	-159.11

Source: JICA Study Team



Source: JICA Study Team

Figure 5.32 Predictability of Public Mode Trips by Modal Split Model for OP



Source: JICA Study Team

Figure 5.33 Predictability of Private Mode Trips by Modal Split Model for OP

5.5.4 Traffic Assignment Model

(1) Model Structure

The private and public OD matrices are produced through the developed models mentioned above, namely, the trip generation mode, trip distribution mode, and modal split model.

The OD matrices are assigned to the traffic and transit network that are described in 5.3.

The assignment is done under the following two concepts:

- User Equilibrium Method;

- Delay Function;

1) User Equilibrium Method

In this method, it is assumed that the traffic situation where no user can reduce the generalized cost will actualize. The algorithm considers that each user tries to minimize the generalized cost by changing the path.

2) Delay Function

The equilibrium assignment is based on a volume delay function. This function is a mathematical relation between the travel time and the traffic flow on a link.

The function utilized is the generalized cost delay function based on the BPR function (Bureau of Public Roads), which is popular function in many transport studies.

The BPR function is as follows:

$$T_i = t_{0i} * (1+\alpha*(x_i/C_i))^{\beta}$$

Where:
T_i – trip time in link i
t_{0i} – free flow time in link i
x_i – load in link i
C_i – capacity in link i
α – constant
β –constant

The function of the generalized cost is:

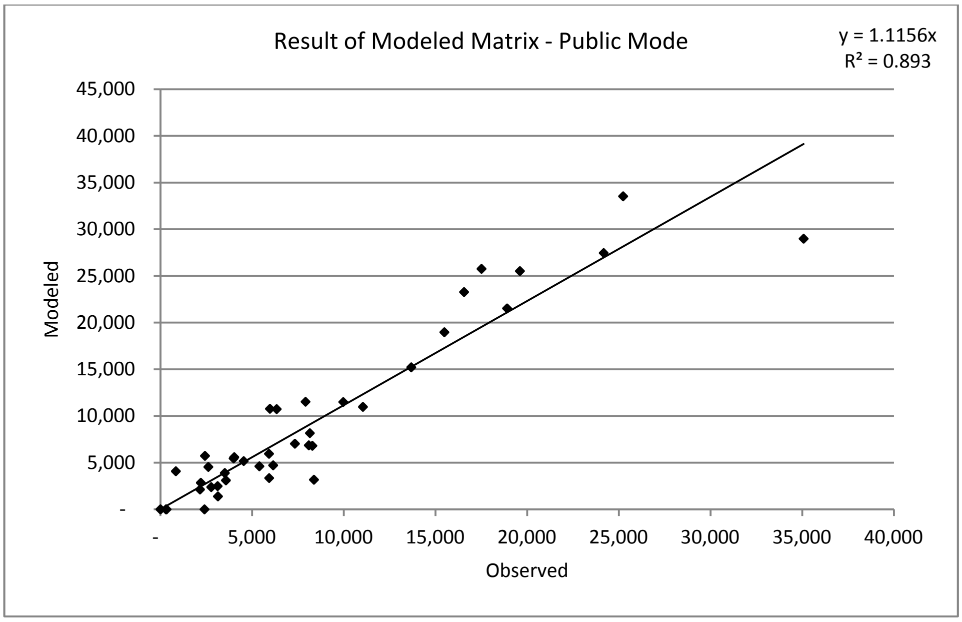
$$C_{i(x)} = k_i + \sigma*L_i + \theta * t_i * (1+\alpha_i *(x_i/C_i)^{\beta i}$$

Where:
$C_{i(x)}$ – generalized cost in link i;
k_i– cost of toll in link i;
σ – operational cost by km in link i;
L_i – length in link i;
Θ – value of time;
T_i – free flow time in link i;
x_i – load in link i;
C_i – capacity in link i;
α_i – constant;
β –constant.

The constant β is normally taken from similar studies and α_i depends on the hierarchy and type of the road.

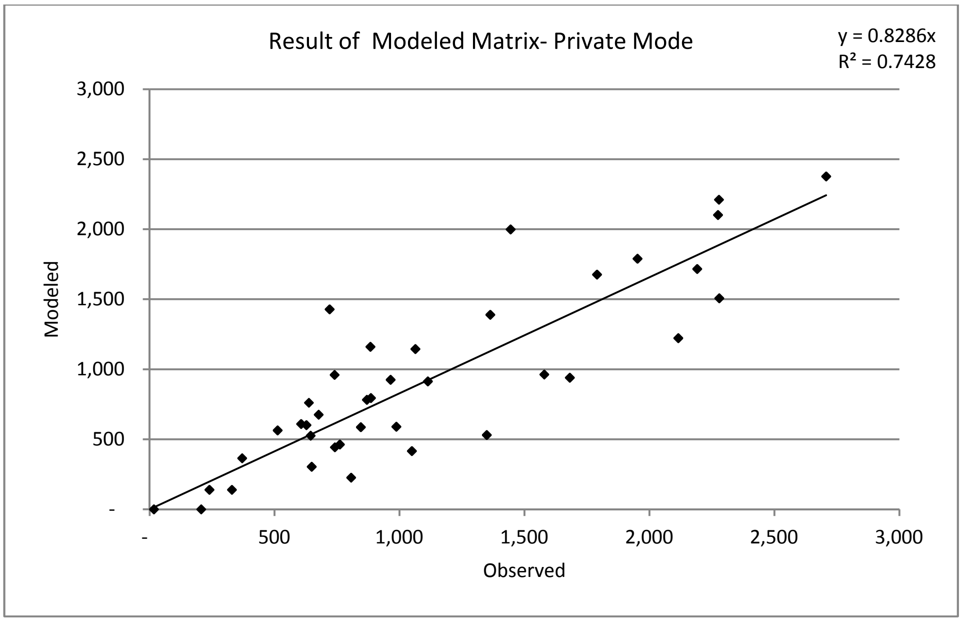
(2) Results of the Assignment with modeled matrices

Figure 5.34 and Figure 5.35 illustrate the comparison of the traffic volume at the Screen Line points between the traffic counts in the Screen Line Survey and the results of the traffic and transit assignment, respectively. As can be seen, the assignment model can produce the similar traffic situation by using the estimated OD matrices.



Source: JICA Study Team

Figure 5.34 Predictability of Screen Line Traffic by Assignment Model for Public Mode



Source: JICA Study Team

Figure 5.35 Predictability of Screen Line Traffic by Assignment Model for Private Mode

5.6 Supply Scenarios

Traffic and transit assignments require the road and transit network model to which the estimated demand is assigned.

For public transport mode, five metro lines in the metro plan in 2010 are considered in the transit network in 2020 and 2030. All lines are assumed to have an exclusive right-of-way with elevated or underground structure. The existing BRT (Metorplitano) is included in the network.

In addition, a new route of a medium transit capacity system (monorail) is studied in Chapter 6, and the demand is analyzed in this chapter. The new route is proposed on Av. Universitaria and Angamos Este, of which roadsides are being not covered with effective area of Metro lines. There are three alternatives for the new routes.

- **Monorail A:** Los Alisos (Terminal Naranjal-Metropolitano), Av. Universitaria, Av. Del Ejército, Angamos Este

- **Monorail B:** Av. Tomás Valle (Aeropuerto-Est. Metropolitano), Av. Universitaria, Av. Del Ejército, Angamos Este

- **Monorail C:** Av. Tomás Valle (Aeropuerto), Av. Universitaria, Av. Del Ejército, Angamos Este

The road network is developed based on the proposed projects in PMTU 2025. Small scale projects such as Rio Banba Bridge (PR-20) and Delgado de la Flor Bridge (RP-21) are not included, because adding new links for these projects will not affect the traffic assignment. Peripheral roads (PR-06 – PR-10) are excluded because these roads run the peripheral of the Study Area to provide road access to rural areas and will not affect the traffic assignment. Linea Amarillo, the expressway along the Rimac River, is built into the network. The projects in the road network are shown in Table 5.15.

Table 5.15 Projects to be considered in private transport

Item	Location
1	Santa Rosa Tunnel (Intersection Tacna/Alcazar in Rímac)
2	Construction of Rimac / San Martin Tunnel
3	Construction of San Francisco (Unirá with La Molina y Surco) Tunnel
4	Yellow Line
5	Construction of Av. La Costa Verde Ámbito Callao
6	Construction of Av. La Costanera
7	Construction of the extension of the Av. Paseo de la República Sur
8	Construction of Vía de Periférica
9	Construction of the extension of Autopista Ramiro Prialé

Source: JICA Study Team

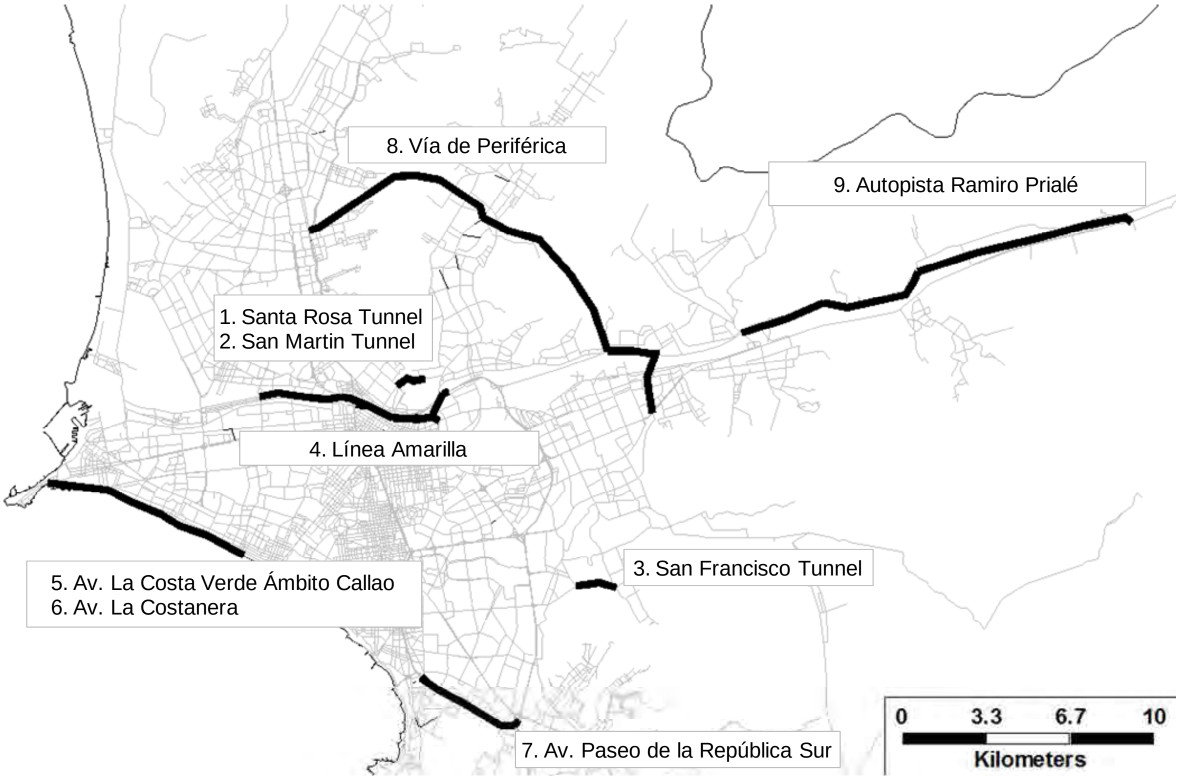


Figure 5.36 Locations of Projects of Road Network

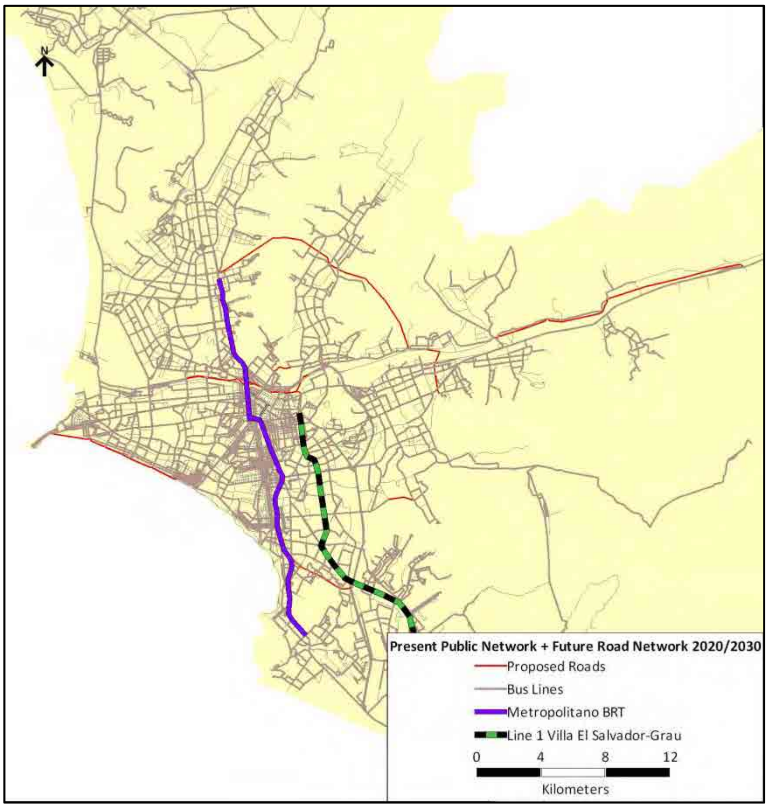
Table 5.16 summarizes the cases selected for the simulations. No projects are included in Case-1. This is the "Without Case". In Case-2, only road projects are implemented. The road projects are included in the cases from Case-3 to Case-7. Case-3 was tested to evaluate the necessity of Line-3 and Line-5 because these lines are overlapped with Metropolitano. Case-4 is the case when all metro lines in the metro plan in 2010 are implemented. Case-5, 6 and 7 are tested for the concept study of medium capacity transit systems in Chapter 6.

Table 5.16 List of Cases defined for analysis

Case	Network	Year
1	Present Road Network + Present Transit Network	2020, 2030
2	Future Road Network + Present Transit Network	2020, 2030
3	Lines 1,2, and 4 & BRT	2020, 2030
4	Metro Plan (Lines 1,2,3,4 and 5) + BRT	2020, 2030
5	3 + New Route A (refer Chapter 6)	2030
6	3 + New Route B (refer Chapter 6)	2030
7	3 + New Route C (refer Chapter 6)	2030

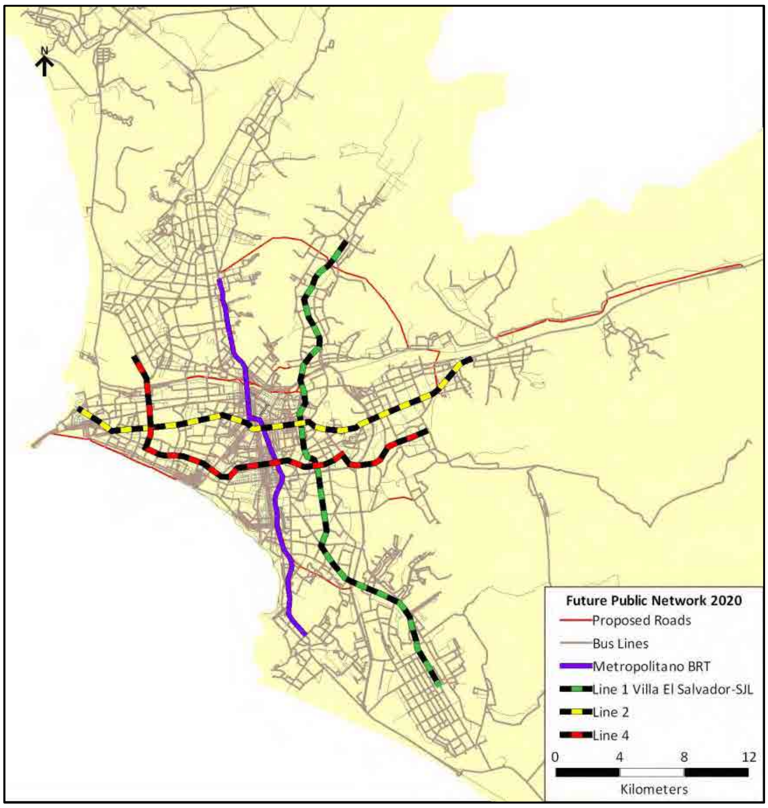
Source: JICA Study Team

The following maps illustrate the projects shown in Table 5.16.



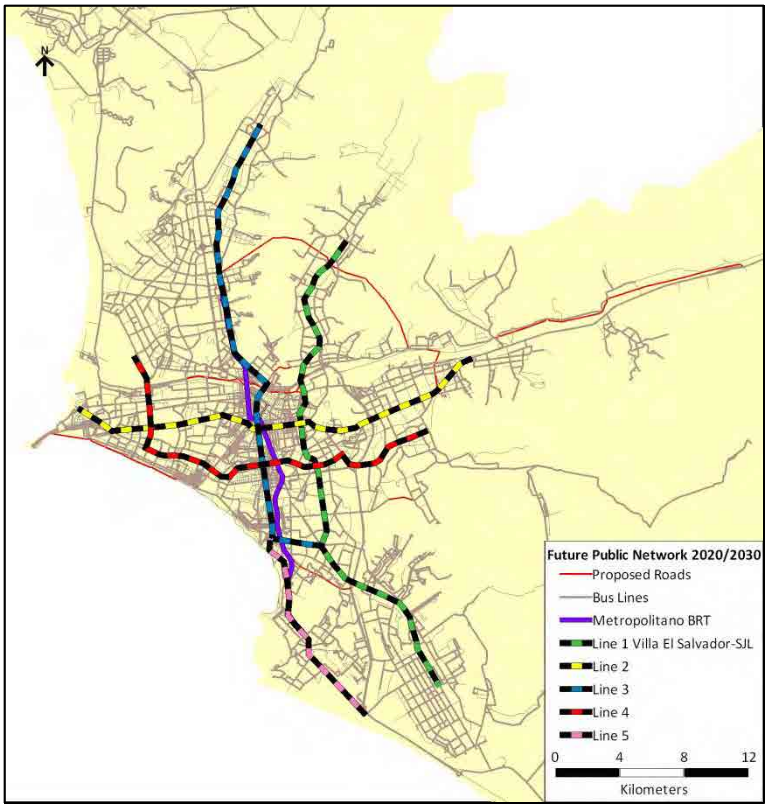
Source: JICA Study Team

Figure 5.37　Present Public Network



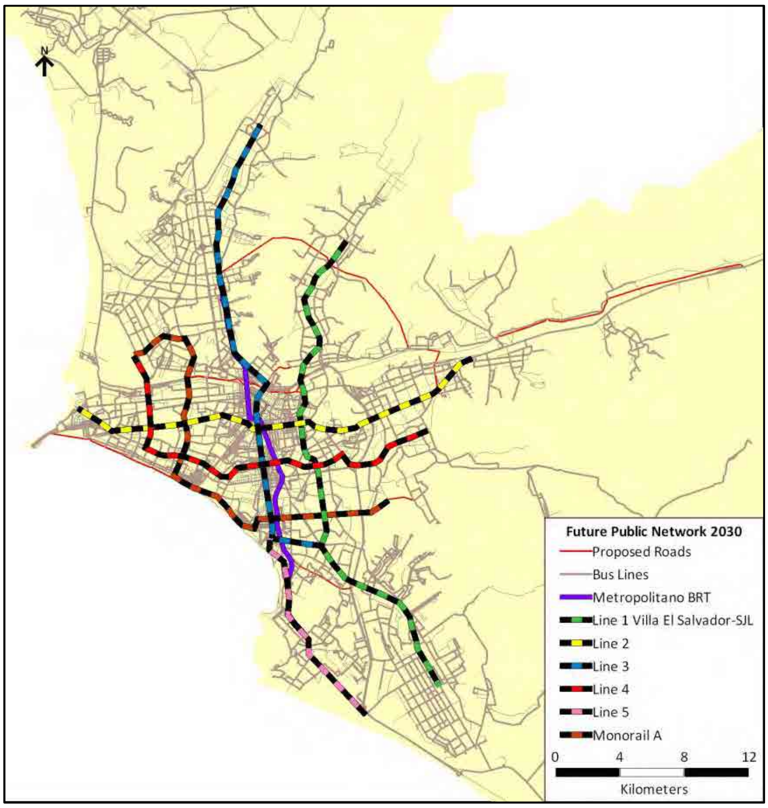
Source: JICA Study Team

Figure 5.38　Line-1, 2, and 4 + Metropolitano



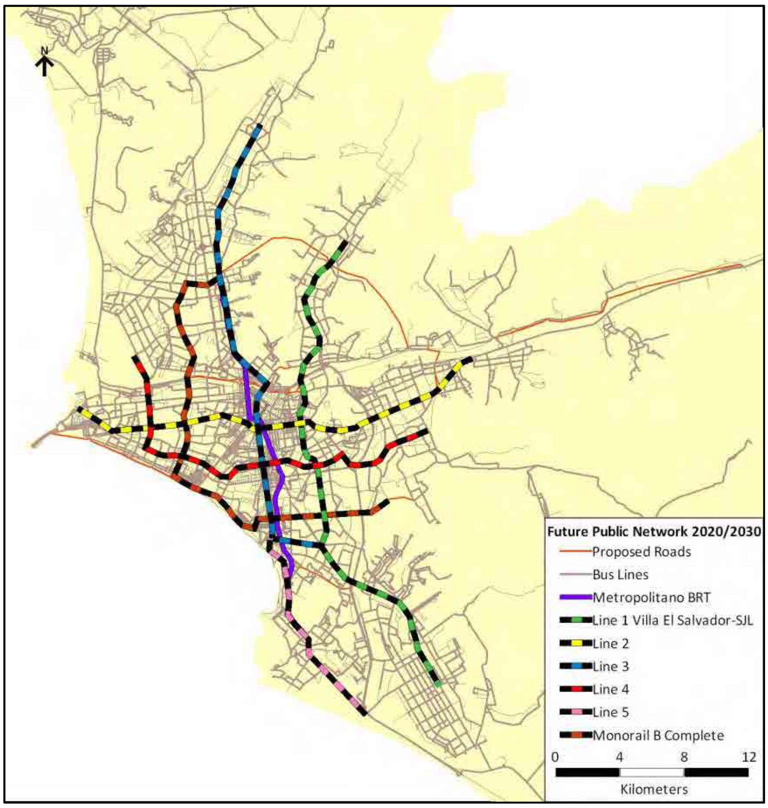
Source: JICA Study Team

Figure 5.39 Metro Plan



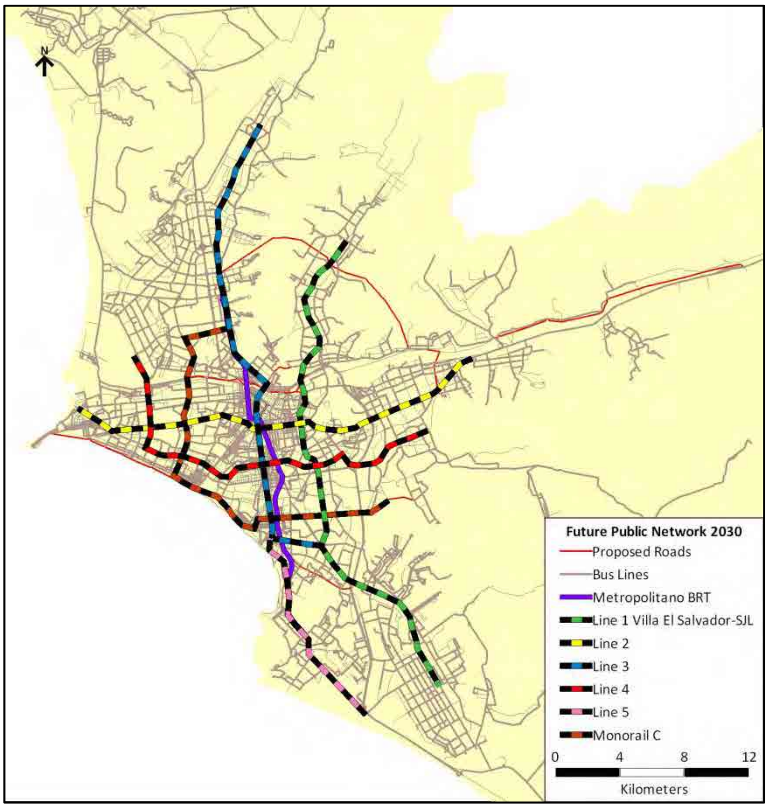
Source: JICA Study Team

Figure 5.40 Metro Plan + New Route A



Source: JICA Study Team

Figure 5.41 Metro Plan + New Route B



Source: JICA Study Team

Figure 5.42 Metro Plan + New Route C

The operational parameters adopted for the new projects are listed in the table below.

Table 5.17 Operational parameters considered in the projects

Line	Length (km)	Fare (S/.)	Peak Hour Headway (min)	
			2020	2030
Line 1	33.19	1.5	3.0	3.0
Line 2	26.72	1.5	3.0	3.0
Line 3	30.85	1.5	3.0	3.0
Line 4	25.81	1.5	3.0	3.0
Line 5	13.26	1.5	3.0	3.0
New Route A	27.95	1.5	3.0	3.0
New Route B	30.14	1.5	3.0	3.0
New Route C	26.79	1.5	3.0	3.0

Source: JICA Study Team

5.7 Results of Demand Forecast

5.7.1 Trip Generation and Modal Share

The future demand was determined initially by applying the Generation Model considering the socio-economic scenarios forecasted for the years 2020 and 2030.

For the Distribution Model, the impedances were calculated considering the supply scenario of the target year and the trip matrix of the previous period. That means, to calculate de impedance matrix for 2020 the network considers the projects for 2020 and the trip matrix of 2012. The same procedure was done to calculate the impedance matrix of year 2030. The same impedance matrices were used to calculate the Modal Split resulting in the private and public mode matrices for 2020 and 2030.

The results of the new matrices for the public and private mode for the morning peak are presented in the table below. It indicates that the despite the large investments expected in public transport the private mode increases its participation on the modal split. This tendency is explained for the strong increasing in the motorization rate of the population and for investments also expected in the road network.

Table 5.18 Future demand estimated for 2020 and 2030

Year	Public	Private	Total	Public	Private
2012	999,972	303,114	1,303.086	76.7%	23.3%
2020	1,090.237	346,943	1,437.180	75.9%	24.1%
2030	1,215.816	390,897	1,606.713	75.7%	24.3%
Evolution 20-12	9.0%	14.5%	10.3%		
Evolution 30-20	11.5%	12.7%	11.8%		

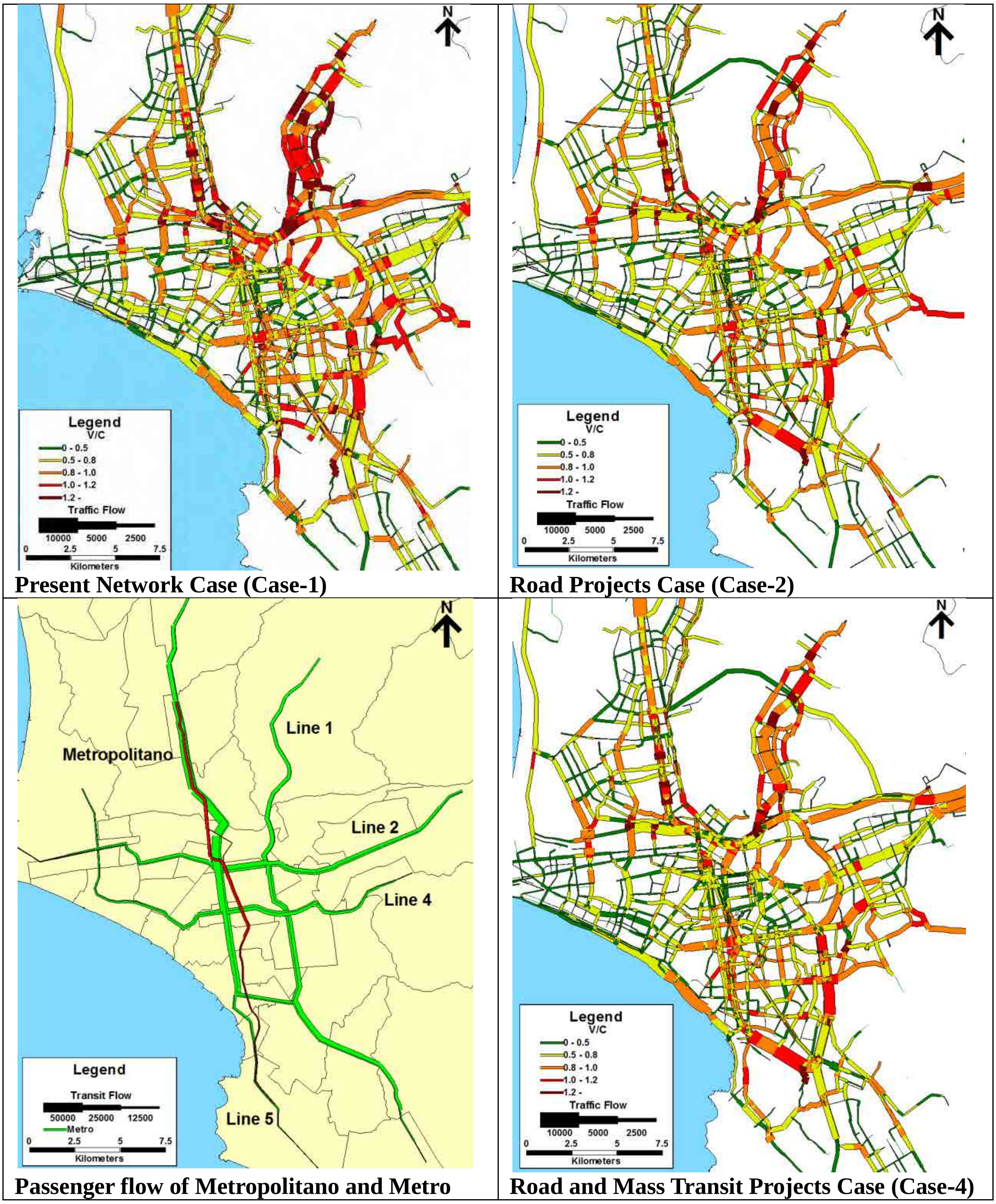
Source: JICA Study Team

5.7.2 Traffic Assignment

The OD matrices (the morning peak hour) were assigned to the network model described in 5.3. The traffic volumes of the transit routes were calculated from the transit assignment, and the estimated volumes were used as the preload traffic for the traffic assignment.

Figure 5.43 and Figure 5.44 illustrate the traffic flows in 2020 and 2030, respectively. The left top figure shows the estimated traffic flow of Case-1 (“Do Nothing”), while right top figure shows that of Case-2 (Road development case). These figures show that traffic volume on the new roads such as Vía de Periférica and Av. Paseo de la República Sur will be very large. It is estimated that the peak hour traffic for peak direction of these roads in 2020 will be 2,700 and 5,000 passenger car units (PCUs), respectively.

The bottom right figure shows the assignment result of Case-4. The difference between Case-3 and Case-4 is not clear in 2020, while the reduction in volume to capacity ratio (V/C) is observed in 2030. Since the demand forecast assumes that the present bus network will remain in the future, many competitive routes run in parallel with mass transit lines. Although the frequency of bus services is reduced in accordance with the passenger shift to mass transit lines, demand in the bus services that connect origin and destination directly will be high due the additional payment to transfer to the mass transit lines. In addition, it is estimated that the car traffic will increase in the future, which increases the traffic volume of the road network. However, the road congestion on the major roads in 2030 will be improved in Case-4.



Present Network Case (Case-1)

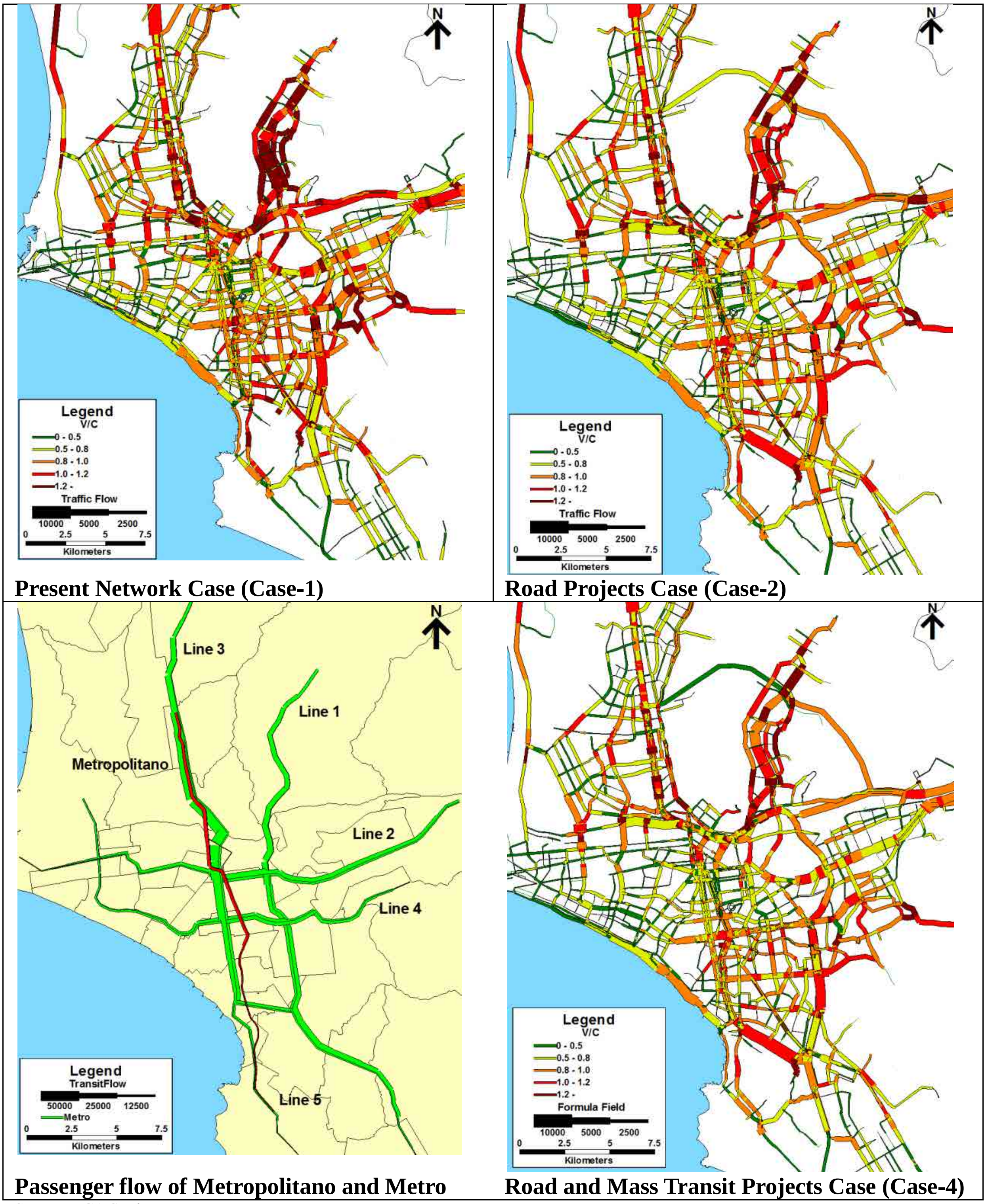
Road Projects Case (Case-2)

Passenger flow of Metropolitano and Metro

Road and Mass Transit Projects Case (Case-4)

Source: JICA Study Team

Figure 5.43 Traffic Flow in 2020



Source: JICA Study Team

Figure 5.44 Traffic Flow in 2030

5.7.3 Traffic Indicators

(1) Private Mode

In order to compare the future scenarios here is presented the indicators related to the base year of 2012 in the alternative of "do nothing" and with the road projects.

Table 5.19 Summary of indicators for private mode

Indicator	Present Road Network			Future Road Network	
	2012	2020	2030	2020	2030
Vehicles x km	1,181,861	1,389,319	1,585,721	1,381,162	1,563,480
Vehicles x hour	35,420	45,799	58,433	40,704	49,907
Average Speed (km/h)	33.37	30.33	27.14	33.93	31.33

Comparison with Base Scenario

Indicator	Present Road Network			Future Road Network	
	2012	2020	2030	2020	2030
Vehicles x km	0.0%	17.6%	34.2%	16.9%	32.3%
Vehicles x hour	0.0%	29.3%	65.0%	14.9%	40.9%
Average Speed (km/h)	0.0%	-9.1%	-18.7%	1.7%	-6.1%

Source: JICA Study Team

It can be seen that if nothing is done in the future, the average speed of the private mode will decrease 9.1% in year 2020 and 18.7% in 2030. That means that the average speed estimated presently in 33.37 km/h will decreases to 27.14 km/h in 2030.

Otherwise, with the new road projects, the average speed will increase slightly in 1.7% in 2020 and will decrease 6.1% in 2030. It means that the new projects can keep the same level until 2020 but will not avoid the decreasing in the average speed in 2030.

(2) Public Mode

For the public mode, it is initially presented the indicators for the base year of 2012 and after the indicators for the different scenarios and target years.

The table below shows the main indicators related to the base year for the public mode. The average trip time of the public system is 49.42 minutes.

Table 5.20 Summary of indicators of public mode in base year 2012

Indicator	Present Road Network + Present Transit Network
Generalized Cost (Soles - S./)	5.86
Fare (Soles - S./)	1.79
Total Trip Time (min)	49.42
In-vehicle Time (min)	38.75
Initial Wait Time (min)	2.16
Transfer Wait Time (min)	0.41
Transfer Time (min)	0.12
Access Time (min)	4.08
Egress Time (min)	3.89

Source: JICA Study Team

The next tables the results simulated for all the cases seen before are presented and compared with the alternative of “do nothing”.

The results show that all indicators such as generalized cost and total trip time tends to decrease according to the supply scenarios compared with the alternative of “do nothing”.

For example, in 2020 the alternative “do nothing” indicates that the total trip time reaches 64.12 minutes and generalized cost of 6.98. The alternative with future road network associated with Lines 2, 3, 4 and 5 and Monorail B reduces the trip time in more than 20% and the generalized cost in 15%.

The same indicators in 2030 reach more significant results. The alternative “do nothing” gives the total trip time of 78.69 minutes and generalized cost of 8.05. The alternative with future road network associated with Lines 2, 3, 4 and 5 and the new line reduces the trip time in more than 23% and the generalized cost in 17%.

Table 5.21 Summary of indicators for public mode in year 2020

Indicator	Do Nothing	Road Development Only	MTC Plan	MTC Plan + New Route (B)
Generalized Cost (Soles - S./)	6.98	6.65	6.08	5.98
Fare (Soles - S./)	1.85	1.82	1.84	1.82
Total Trip Time (min)	64.12	60.14	52.07	50.99
In-vehicle Time (min)	53.53	49.68	42.60	41.54
Initial Wait Time (min)	2.01	1.94	1.79	1.82
Transfer Wait Time (min)	0.46	0.42	0.47	0.53
Transfer Time (min)	0.16	0.15	0.32	0.41
Access Time (min)	4.08	4.08	3.59	3.48
Egress Time (min)	3.88	3.87	3.30	3.20
Comparison with Base Scenario				
Indicator	Do Nothing	Road Development Only	MTC Plan	MTC Plan + New Route (B)
Generalized Cost (Soles - S./)	-	-4.6%	-12.8%	-14.3%
Fare (Soles - S./)	-	-1.4%	-0.2%	-1.4%
Total Trip Time (min)	-	-6.2%	-18.8%	-20.5%
In-vehicle Time (min)	-	-7.2%	-20.4%	-22.4%
Initial Wait Time (min)	-	-3.4%	-11.1%	-9.2%
Transfer Wait Time (min)	-	-10.0%	1.9%	15.4%
Transfer Time (min)	-	-4.3%	103.6%	163.4%
Access Time (min)	-	0.0%	-12.1%	-14.7%
Egress Time (min)	-	-0.1%	-14.9%	-17.5%

Source: JICA Study Team

Table 5.22 Summary of indicators for public mode in year 2030

Indicator	Do Nothing	Road Development Only	MTC Plan	MTC Plan + New Route (B)
Generalized Cost (Soles - S./)	8.05	7.55	6.82	6.69
Fare (Soles - S./)	1.89	1.89	1.92	1.86
Total Trip Time (min)	78.69	71.70	61.17	60.26
In-vehicle Time (min)	68.14	61.34	51.66	50.68
Initial Wait Time (min)	1.91	1.77	1.68	1.68
Transfer Wait Time (min)	0.51	0.47	0.51	0.61
Transfer Time (min)	0.18	0.17	0.41	0.65
Access Time (min)	4.06	4.06	3.60	3.49
Egress Time (min)	3.89	3.89	3.31	3.16
Comparison with Base Scenario				
Indicator	Do Nothing	Road Development Only	MTC Plan	MTC Plan + New Route (B)
Generalized Cost (Soles - S./)	-	-6.3%	-15.3%	-16.9%
Fare (Soles - S./)	-	-0.1%	1.3%	-1.4%
Total Trip Time (min)	-	-8.9%	-22.3%	-23.4%
In-vehicle Time (min)	-	-10.0%	-24.2%	-25.6%
Initial Wait Time (min)	-	-7.3%	-12.0%	-11.8%
Transfer Wait Time (min)	-	-7.5%	1.0%	18.9%
Transfer Time (min)	-	-4.0%	125.3%	259.8%
Access Time (min)	-	0.0%	-11.4%	-14.1%
Egress Time (min)	-	0.0%	-14.9%	-18.8%

Source: JICA Study Team

5.7.4 Passenger Demand of Mass Transit System

(1) Case-1

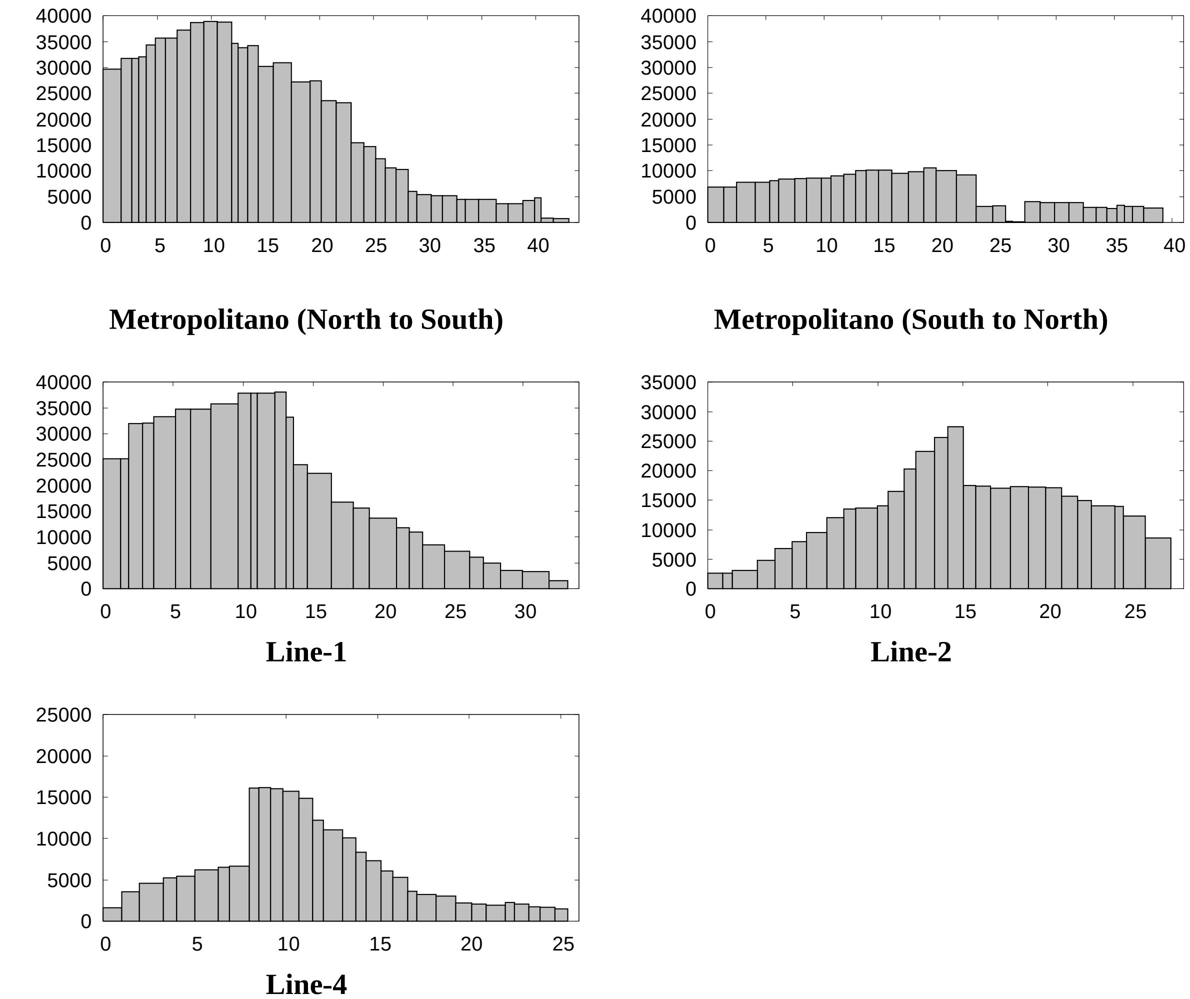
The passenger demand of Metropolitano will reach 39,000 PHPDT in 2030, in case that no projects are implemented. Since the passenger demand exceeds the capacity of the present system, the actual demand will be smaller than the projection. The passenger demand of Line-1 will remain the same level as the present demand.

(2) Case-2

The results are almost the same as Case-1.

(3) Case-3

Figure 5.45 shows the passenger flow of Case-3 (Line-3 and 5 are excluded.) in the peak hour for peak direction in 2030. The passenger flow of Metropolitano will reach 39,000 PHPDT. At present, only TransMilenio, the full scale BRT in Bogota, Colombia achieved this volume of passenger transport. In order to carry 39,000 passengers per hour by BRT, overtaking lanes at stations are necessary, but this is difficult for Metropolitano in the central area. Therefore, even if Line-3 is planned in parallel with Metropolitano, the line is necessary to cope with the future transport demand. The bottom right chart shows the passenger flow of Metropolitano in the direction from the south to north. The passenger demand is 7,000-10,000 passengers per hour in the peak hour. This means that the priority of Line-5, which overlaps with Metropolitano, is low.



Note: vertical axis = kilometers from the beginning of the line
horizontal axis = No. of passengers per hour per direction

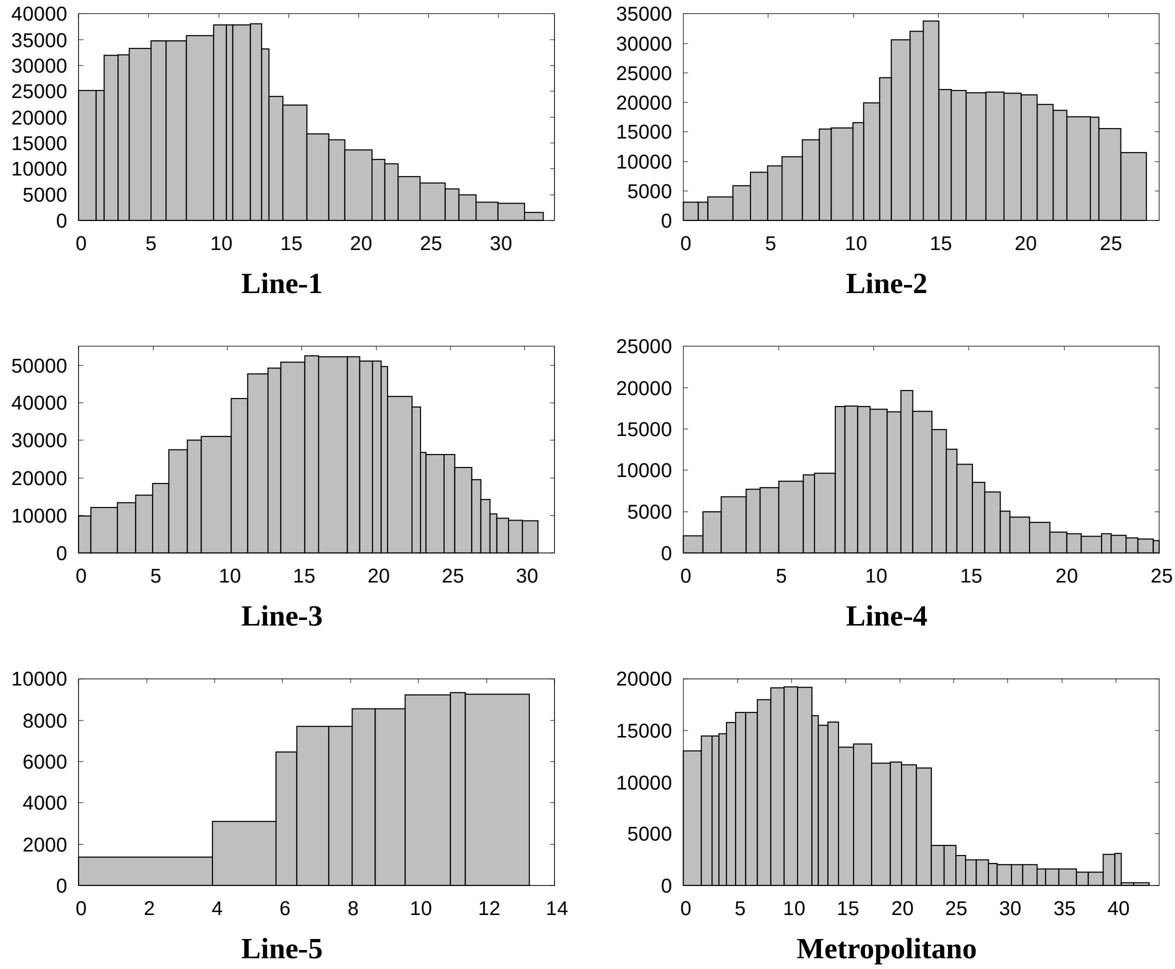
Source: JICA Study Team

Figure 5.45 Passenger Flow of Metro and Metropolitano (Case-3) in 2030

(4) Case-4

Figure 5.46 shows the passenger flow in Case-4 (MTC Plan) in the peak hour for the peak direction in 2030. Although the route of Line-3 is close to that of Metropolitano, its demand would be very large, and the Line-3 would absorb the demand of Metropolitano.

The projection of the maximum number of passengers in the morning peak hour per direction shows that only the railway system will be possible for Line 1 and Line 3. Line-1 is already constructed as a railway system. Even if Metropolitano takes a part of the corridor demand, the number of passengers on Line-3 still remains high enough to justify a railway system. On the other hand, medium capacity transit systems will be possible for other lines. For Line 2, the demand is a little high for medium capacity transit systems; although a large type monorail can carry the passenger demand. From the demand forecast, a railway system would be suitable for Line 2. It is difficult to derive the suitable system for Line 4 from the result of the demand forecast. The result shows that a large type monorail can deal with the demand, but it is necessary to check other aspects to conclude the suitable system.



Note: vertical axis = kilometers from the beginning of the line
horizontal axis = No. of passengers per hour per direction

Source: JICA Study Team

Figure 5.46 Passenger Flow of Metro and Metropolitano (Case-4) in 2030

(5) Case-5, 6, and 7

The results of “New Route” cases are described in Chapter 6.

Table 5.23 Daily Number of Boarding Passengers

	2020			2030		
	Line-1, 2, 4	MTC Plan	MTC Plan & New Route	Line-1, 2, 4	MTC Plan	MTC Plan & New Route
Line 1	436,000	428,000	530,000	574,000	672,000	697,000
Line 2	304,000	379,000	421,000	368,000	498,000	518,000
Line 3	0	569,000	582,000	0	716,000	699,000
Line 4	235,000	333,000	367,000	300,000	434,000	452,000
Line 5	0	104,000	109,000	0	117,000	122,000
New Route	0	0	175,000	0	0	202,000
Metropolitano	341,000	186,000	251,000	414,000	214,000	315,000

Source: JICA Study Team

Table 5.24 Peak Hour Peak Direction Passenger Volume

	2020			2030		
	Line-1, 2, 4	MTC Plan	MTC Plan & New Route	Line-1, 2, 4	MTC Plan	MTC Plan & New Route
Line 1	25,000	24,000	28,000	35,000	38,000	40,000
Line 2	22,000	24,000	27,000	27,000	34,000	35,000
Line 3	0	39,000	39,000	0	53,000	49,000
Line 4	12,000	16,000	18,000	16,000	20,000	20,000
Line 5	0	8,000	9,000	0	9,000	10,000
New Route	0	0	15,000	0	0	17,000
Metropolitano	29,000	15,000	14,000	39,000	19,000	18,000

Source: JICA Study Team

5.7.5 Findings of the Demand Forecast

The followings are major findings of the demand forecast.

1) The road congestion of arterial roads connecting the suburban areas and the center of the city in peak hours will become heavier. Therefore, construction of the road projects proposed in PMTU 2025 is necessary. Especially, the implementation of Vía de Periférica, Av. Paseo de la República Sur, and Autopista Ramiro Prialé are very important.

2) The road capacity of arterial roads in the center of the city, excluding Centro, still has a margin against the commuter traffic demand. Therefore, there is a possibility to solve the congestion problem to some extents by introducing intersection improvements and traffic managements proposed in PMTU 2025.

3) Since passenger demand in the north south direction is very high, Line-1 and Line-3 should be developed as high capacity system such as railway. Although Line-3 uses Tupac Amaru as same as the BRT (Metropolitano), the capacity of Metropolitano is not high enough to cope with the demand.

4) Line-2 and Line-4 are planned for the east west direction. As far as the demand concerned, there is a possibility that a medium capacity transit system can cope with the demand for these lines. This is further analyzed in Chapter 6.

5) Although Line-5 of the MTC Plan has the demand of approximately 10,000 PHPDT, the line overlaps with Metropolitano. From this, construction of Line-5 would be overinvestment.

6) The transfer demand is very high because the railway lines in the MTC Plan cross each other. Therefore, changes of a line will affect the passenger demand of other lines to a large extent. It is necessary to develop transfer stations so that the transfer is very convenient.

7) Passenger demand in the suburban direction of the railway lines of the MTC Plan is also high. It is desirable to study feeder bus systems at the time of the railway development.

Chapter 6 Concept Study of Medium Capacity Transit System

6.1 Background of the Study

6.1.1 Medium Capacity Transit System as an Alternative of Urban Transit System

(1) BRT and Railway

In the urban transport planning in Peru, the choice of the urban transit system has been discussed between BRT and railway systems as described below. The mass transit plan in PMTU 2025 was also formulated based on Trunk Bus System and Railway System.

1) JICA F/S for East-West Corridor in 2007

The study of PMTU 2025 identified the trunk bus project on Av. Venezuela as one of the high priority projects. Based on the master plan, JICA conducted a feasibility study (F/S) of the trunk bus project along the East West Corridor consisting of Ave. Venezuela, Av. Ayllon, and Carretera Central with the total length of 19.7km as shown in Figure 6.1. The final report of the study was submitted in March 2007. The F/S concluded that the project would be feasible with Economic Internal Rate of Return of 15.4%. Traffic demand on the trunk bus corridor was projected to be 6,000 passengers per hour per direction at peak hours. The proposed system had a capacity of 6,000 passengers per hour per direction with the operation of a 1.7-minute headway by articulated buses having a capacity of 170 passengers. This was a standard type of Bus Rapid Transit (BRT) systems. The basic plan (Perfil) of the East West Corridor project was approved by the Office of Planning and Investment (OPI) of the Municipality of Lima Metropolitan in 2006.

2) COSAC-2 Project

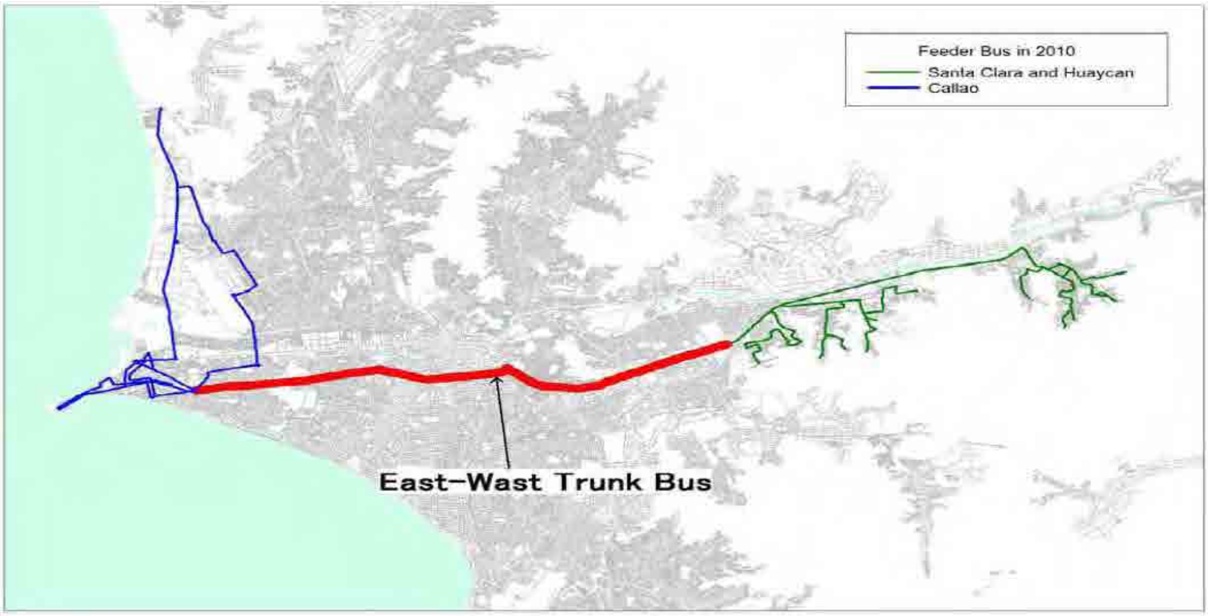
The East-West Corridor was integrated into the COSAC-2 project with a total length of 27.6km as shown in Figure 6.2. A detailed demand study was carried out by Protranspote and FONAM in 2010, and the basic plan (Perfil) was updated in 2011. Due to the limited right of ways (ROWs) along the corridor, the same capacity as applied for the COSAC-1 (Metopolitano) project is not possible for the COSAC-2 project.

3) Metro Plan in 2010

The present metro plan formulated by the Ministry of Transport and Communications (MTC) was notified in 2010, in which Line-2 along almost the same route as the East West Corridor is included. AATE has conducted several demand studies for the lines in the metro plan. The elevated or underground railway system is adopted in the plan, instead of the at-grade type.

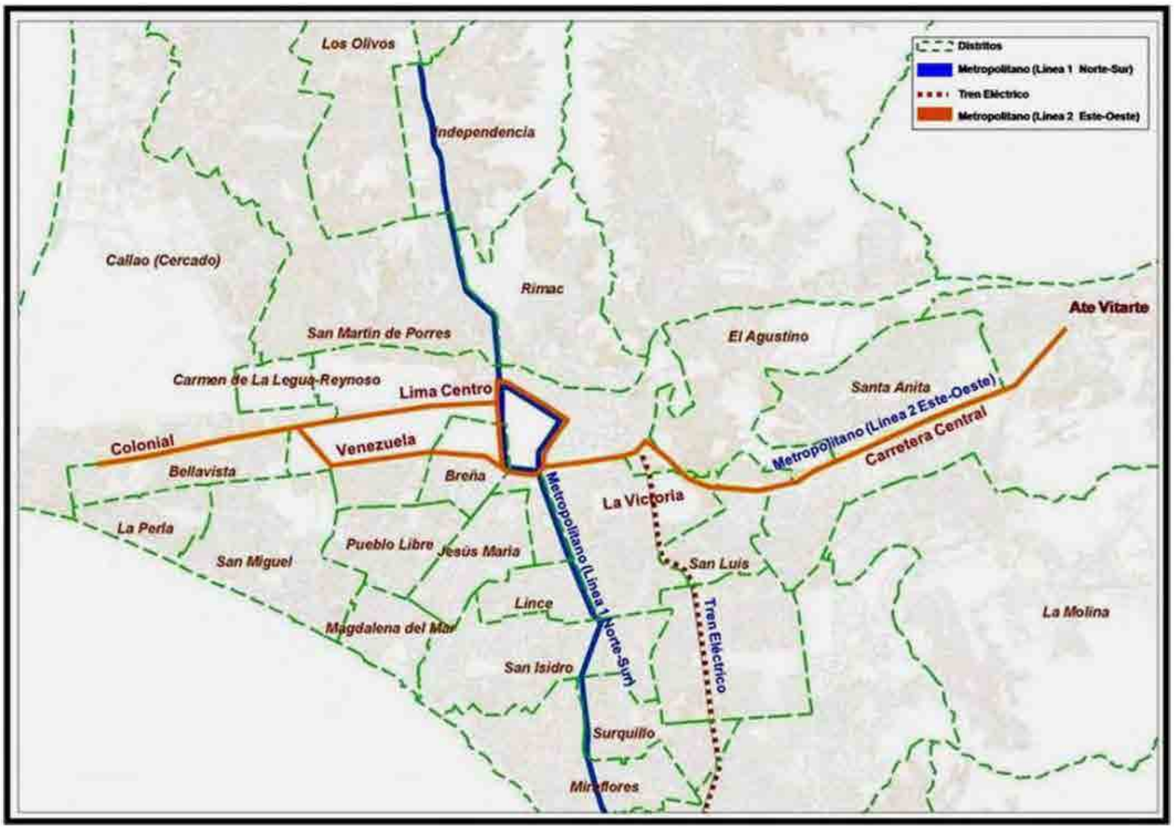
Since COSAC-2 and Line-2 use the same corridor, implementation of both projects would not be economically feasible.

Figure 6.3 shows the locations of lines in the metro plan.



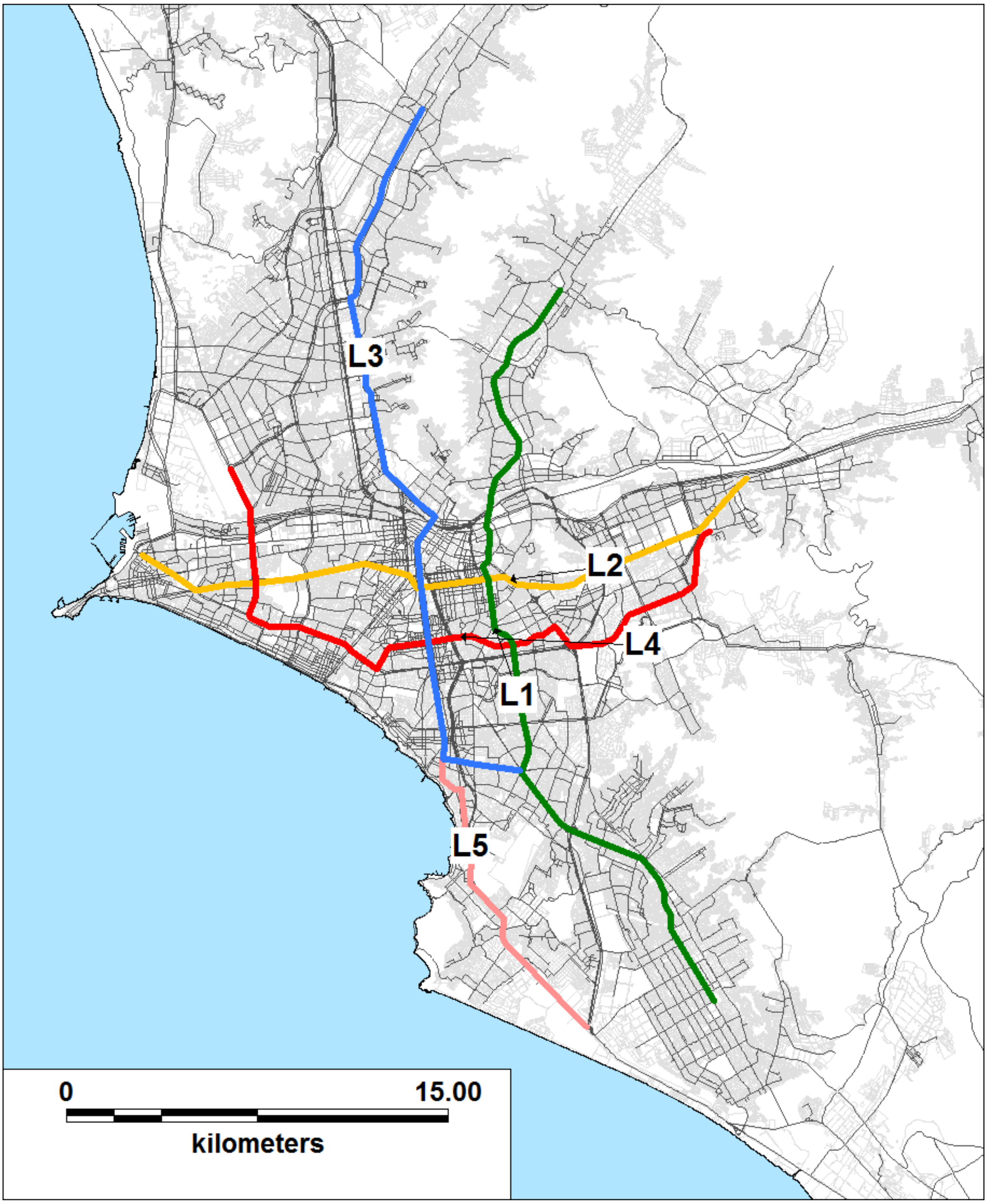
Source: JICA F/S in 2007

Figure 6.1 East-West Trunk Bus Corridor in JICA F/S



Source: “Estudio de Consolidación del Sistema Integrado del Transporte Público de Lima”, 2010

Figure 6.2 Metorpolitano-2 (COSAC-2) Project



Source: D.S. 059-2010-MTC, illustrated by the JICA Study Team

Figure 6.3 Location of Lines in the Metro Plan

(2) Proposal for Monorail

The system capacity of COSAC-2 would be less than 25,000 phpdt due to the limited ROW of the corridor while underground railways can carry more passengers. The selection of either the system of low cost with limited capacity (BRT) or that of high cost with high capacity (underground) along the corridor was discussed. In this connection, there was a proposal by a Japanese group for a monorail system along the corridor in 2011. The capacity of the proposed monorail is higher than that of BRT while its construction cost is smaller than that of the underground railway.

Although the underground railway was selected for the corridor, the idea of introducing a medium capacity transit system in Lima is worth studying.

(3) Demand Forecast

The demand forecast in Chapter 5 shows that it is necessary to consider medium capacity transit systems for Line-2 and Line-4 instead of comparing BRT and railway system.

6.1.2 System Selection

This subsection describes the criteria of selection of a mass transit system from a general viewpoint.

(1) Approach in PMTU 2025

The study of PMTU 2025 considered the railway system and trunk bus system only. Instead of selecting the proper mode for each route, the study evaluated the combination of railway and trunk bus systems. The basic scenarios for the evaluation were:

- Priority Railway Transport System
- Priority Trunk Bus System
- Combination Transport System

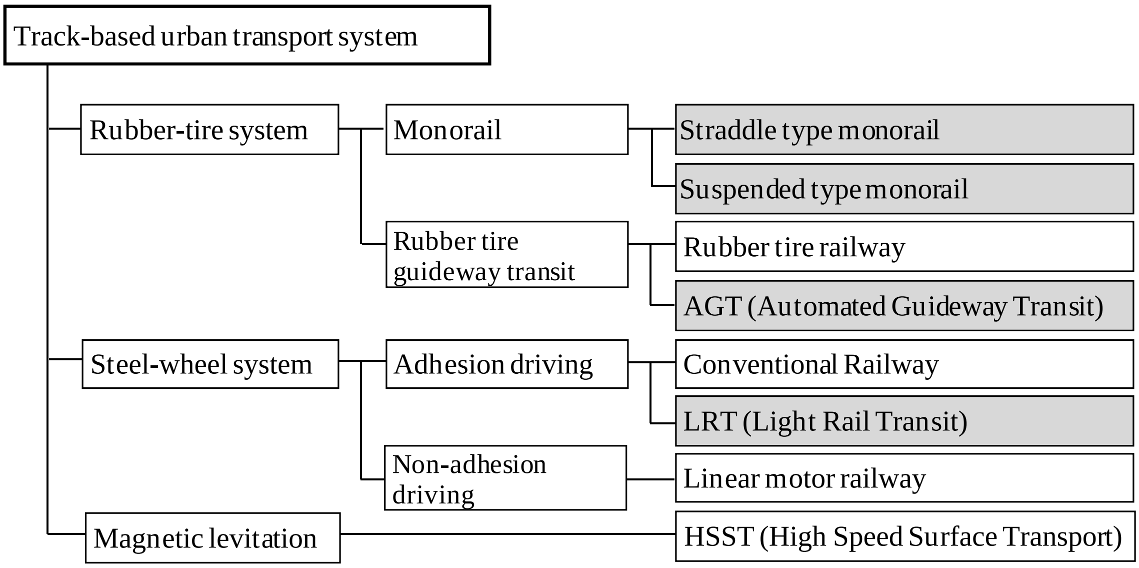
The best combination was selected from several criteria such as the total cost, covered population, benefit to cost ratio, speed on road, distance of congested section, and reduction of CO_2, although the cost-benefit efficiency was very important factor for the selection. The transit capacity was considered for the selection between Light Rail and Heavy Rail. The development cost of public transport was estimated at USD 3,005 million in which railway and Trunk Bus lines accounted for USD 2,024 million and 981 million, respectively. The budget constraint was the major criteria of the system selection reflecting the weak economy in the study period.

In the study of PMTU 2025, Trunk Bus System (Bus Rapid Transit System, BRTS) and Railway Transport System were the only alternatives for the system selection. However, there are other urban transit systems and it is necessary to consider such alternatives.

(2) Candidate for Urban Transit System

An elevated railway such as Metro Line-1 is a generalized and conventional system for urban transport. The columns of its viaduct are built in the central reservation of the road, and the track is installed above the public road space. The elevated railway can secure right-of-way dedication and separation from road traffic and can reduce the construction cost compared with an underground railway.

Generally, track based urban transport systems are categorized into 8 systems as shown in Figure 6.4. All systems can be installed as an elevated railway. Among these, Light Rail Transit (LRT), Automated Guideway Transit (AGT), High Speed Surface Transport (HSST) and monorail can be considered as medium capacity transit systems (grey color in the figure). The most suitable transit system will be selected from the viewpoint of transport capacity, technical capability and economic efficiency. Also, since the track is installed above the road space in the urban area, environmental issues, such as noise and vibration, land acquisition and the impact on city landscape, can be taken into account.



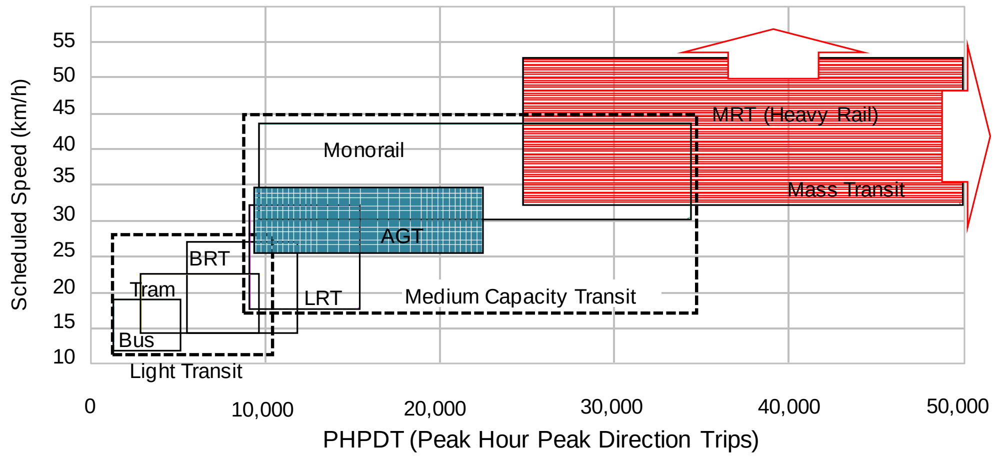
Source: JICA Study Team

Figure 6.4 Track-based Urban Transport System

(3) Traffic Demand

Passenger demand is one of the most important factors to select the proper system along a corridor. If a BRT system can satisfy the demand, other higher capacity systems would be over investment. On the other hand, it is necessary to introduce railway system if the demand exceeds 35,000 passengers per hour per direction (phpdt).

Since the costs of construction and rolling stock of a mass transit system are expensive, there is a range of demand that is optimal for the system. Figure 6.5 illustrates the concept of the optimal range.



Source: JICA Study Team

Figure 6.5 Concept of Optimal Investment of Mass Transit System

It is necessary to avoid both over investment and over saturation in view of the economical feasibility. The idea of the medium capacity transit system is to provide an alternative between railway and BRT systems. If the passenger demand exceeds approximately 15,000 phpdt, BRT systems need overtaking lanes. However, this demand would not justify the investment on an underground railway unless the number of passengers is high even if the demand of the cross section is small. If the passenger demand is the range of approximately 10,000 – 20,000 phpdt, medium capacity transit systems would be proper in view of the optimal investment because the cost of the elevated structure is smaller than that of conventional railway systems. No system other than railway will be applicable in case that the passenger demand exceeds 35,000 phpdt.

In medium capacity transit systems, a large scale monorail can carry 35,000 passengers per hour per direction, although the number of necessary rolling stock is larger than conventional railways. Since the capacity of a monorail car is smaller than that of conventional railways, the former needs more number of cars than the latter. Table 6.1 shows an example calculation of the difference of the number of necessary rolling stock and cost between monorail and railway under the assumption that the round trip takes one hour. In this calculation, monorail needs 55 more cars compared to the railway system when the passenger demand is 35,000 phpdt. The larger number of necessary rolling stock means more investment and maintenance cost. The cost of elevated structure is approximately USD 12 million per km in Lima (Metro Line-1 extension). Assuming that the cost of the elevated structure of a monorail is USD 3.6 million (30%) less than that of railways, the monorail is more expensive when the passenger demand exceeds 20,000 phpdt. Although this is a test calculation under certain conditions, the result shows that criteria other than the cost are necessary for the passenger demand of approximately 20,000 – 35,000 phpdt.

Table 6.1 Example Calculation of No. of Rolling Stock

Passenger Demand (phpdt)	a	20,000	25,000	30,000	35,000
No. of Monorail Cars (No.)	b=a/158	127	158	190	222
No. of Railway Cars (No.)	c=a/210	95	119	143	167
Difference (No.)	d=b-c	32	39	47	55
Cost (Million USD)	e=d*2	64	78	94	110

Precondition: Round trip time = 1 hour (Route length=17.5km, Scheduled speed=35 km/h), monorail car capacity= 158 passengers/car, railway car capacity= 210 passengers per car, cost of a car= 2 million USD
Source: JICA Study Team

(4) Route Condition

The ROW width along the mass transit route affects the system selection. If the corridor is wide enough to accommodate 4 lanes with a station space in the median, a full scale BRT such as Metropolitano 1 and Transmilenio in Bogota would be possible. Transmilenio achieves the capacity of 45,000 phpdt. In case that transferring carriageways for cars to the exclusive lanes for a BRT system is difficult, elevated structure will be necessary. If the road is too narrow to accommodate elevated structures and stations, underground system will be the final solution.

In addition to the width of roads, the radius of curvature at corners of the routes affects the system selection. The medium capacity transit system enables smaller curve than that of a standard railway system. Vertical slope is also an important item in some urban conditions. Rubber tire system should be considered in case that steep slopes for steel wheel exist.

Sometimes, urban landscape is an element of the system selection. Underground structure is better than the elevated structure with a standard slab type where historical or cultural buildings exist.

(5) System Integration

It is convenient for public transport users in case that an inter-city or suburban railway can go through another system in the central area. The inter-line through operation within the center of the city would be also beneficial for passengers, although such operation of mass transit systems is not common. Since the lines in the present metro plan cross each other, the through operation will not be necessary. System integration is also beneficial for operators because it will enable efficient use of depot, facilities, spare parts, and human resources. Since the area of depots is limited in Lima, it is better to employ the same system among the lines in case that the lines can go to the same location.

(6) Sustainability

Mass transit systems can be operated commercially in case that the fare and non-fare revenue can cover the initial investment costs and operation costs. There are many private companies that operate their mass transit system on a commercial basis. However, the commercial operation of a mass transit system is generally difficult, and many transit systems in the world are operated as a public service by a public company, semi-public company, or private company with subsidies. In either case, public transport systems should be operated without deterioration of the level of services. Financial stability is one of the most important issues for the sustainable operation. Therefore, the following items should be considered for the system selection.

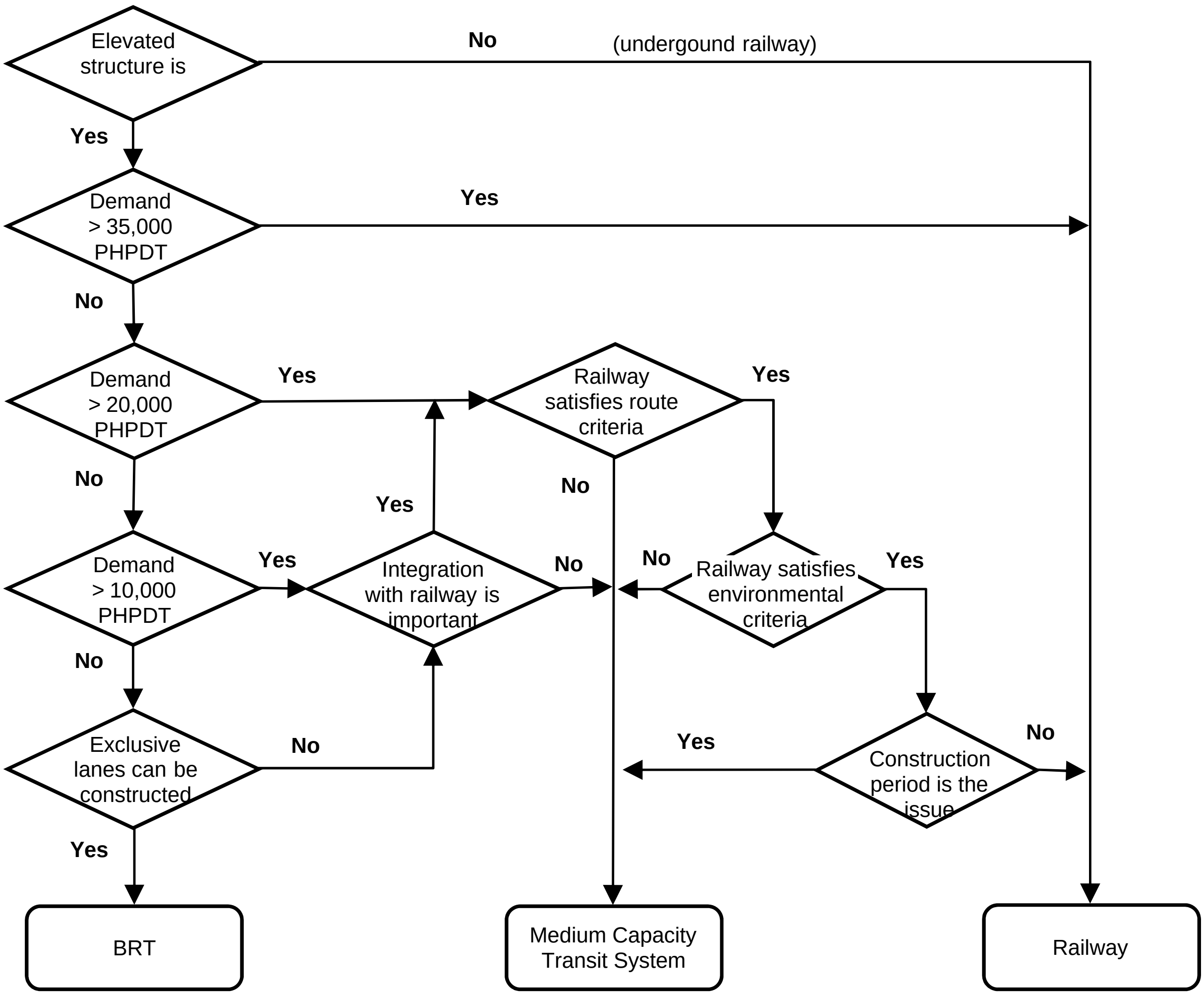
- Financial arrangement for the initial investment: The availability of international financing such as bi-lateral export-import banks and regional development banks is sometimes an important factor for the system selection.
- Future expansion: Generally, infrastructure of mass transit systems is designed in such a way that the future expansion is possible. However, a large scale investment compared to the present demand tends to be overinvestment. The necessity or compromise of the future expansion is also a criterion of the system selection.
- Proper O&M and re-investment costs: Low operation and maintenance (O&M) costs per passenger is one of the selection criteria, in addition to re-investment costs for new rolling stocks or replacements.

(7) Development Timing

The growth of megacities in the world is so dynamic that a project delay can cause a long term mess in the city while an early implementation of a project contributes to improvement of the congestion of the city. Sometimes, it is necessary to introduce a mass transit system with low cost but a short period implementation even if the lack of capacity in the future is expected. For example, there are several metro lines whose capacity is far below the traffic demand in Tokyo, but this does not mean that the projects were mistakes – the early implementation of mass transit systems contributed to the stable growth of the city. In 2010, Metropolitano commenced the operation and brought about a large scale impact on the city. The project is successful, although the system already shows saturation. In case that early implementation is very important, the system with low cost and short term construction period will be better than the project with high capacity and expensive cost that takes more time to be implemented.

(8) System Selection Chart

As described above, there are many factors to be considered to select the best system for a mass transit route. Multi-criteria analysis (MCA) is a popular technique to choose the best system among several alternatives under various conditions, when each alternative is applicable for the route. However, the system selection can be simplified in case of the selection among Light Transit, Medium Capacity Transit, and Mass Transit because traffic demand is the most important criterion. Figure 6.6 shows a system selection flowchart which is proposed in this study. If demand exceeds 35,000 phpdt, railway systems are selected. There is a chance that railway systems are not possible due to route conditions even if the demand exceeds 35,000 phpdt. Although this flowchart excludes such case, other systems should be considered, or the mass transit route should be reviewed. If demand is between 10,000 and 20,000 phpdt, introduction of a medium capacity transit system is recommended while other criteria should be considered if the demand is between 20,000 and 35,000 phpdt.



Source: JICA Study Team

Figure 6.6 System Selection Chart

6.1.3 Evaluation of the Present Plan

(1) Conventional bus and BRT

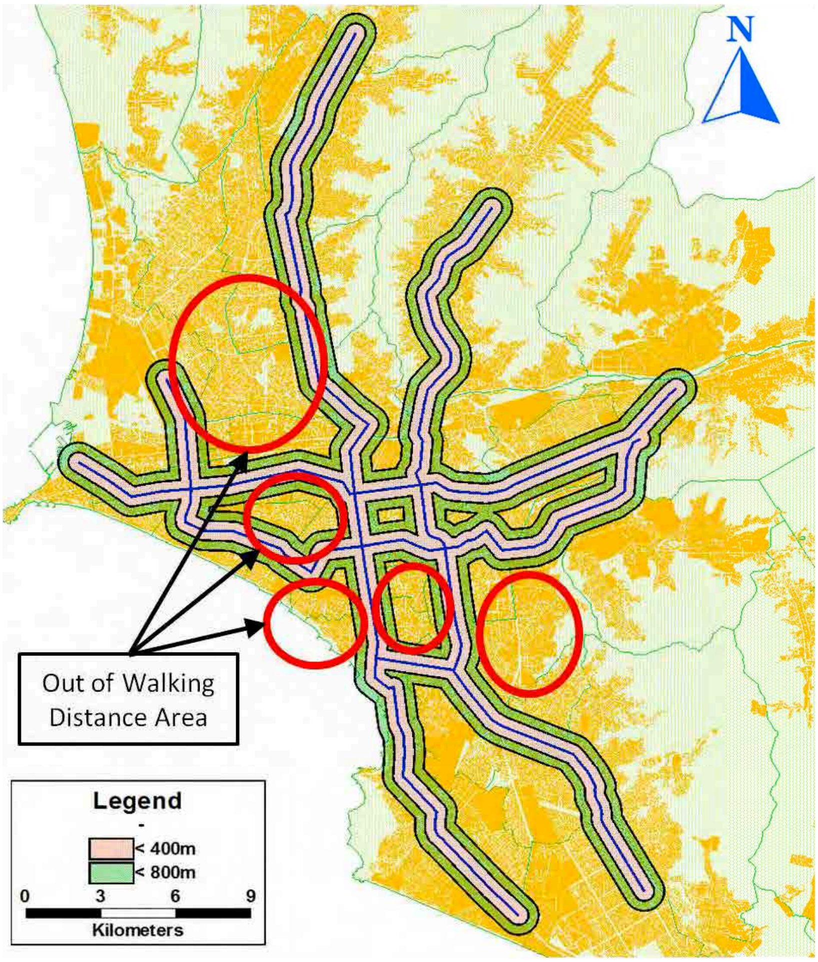
According to the Passenger Interview Survey, most passengers of conventional bus services would pay extra fare if their buses run faster while most BRT passengers are satisfied with the speed. Passengers' willingness to pay for 10 minutes travel time reduction was asked in the interview survey. 31% of BRT passengers answered that they would not pay while 4% of bus passengers answered the same way. This means that 31% of BRT passengers consider that travel speed is acceptable while most bus passengers are willing to pay for travel time reduction. The average value of the 10 minutes reduction is S/. 0.77 for BRT passengers, and S/. 1.11 for bus passengers. From this, travel time reduction is one of the important issues for conventional bus passengers. The service area of mass transit system should be expanded so that people can access to high speed transit systems.

As shown in Chapter 5, traffic demand along the major corridor is very high, and traffic congestion will remain in the peak hour even if the lines in the metro plan are constructed. Since BRT uses traffic lanes exclusively, the impact of the lane reduction on road traffic should be examined in detail in case of BRT projects. Although some parts of BRT can handle transport capacity of more than 10,000phpdt, BRT has a negative impact on road traffic by reducing the number of lanes. Moreover, its operation speed decreases when vehicles are operating with high frequency. In case of the Curitiba BRT where capacity is 20,000phpdt, average operation speed was less than 20km/h in 2007.

(2) Area of Influence

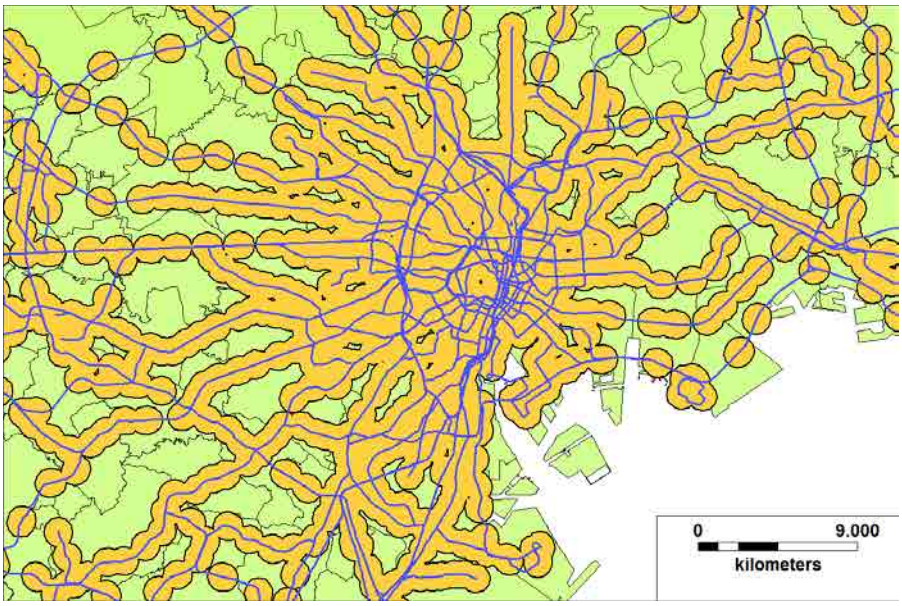
With the dense network of public transport services such as combi, minibus, and bus, the service area stretches over the Study Area. However, the service area of the mass transit systems such as BRT and Line-1 is limited to the corridors although feeder services can extend the service area. The railway network of the master plan can cover a large portion of the center of the city with its walking distance areas as shown in Figure 6.7. The bands in the figure show the area within a distance of 400m and 800m from each line. The distance of 800m would be the maximum walking distance in general. The access to the areas which are not covered with the bands is provided by feeder services. There is a blank area along Av. Universidad in the north of the Rimac River. This is a populated area, and the traffic demand is very high. Presently, this area is served by the feeder services of Metropolitano.

Figure 6.8 illustrates the walking area (800m) from railway stations in Tokyo. The center of the city is covered with the service area of the railway system.



Source: Elaborated by JICA Study Team

Figure 6.7 Walking Distance Area of Railway System in Lima

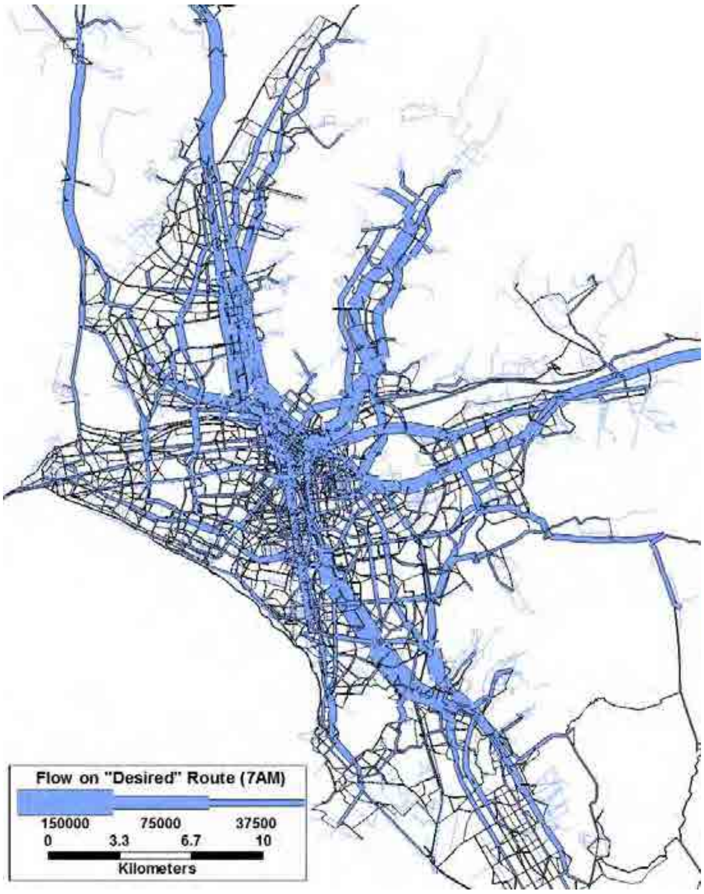


Source: Elaborated by JICA Study Team

Figure 6.8 Walking Distance Area of Railway System in Tokyo

(3) Demand Analysis

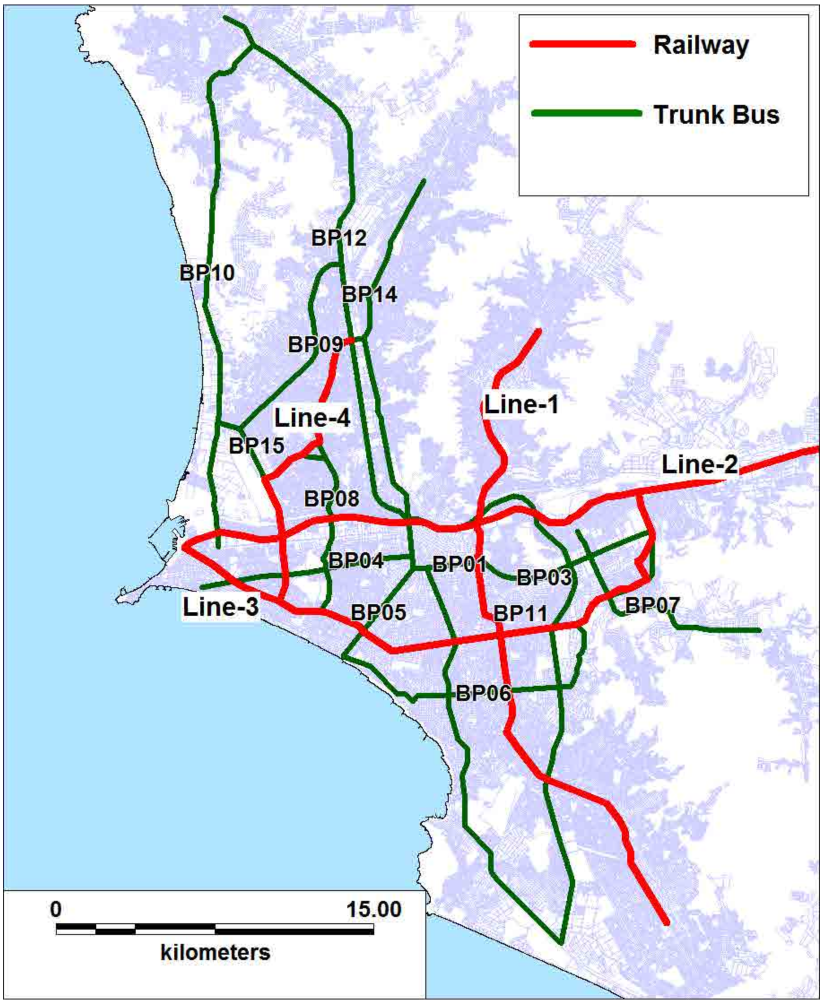
The traffic demand forecast is described in Chapter 5. The results show the present and future demands of each line of the railway system. The projected demand is influenced by the capacity condition of the highway network and fixed routes of the railway system. The selected routes in the traffic assignment are the best routes under the limited conditions. This means that it is the result of compromise of route choice. On the other hand, Figure 6.9 illustrates the desired routes, which are calculated by assigning travel demand to the route of the shortest distance. Therefore, this figure illustrates which route people really want to use. As can be seen, there is a high demand corridor in the north-south direction and an east-west corridor. The extension of Line-1 goes through the high demand corridor in San Juan de Lurigancho. The demand of the east part of Line-2 is also high. Line-3 also goes through the high demand corridor in the north-south direction. Other corridors with relatively high demand are found such as Av. Universitaria, Av. Nestor Gambetta and Av. Angamos Este.



Source: JICA Study Team

Figure 6.9 "Desired" Route at Peak Hour (7AM)

Figure 6.10 shows the proposed mass transit routes in PMTU 2025. The numbers of railway lines (from 1 to 4) are different from that of the present metro plan. The Trunk Bus "BP08" and a part of the railway "Line-4" runs through Av. Universitaria while BP06 runs through Av. Angamos Este. BP05, BP07, and BP10 also run through high demand corridor. The east part of "Line-2" also runs through the high demand corridor.



Source: PMTU 2025 (Illustrated by the JICA Study Team)

Figure 6.10 Mass Transit Routes in PMTU 2025

Since the present metro plan is different from that of PMTU 2025, the mass transit network should be rearranged.

Table 6.2 Proposed Rearrangement of PMTU 2025

No	PMTU 2025	Proposed Rearrangement based on Metro Plan in 2010
1	Line-1	Line-1 (same)
2	Line-2 (Conversion of the freight railway track to an urban transit system)	The freight railway will remain for freight transportation. The east part of “Line-2” (PMTU 2025) will be substituted by Line-2 (Metro Plan in 2010)
3	BP11, Line-3 and Line-4 (Emer Faucett)	Line-4 in Metro Plan in 2010
4	BP01 and BP04	Line-2 in Metro Plan in 2010
5	BP14	North part of Line-3 in Metro Plan in 2010
6	BP12 (Metropolitano)	Metropolitano and Line-3 (Since the demand of the corridor is larger than the capacity of Metropolitano, Line-3 is necessary.)
7	Line-4 (Av. Universitaria), BP08, BP06	A new mass transit route is recommended for this high demand corridor.
8	Others (BP03, BP05, BP07, BP10, BP15)	Trunk Bus System (not full-scale BRT)

Source: Proposal of the JICA Study Team

6.2 Study Route

6.2.1 Route Selection from the Metro Plan in 2010

The system selection chart in Figure 6.6 was applied to metro lines in the metro plan based on the demand forecast in Chapter 5 to select the study routes for the medium capacity transit system.

As shown in Table 6.3, a railway system is selected for Line-1 and Line-3. The extension of Line-1 is already under construction as the same system as the existing Line-1. Only railway system is possible for Line-3. There is a possibility that the demand of Line-3 decreases if another mass transit system is constructed in parallel with Line-3. Since Pan American Norte is too close to Line-3 (Tupac Amaru), Av. Universitaria is the candidate route for the parallel line. As described later, this route is proposed as Metro “Line-6”, and the demand analysis shows that the passenger demand of Line-3 will be larger than 35,000 even if the new line is constructed. Since applying an elevated structure is difficult along Line-3 due to the route conditions, railway system will be the only solution for this line.

The passenger demand forecast shows that both railway and medium capacity transit systems are applicable for Line-2, although only monorail is possible as the medium capacity transit system. However, the demand is close to the upper limit of the capacity of large-scale monorails, and the initial investment cost of the monorail would be larger than that of railways considering the larger number of necessary rolling stock. Based on the system selection chart, route conditions are studied in 6.5.2.

A medium capacity transit system can be selected for Line-4, but it is necessary to check the advantages of monorail because the initial investment cost would be similar between monorail and railway systems. This route is studied in 6.4.3.

The demand forecast shows that BRT or LRT would be suitable for Line-5, although Metropolitano runs in parallel with this line. A medium capacity transit system is possible if Metropolitano is not extended. Although railway systems are not recommended for this line, it is necessary to consider the system integration with Line-3 which should be constructed as a railway system. In any case, the priority of Line-5 is low among the five lines.

Table 6.3 Passenger Demand in 2030 and Selected System

	phpdt in 2030	System
Line-1	38,000	Railway
Line-2	34,000	Railway or Medium Capacity Transit System (Monorail)
Line-3	53,000	Railway
Line-4	20,000	Railway or Medium Capacity Transit System (Monorail)
Line-5	9,000	BRT/LRT

Source: JICA Study Team

Based on the analysis mentioned above, Line-2 and Line-4 are selected for the study of medium capacity transit system.

6.2.2 New Route

As described in 6.1.3, the service area of the metro network in the metro plan does not necessarily cover the center of the city, and rearrangement of mass transit routes in PMTU 2025 is recommended. Among the major routes, No. 7 in Table 6.2 runs through the area where the access to metro lines of the present metro plan is out of walking distance. This route is tentatively considered as "Line-6", and the passenger demand forecast, which is described in 6.5.4, shows that a medium capacity transit system is suitable for the new route.

As of 2012, Metro Line-2 is being designed as an underground railway. As a premise, it is expected that other Metro lines including Line-4 will be planned as underground railways in accordance with Line-2. Since the construction cost of an underground railway is very high, it is necessary to consider the economic benefits and financial viability. If BRT can cope with the passenger demand along the corridor, BRT can be a practical alternative system where the construction cost is lower than that of an underground railway.

On the other hand, a medium capacity transit system, which runs on a viaduct, has the following advantages. From this point of view, adding the medium capacity transit system as a candidate for the urban transport system in the Lima and Callao Metropolitan Area is recommended if it can cope with the passenger demand.

- It can fill the gap in capacity between BRT and railway.
- Construction cost is lower than that of an underground railway.
- Negative impacts on road traffic are lower compared with BRT.
- Operation speed can be kept higher than that of BRT.
- Applicable minimum curve radius is smaller than that of conventional railway. This will contribute to minimizing land acquisition.

The proposed medium capacity transit system and conventional railway can't run directly between mutual tracks. However, passengers can transfer easily and smoothly at transfer stations between the two systems by appropriate design of the station.

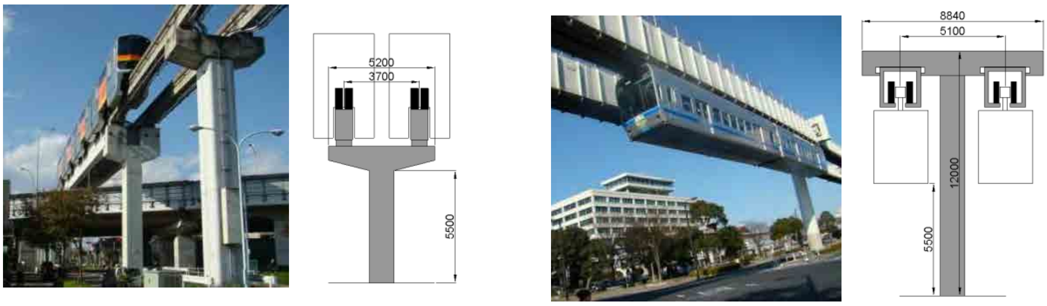
6.3 Advantages and Features of a Monorail

6.3.1 Selection of the Monorail

Because of the advantages described later, a straddle type monorail is proposed as the medium capacity transit system for the Lima and Callao Metropolitan Area. The straddle type monorail is a transit system in which cars straddle and runs along an exclusive elevated track beam by rubber tires.

Here, as shown in the chart above, there are two kinds of monorails, the straddle type monorail and the suspended type monorail. Each monorail is running on and below the exclusive track beam, and each track beam is made from pre-stressed concrete and metal, respectively.

The proposed monorail system for the Lima and Callao Metropolitan Area is the straddle type monorail of which the car length is approximately 15m, and train configuration is between 2 car-train and 6 car-train. The straddle type monorail is more advantageous in respect to construction cost than the suspended type monorail.



Source: JICA Study Team

Figure 6.11 Straddle Type Monorail and Suspended Type Monorail

As of September 2012, the straddle type monorail (hereinafter referred as “monorail”) is operating and/or being constructed in various countries including U.S.A., China, U.A.E, India, South Korea and Japan. In Sao Paulo, Brazil, the monorail has been selected for the urban transit system on the route where demand is expected to be 33,000phpdt.

As of 2012, there are 6 monorail lines for public transport in Japan. The total route length and ridership of these 6 lines in 2009 was 88.5km and 167 million passengers per year. The monorail is a proven transit system which has accumulated more than 48 years of operating experience in Japan.

6.3.2 Advantages of a Monorail

(1) High Flexibility in Route Alignment Condition

Owing to the use of rubber tires, the monorail system can cope with steep gradients and small curve radii, allowing flexibility in the design of route alignments.

Applicable maximum gradient on the main line of a monorail is 6%. This figure is steeper than the 3.5% of a conventional railway. Since the main part of the city of Lima and Callao is located on the fan-shaped plain of the Rimac River Basin, roads in Lima and Callao are generally flat except for the roads existing between the cliff-top and seashore. Therefore, with the monorail route, a steep slope section caused by topographical structures will not occur. However, in the sections where the monorail route crosses over the road flyovers and the viaduct of Metro Line-1, a slope section will occur. In these sections, in order to avoid an intrusion of the slope into the planned station area, short and steep slopes will be applied.

The applicable minimum curve radius in the main line of the monorail is 60m. This figure is smaller than half of that of conventional railways. Small curve radius can minimize the land acquisition and/or resettlement of inhabitants for construction purposes along the route.

(2) Environmentally Friendly

Owing to the use of rubber tires, the noise and vibration caused by the running of the train are significantly lower than those of a general railway running on steel wheels.

In comparison with the AGT system which also uses rubber tires, the superstructure of the AGT is a slab structure and which may affect the city landscape. Meanwhile, that of the monorail is of a slender track beam and impact to the city landscape by the existence of the structure is minimized.

Source: JICA Study Team

Figure 6.12 Monorail's Superstructure and Conventional Slab Structure

(3) Wide-ranging Transport Capacity

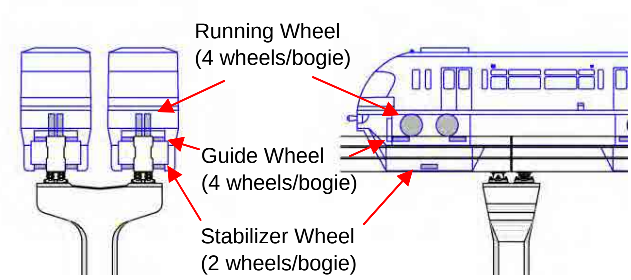
The monorail has large transport capacity among the medium capacity transit system and can transport up to 35,000 phpdt. The range of transport capacity of monorails is wide.

(4) Shortness of construction Period

The track beams of the monorail will be fabricated in the specialized factory, transferred to the installation site and erected. A construction period is shorter than that of other transit systems.

6.3.3 Features of a Monorail

A monorail includes the feature of bogies. A monorail bogie has 4 running wheels, 4 guide wheels and 2 stabilizer wheels. The guide and stabilizer wheels hold the track beam strongly, and it has stability against horizontal vibration. This gives it advanced performance not only on straight sections, but also on curved sections. In addition, the rubber tire and air spring between the car body and the bogie provide riding comfort. Furthermore, there are no derailments because straddling secures the cars to the track beam.



Source: JICA Study Team

Figure 6.13 Bogie and Track Beam of Monorail

6.4 Preliminary Design of a Monorail Car

6.4.1 Study Route

The following studies will be considered.

- Confirming the appropriateness of proposing the monorail for Line-2.
- Studying the technical feasibility and rough cost estimate of a monorail for Line-4.
- Proposing a new route for the monorail.

6.4.2 Rolling Stock

(1) Train Capacity

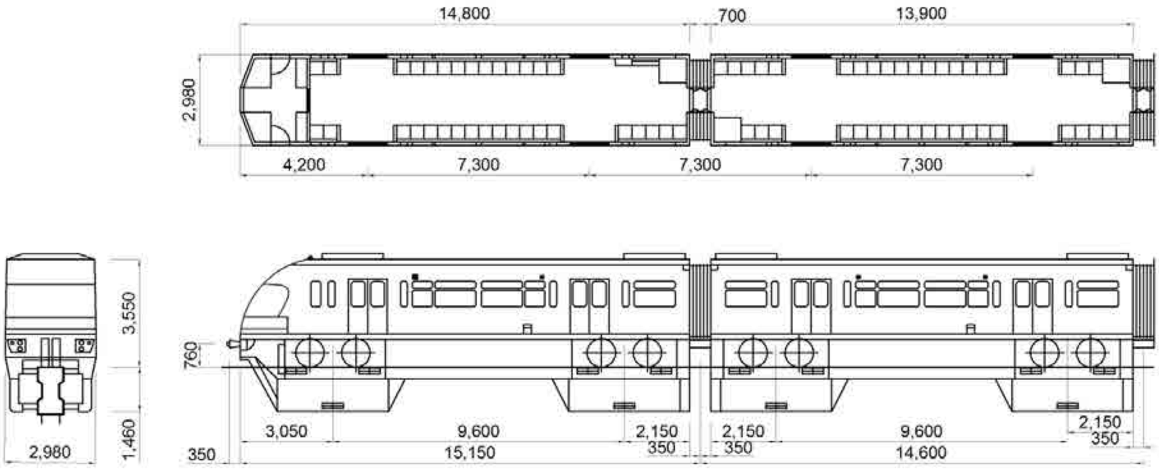
In order to meet the planned wide-ranging passenger demand, the train configuration of the monorail will be selected between 2-car train and 8-car train.

Source: JICA Study Team

Figure 6.14 Sample Photos of Train

Figure 6.15 shows an example of the seat arrangement of the monorail. Longitudinal seats will be applied as same as Line-1. Wheelchair spaces and the emergency equipment such as spiral chutes shall be positioned accordingly.

Seating capacity and passengers density for standees determine train capacity. Table 6.4 and Table 6.5 show the calculation of car capacity and train capacity, respectively. As for the passenger density of standees in a fully loaded condition, 6 passengers per square-meter is applied in accordance with Line-1,



Source: JICA Study Team

Figure 6.15 Dimension and Seat Arrangement of Monorail

Table 6.4 Car Capacity

	End car	Middle car
Seating capacity (passengers)	33	40
Space for standees	19.7 m^2	20.3 m^2
Number of standees	118	121
Car capacity (passengers)	151	161

Note) Standees: 6 passengers per square meter

Source: JICA Study Team

Table 6.5 Train Capacity

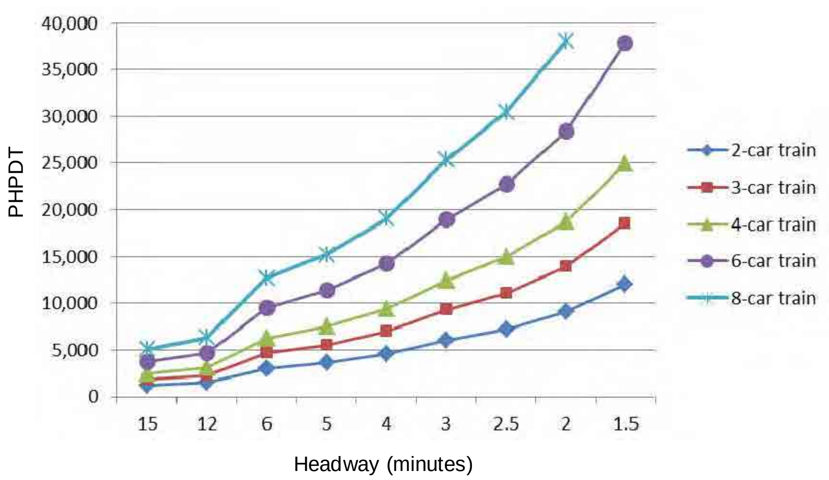
	2 car-train	3 car-train	4 car-train	6 car-train	8 car-train
Train capacity (passengers)	302	463	624	946	1,268
Train length	30.3m	44.9m	59.5m	88.7m	117.9

Note) Standees: 6 passengers per square meter
Source: JICA Study Team

(2) Transport Capacity

Based on train capacity, transport capacity by headway is calculated as shown in Figure 6.16. The monorail system can operate with a 1.5 minutes headway. However, in order to secure the margin for recovering a train operation when a train is delayed, operation by 2 minutes or more headway is recommended. Even if a 2-minute headway operation is adopted, 6 car-train and 4 car-train can carry 28,000phpdt and 18,000phpdt, respectively.

In addition, the train capacity of Line-1 is 1,260 passengers per train in a 6 standees/m^2 case. This train is a 6 car-train with a length of 107.4m, and the transport capacity as of August 2012 was 5,000phpdt with 15 minutes headway operation. Since the system can perform a 3-minute headway operation, the maximum performance of Line-1 will be 25,000phpdt.



Source: JICA Study Team

Figure 6.16 Transport Capacity

(3) Specification of Rolling Stock

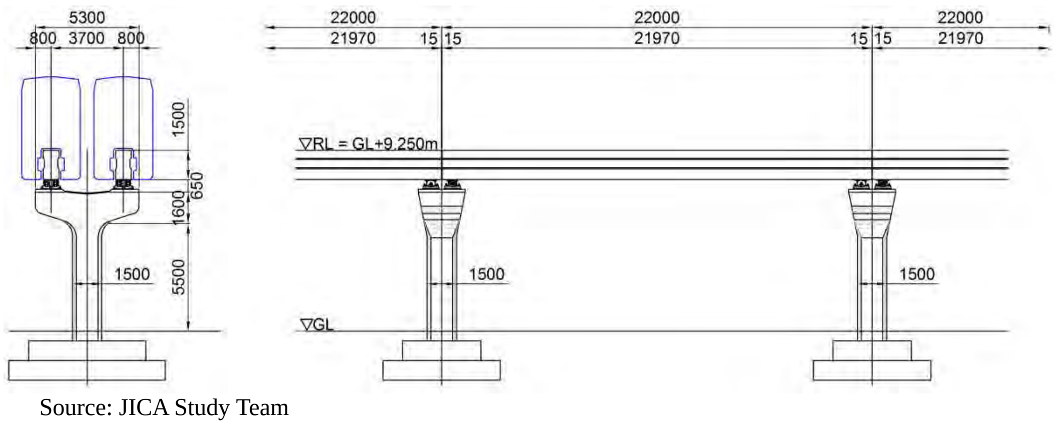
Table 6.6 Specification of Rolling Stock

Item	Features
Length	Mc:15.5m, M:14.6m
Width	2,980mm
Maximum Height	Mc:5,200mm, M:5,140mm
Weight	Mc:26.3tons, M:26.0tons
Passenger capacity (6pas/m2)	Mc: 151 (standees: 118, seated:33) M: 161 (standees: 121, seated: 40)
Electric method	DV 1500V, side catenary wire method)
Motor control	VVVF inverter control (with regenerative brake)
Traction Motor	Three phase squirrel-cage induction motor
Brake unit	Electric command electromagnetic straight liquid pressure converter air brake equipment
Maximum operation speed	75km/h
Acceleration	3.0km/h/s
Deceleration	4.0km/h/s
Maximum Gradient	6%
Minimum curve radius	R= 60m (Main line), R= 50m (Side track)
Door	2 doors/side
Gangway Door	Equipped
Air condition	Unit cooler on roof
Running Wheel	Nitrogen gas tubeless tire
Guided Wheel	Air Rubber tire
Stabilizer Wheel	Air Rubber tire

Source: JICA Study Team

6.4.3 Civil Structure

The civil structure of the monorail is mainly concrete which has a lower construction cost compared to that of a steel structure.



Source: JICA Study Team

Figure 6.17 Civil Structure

(1) Construction Standard

In this Study, a construction standard for the straddle type monorail which is being applied in Japan is used as a reference. As for the minimum curve radius in the main line, deviation from the Japanese standard to adopt a smaller radius of 60m is allowed when the suitable space for ROW cannot be allocated.

Table 6.7 Construction Standard of Monorail

Item	Description
Minimum curve radius	Main Line: R=100m (R=60m in unavoidable case) Station Platform area: R=300m Side track: R=50m
Minimum Transition curve length	$L = V^3/14R$ Where; L: Transition curve length (m) V: Vehicle running speed (km/h) R: Curve radius (m)
Superelevation (Cant)	$C=V^2/1.27R \leqq 12\%$, Permissible deficiency of cant is 5% Where; C: Equilibrium cant(%) V: Vehicle running speed (km/h) R: Curve radius (m)
Maximum gradient	Main Line: 60‰ Station Platform area: 5‰ (Level is desirable) Side Track: 50‰
Minimum VCR(m)	1000m
Minimum VCL(m)	15m
Minimum distance between tracks	W = 3,700mm, It shall be enlarged according to curve radius.

Source: JICA Study Team

(2) Superstructure

The typical superstructure of monorail is a slender track beam. The track beams adopted in this Study are of the following four types.

1) Pre-stressed concrete girder (PC girder)

The PC girder is a typical and standard type of monorail track beam. The PC girder will be pre-cast at the PC yard which is a specialized facility for PC girder fabrication. Subsequently, fabricated PC girder will be transferred to the installation site by trailer truck and erected by crane. In this Study, the maximum length of this track beam is defined to be 22m from the standpoints of transporting, fabricating and structural dynamics.

2) Reinforced concrete girder

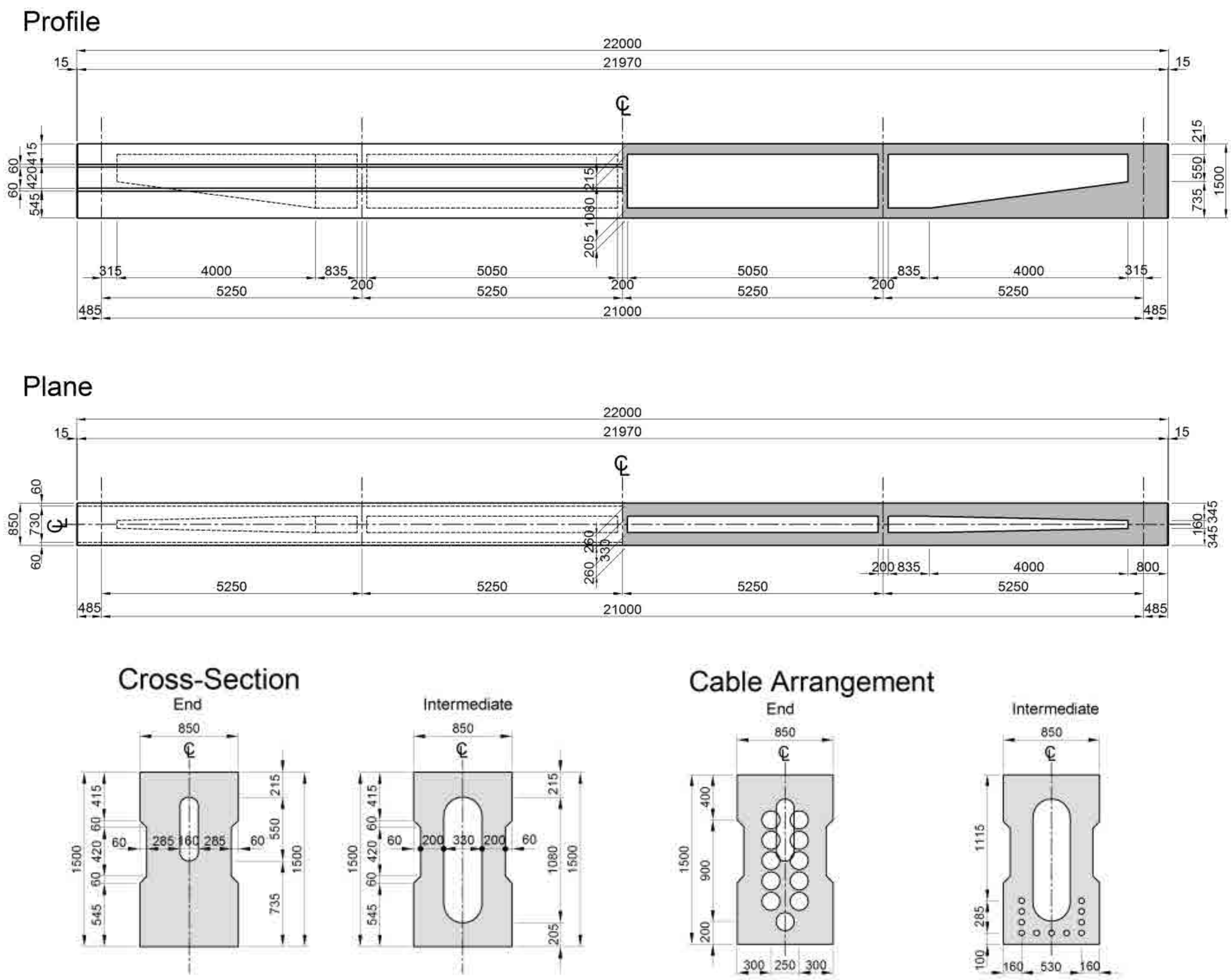
The reinforced concrete girder will be applied to tracks in the storage line in the depot. The span length is less than 10m.

3) Steel girder

The steel girder will be applied for crossing over roads where the span length is 50m or less.

4) Long span bridge

In the section where the span length exceeds 50m, a long span bridge of which the PC girders are installed on the upper surface will be constructed



Source: JICA Study Team

Figure 6.18 PC Girder

Source: JICA Study Team

Figure 6.19 Steel Girder

(3) Substructure

The Structural requirement of columns for the monorail is about 1.5m diameter in the case of circular piers, which can be accommodated easily in the central median of the road. The typical type of substructure is a T-shaped reinforced concrete column. At the points where the T-shaped column can’t be accommodated on the median strip, a portal type column will be adopted.

Vertical clearance of 5.5m over the road surface and below the column head shall be secured as the construction gauge of road traffic.

(4) Foundation

Footing foundation will be applied for monorail construction.

As for the soil conditions for the railway structure of the Lima metro, the following parameters have been described in PMTU-2025.

a) Most of the areas 1.5m below the natural ground level, and in some other cases, will lie on conglomerated material.

b) The load bearing capacity of the ground soil will obtain considerations of more than 40 ton/m^2; this value is enough to support the construction of a viaduct structure and an elevated station building without any piling.

Also, according to AATE, the Line-1 extension section is adopting the footing foundation.

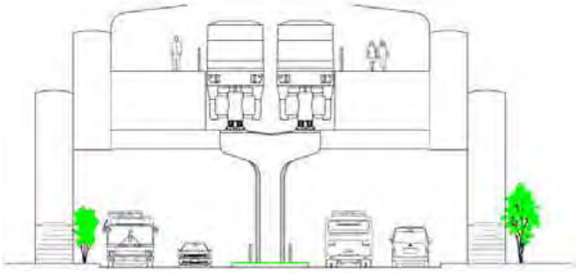
(5) Switch Bridge

A switch machine will be equipped on the concrete hollow slab of the switch bridge.

6.4.4 Station

Elevated stations with separated type platform are proposed for the intermediate stations.

Compared with an island type platform, the separated type platform is advantageous from the viewpoint of alignment settings since no funnel shape section is required at the front and back of the station. Although the station size shall be determined by the train length and passenger volume, the platform length is assumed to be as the same as the train length in this Study.



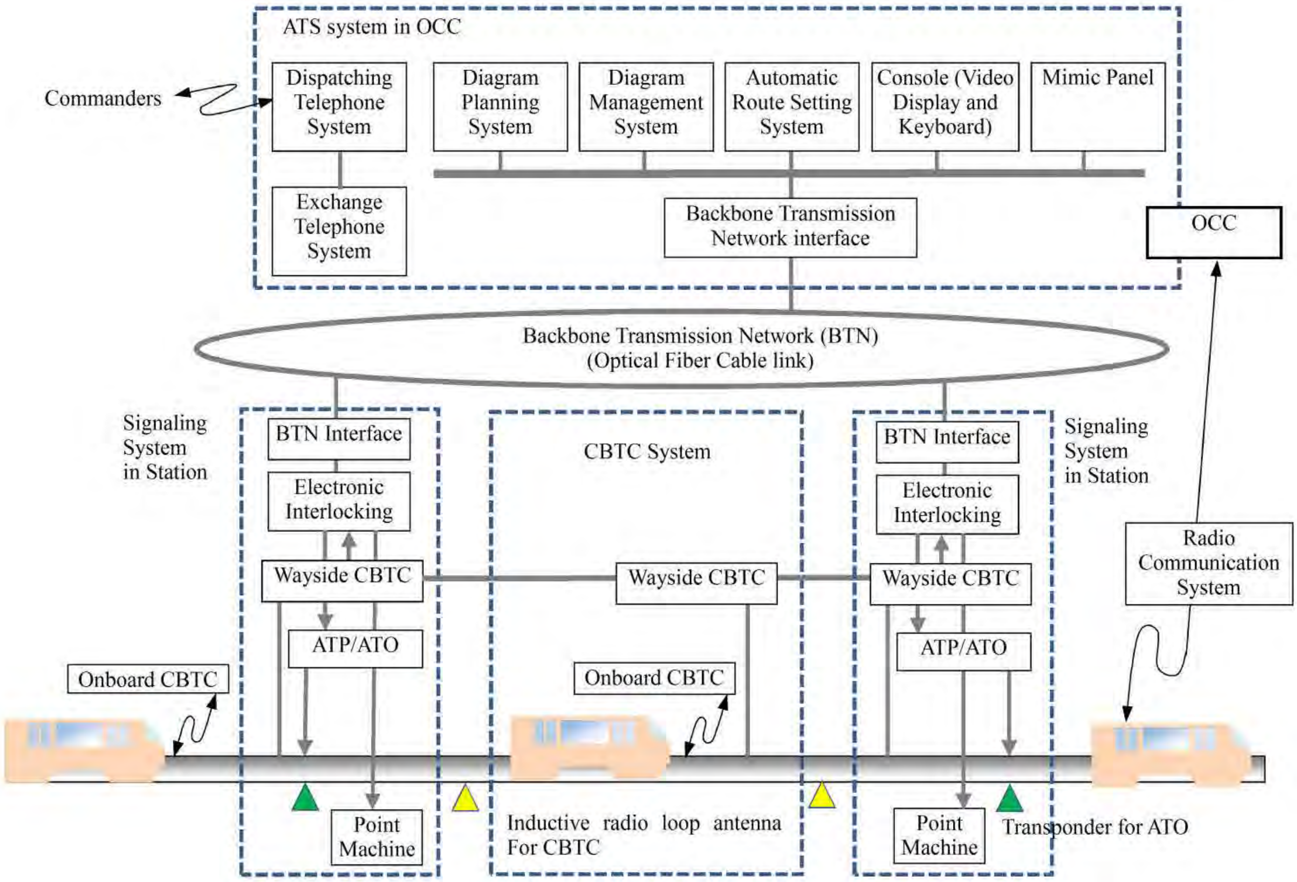
Source: JICA Study Team

Figure 6.20 Separated Type Station

6.4.5 Signaling System

(1) Outline

It is proposed that an Automatic Train Operation system (ATO) with a train driver be introduced. The trains will be operated automatically by the ATO on the main line and cab signal with a Communication Based Train Control system (CBTC) will be used. The train driver only monitors the ATO and makes sure of ahead safety visually, and in the case of a failure or emergency, he operates the train manually after changing from ATO mode to manual mode. On the other hand, the shunting in the station yard and the depot access line will be operated manually. An Automatic Train Protection system (ATP) will be used between the main line and the depot storage line while wayside signal will be used between the storage line and the workshop.



Source: JICA Study Team

Figure 6.21 Outline of Signaling System

(2) CBTC

CBTC is one of the signaling systems based on the new principle that is detecting locations on-board itself and moving block system without fixed block system depending on the conventional train detection system using inductive loop antenna.

CBTC allows to minimize the interval safe length between trains ahead and behind in accordance with their speed and also to increase the traffic density without modifying the signaling system.

Therefore, CBTC is recommended as an applicable signaling system which can minimize the train headway at a lower cost than that of a conventional fixed block system. The outline of the CBTS system is as follows.

1) Train detection system

The characteristic of the CBTC system is that a train detects its location by itself. The principle of train location is the calculation of running distance from a tachometer attached to a tire wheel and beacon or transponder which transmits the absolute locations.

On wayside passive transponder will be installed. The necessary equipment for the CBTC for train detection is less than that of a conventional signaling system.

2) ATP function

The ATP on-board system automatically calculates the brake profile in accordance with the distance to the preceding train, and continuously controls the speed of the train on which the ATP is installed. This block system is called “Moving Block system”.

The train headway of a conventional ATP depends on the block length, but the headway of the CBTC system does not depend on the block length. The safety interval distance changes in accordance with the movement of the preceding train.

3) Communication between train and ground

Among the various methods for communication between the train and ground, an inductive radio loop method for communication for the CBTC is recommended. On board antenna and loop antenna at the ground are always coupled keeping a constant gap. Therefore, this method is steady against outer wave noise. It is better to select this method because the monorail route passes through the noisy environment of airplane communication.

Induction radio method is already used for train detection and ATP system of conventional signaling system for monorail and is a matured communication technology.

6.4.6 Telecommunication System

The telecommunication system has a feature that can be commonly utilized for every transport mode such as MRT, LRT and monorail. The objective of the telecommunication system is to secure a safe and efficient train operation and business environment.

The telecommunication system consists of 7 sub-systems

1) Radio communication system
2) Telephone system
3) Closed Circuit television (CCTV) System
4) Passenger Information System (PIS) and Passenger Address (PA)
5) Clock System
6) Backbone Transmission Network (BTN)
7) OA and IT system which consists of OA network and client PC

6.4.7 Electric Power System

(1) Outline

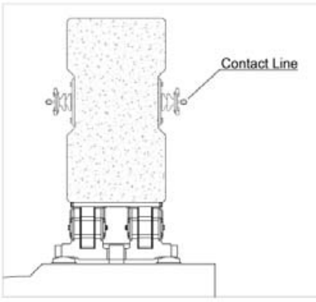
The Receiving substation receives the electric power of AC20 KV from an electricity supply company, changes this to DC 1500V and then sends the power to the contact line. In addition, the substation exchanges it to the distribution power for the facilities and equipment of stations, the depot, and along the track. The main functions of substations are controlled by the remote supervisory control system of the Operation Control Center (OCC).

(2) Feeding circuit

The parallel feeding system is adequate to maintain the system in case of a voltage drop and raise the efficiency of regenerating system.

(3) Contact line system

The contact line is laid on both sides of the girder of the viaduct. The contact line is composed of aluminum trestles and copper contact wires because aluminum and copper are excellent in regards to weather resistance and electric conductivity.



Source: JICA Study Team

Figure 6.22 Contact Line

6.4.8 Depot

In the depot, storage tracks, maintenance tracks, a workshop and an Operation Control Center will be allocated. The size of the depot will be determined by train length and number of train sets.

Main maintenance facilities are summarized below.

1) Overhead Traveling crane (10t x 2, 7.5t, 2.5t)
2) Compressor
3) Bogie Drop
4) Car washing machine
5) Bogie Air Blowing Machine
6) Movable Air Blowing Machine
7) Battery Charger
8) Various Testers
9) Scissor Lift
10) Cargo Lift Trolley
11) Trolley for Car Parts
12) Forklift

6.4.9 Operation Control Center

The Operation Control Center (OCC) will be provided in the Depot for the centralized traffic management of the monorail lines. The Automatic Traffic Supervision System (ATS) and Telecommunication System will be installed in OCC for the automatic control of trains in accordance with the train schedule.

6.5 Route Study

6.5.1 Summary

Target routes of the concept study are Line-2, Line-4 and a proposed route.

Regarding Line-2, as a consequence of confirming the appropriateness of proposing the monorail, operation of the monorail is technically possible. However, if the monorail is selected, an elevated system is recommended instead of an underground system from the view point of construction cost saving. Also, the elevated stations of which platform length is 150m are required because of the large passenger demand.

Outline of Line-4 and a proposed route are described below.

Table 6.8 Outline of Line-4 and proposed Route

Item	Line-4	Proposed Route
Route length	29k500m	29k900m
Station	32 stations	35 stations
Passenger demand	25,000 phpdt	18,000phpdt
Train Operation	6-car train 2 minutes headway	6-car train 3 minutes headway

Source: JICA Study Team

6.5.2 Line-2

(1) System and Route Alternatives

According to the bidding conditions for hiring a consultant for the comprehensive tender of the Metro Line-2 project (April 2012, Ministry of Economy and Finance, Procurement and Contracting Standing Committee), for Line-2, underground EMU (Electric Multiple-Unit), which is a conventional railway running with steel wheels and steel rail, has been selected. Three alternative routes to be evaluated have also been indicated as quoted below.

1) ALTERNATIVE 1

Line-2, including access to the Airport Jorge Chavez, which goes from Elmer Faucett Avenue between Venezuela Avenue and Nestor Gambetta Avenue. Line-2 will consider the layout through 28 de Julio Avenue according to the Basic Network established in D.S. 059-2010-MTC.

2) ALTERNATIVE 2

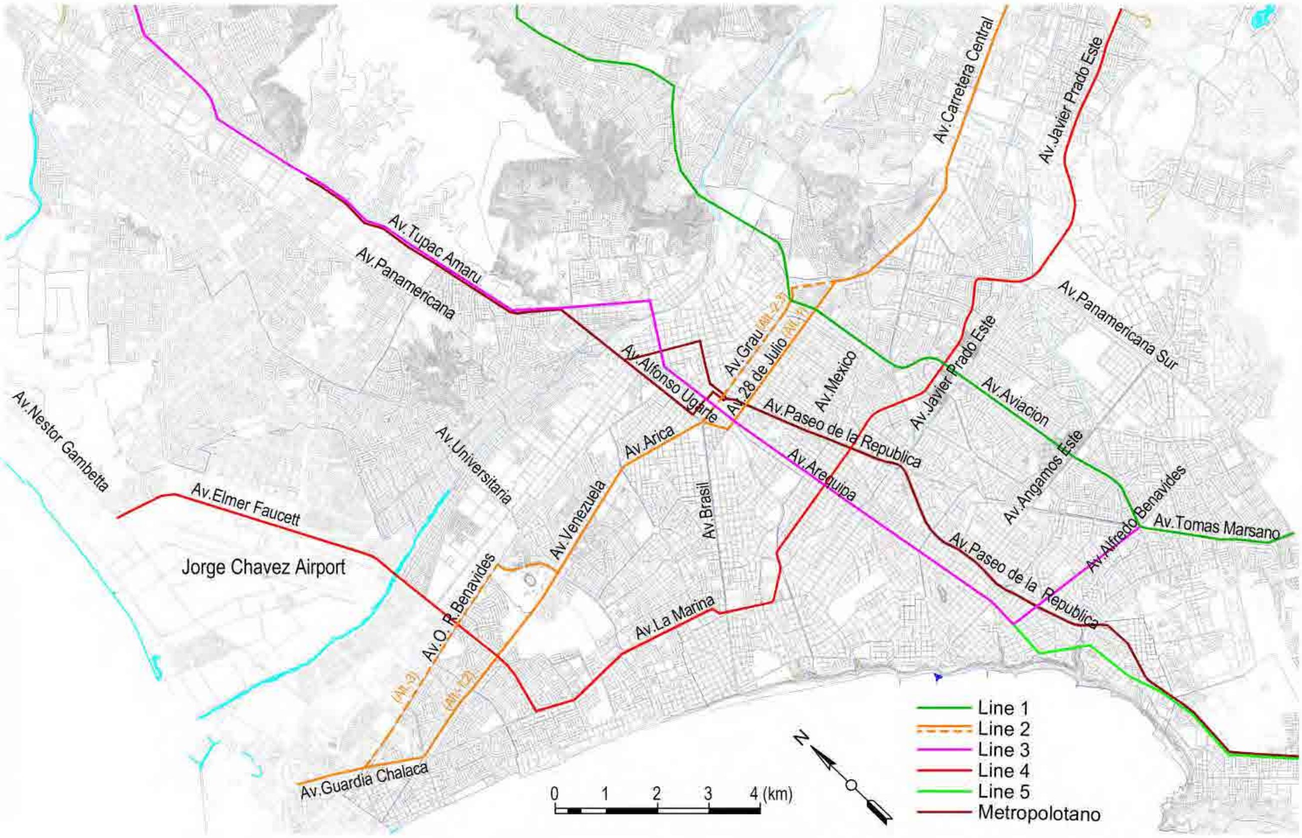
Similar to the above (Line-2 including access to the Airport), however, it will consider the layout through Victor Raul Haya de la Torre Avenue (Central Highway), Nicolas Ayllon Avenue, Calle Junin, Grau Avenue, 9 de Diciembre Avenue, Arica Avenue, Venezuela Avenue and Guardia Chalaca Avenue. This section considers the axis of the

Grau Expressway, through Central Station of COSAC I and Grau Station of Line 1 of the Metro of Lima, instead of the layout along 28 de Julio Avenue.

3) ALTERNATIVE 3

Layout considering the following axis: Victor Raul Haya de la Torre Avenue (central Highway), Nicolas Ayllon Avenue, Calle Junin, Grau Avenue, 9 de Diciembre Avenue, Arica Avenue, Venezuela Avenue, German Amezaga Avenue, Oscar R. Benavides Avenue (Colonial), Guardia Chalaca Avenue. It is also necessary to include access to the Airport Jorge Chavez, which goes from Elmer Faucett Avenue between Oscar R. Benavides Avenue (Colonial) and Nestor Gambeta Avenue. This section considers the axis of the Grau Expressway, through central Station of COSAC I and Grau Station of Line 1 of the Metro of Lima.

Each alternative is illustrated in Figure 6.23. Airport access is a precedent of Line-4 and is included in each alternative.



Source: JICA Study Team

Figure 6.23 Route Map of Metro Line

According to MTC, Alternative-1 (Av. 29 de Julio) was selected for the east part of the route while Alternative-3 (Av. Oscar R. Benavides Avenue) was selected for the west part.

(2) Alignment Condition

The following alignment conditions are described in the bidding conditions.

- Minimum curve radius: 250m

- Distance Between track center: 3.8m
- Maximum Gradient: 3.5%

This condition is not possible if the railway is constructed as an elevated structure because of the route condition. In case of monorails, the curve at the intersection of Av.Grau and Av. Aviacion should be over the existing Line-1 with a small radius to keep a distance from surrounding buildings. Since the alignment condition is harsh, Alternative-3 (Av. Grau) is not recommended for the monorail route. The alignment along Alternative-1 (Av. 28 de Julio) also faces problems because the width of the road is narrow.

(3) Passenger Demand

The passenger demand of Line-2 in 2030 is estimated at 34,000 phpdt, although the forecast varies depending on the alignment. If the proposed “Line-6” is constructed, the demand will increase to 35,000 phpdt. The high passenger flow is estimated between the transfer stations with Line-3 and Line-1. The demand forecast assumes that a flat fare system is applied for all railway lines and the monorail line.

(4) Depot

A depot will be constructed in the Santa Anita district, on the eastern side of the route.

(5) Right-of-Way

The road where the route is planned is almost level and has 6 or more lanes except for Av. 28 de Julio, which is one way with 3 lanes.

(6) Technical Feasibility of Monorail for Line-2

The monorail is not recommended for the underground track. From the technical point of view, the monorail can run underground and comply with stricter condition than the designated alignment condition of Line-2. However, since the height of the monorail car is higher than that of a conventional railway, the cross-section area of the tunnel become proportionally bigger. This causes construction cost to rise. So, the monorail is not recommended for the underground track if no other significant advantages can be found compared with the other systems.

Even if the elevated structure is approved instead of the underground tunnel, the passenger demand of Line-2 is exceeding the transport capacity of a monorail of a reasonable train length, although the monorail can carry the demand of 35,000phpdt if 8 car-trains are adopted.

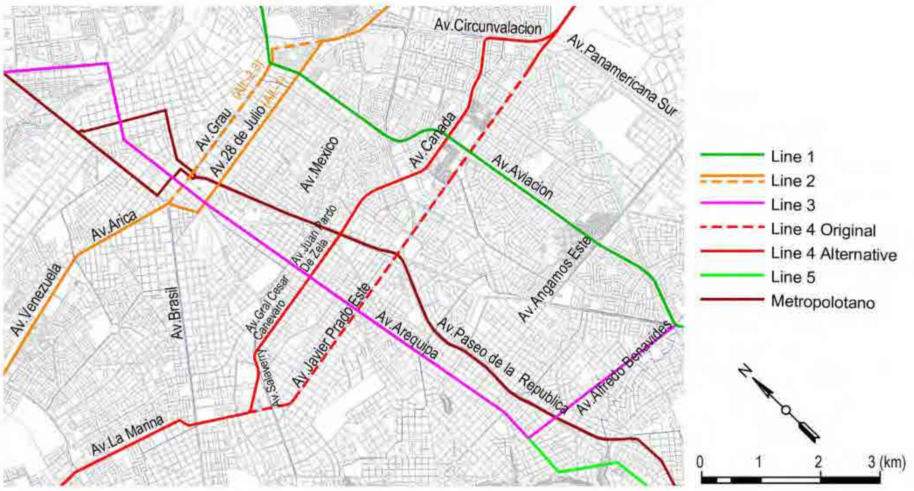
The columns of the railway substructure can be built in the central reservation of the road. Generally, the monorail is more advantageous than an elevated conventional railway from the view points of the flexibility of the route alignment and the effect on city landscape. However, in the case of Line-2, this advantage of the conventional railway is not clear because the route alignment will be almost level.

6.5.3 Line-4

(1) Route

According to the D.S. 059-2010-MTC, Line-4 will be located on Elmar Faucett Avenue, De la Marina Avenue and Javier Prado Avenue, and will connect the Airport Jorge Chavez and the eastern side of the city of Lima. An airport access section, which passes through Elmer Faucett Avenue, is a preceding construction section and is being included in the scope of Line 2 construction.

Meanwhile, a highway construction project by concession contract is being planned under Javier Prado Avenue. Since Line-4 will conflict with this underground highway project, an alternative plan of Line-4 which passes through Ciclovia Salaverry Avenue, Jose Pardo De Zela Avenue, Canada Avenue and Circunvalacion Avenue, instead of Javier Prado Avenue is considered. In this Study, an alternative plan shown below is regarded as Line-4.



Source: JICA Study Team

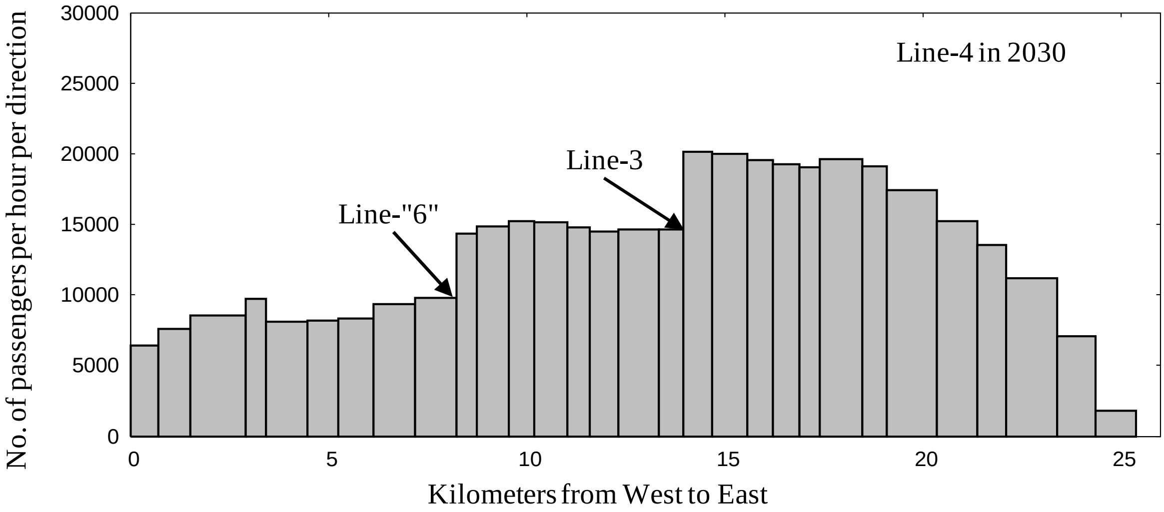
Figure 6.24 Line 4 Alternative Plan

On the other hand, the route alignment near the intersection of Line-2 and Line-4 will become complicated. Line-2 will be constructed underground, and an airport access section of Line-4 will also be underground. If no other line connects to this branching point, an airport access section can branch off from Line-2 at the same level. However, since Line-4 will connect to this point from the southern side in future, Line-2 and Line-4 shall be crossed by a grade separated intersection. This means that large scale underground construction at the intersection of 2 lines will be unavoidable.

In this Study, an alternative plan shown in Figure 6.24 is regarded as Line-4, and Line-4 monorail is planned as an elevated railway which can reduce the construction cost compared with underground railway. An elevated Line-4 monorail will also mitigate the construction cost at the intersection mentioned above.

(2) Passenger Demand

Passenger demand of Line-4 in 2030 is estimated at 20,000 phpdt. The passenger demand increases at the transfer station with Line-3 by approximately 7,000 passengers. Figure 6.25 shows the passenger flow of the peak direction of Line-4 in 2030 in case that the proposed Line-6 is constructed.



Source: JICA Study Team

Figure 6.25 Peak Hour Passenger Flow of Line-4 in 2030 (West to East)

(3) Depot

A depot will be constructed on the government land which is beside the Airport Jorge Chavez.

(4) Technical Feasibility of Monorail

1) Outline of Line-4 monorail Plan

From the technical point of view, monorail is recommended as an elevated railway on Line-4. Table 6.9 shows an outline and assumption of the Line-4 monorail plan.

Table 6.9 Outline and Assumption of Line-4 Monorail

Item	Description
Route Alignment	
Route Length	29k500m
Number of Stations	32 stations
Small curve radius section (less than 300m)	100m: 3 sections 150m: 1 section 300m: 3 sections
Steep gradients section (i=6%)	1 section
Steel girder section	31 sections
Long span bridge	1 bridge
Service	
Estimated demand	25,000 phpdt
Schedule speed	35km/h
Train configuration	6-car train
Headway	2 minutes
Transport capacity	28,300 phpdt

Source: JICA Study Team

2) Advantage of monorail

A monorail can be proposed for Line-4 and has the following advantages compared with other elevated transport systems

- In the section passing through Ciclovia Salaverry Avenue, Gral Cesar Canevaro Avenue, Jose Pardo De Zela Avenue, Canada Avenue and Circunvalacion Avenue, small radius curves will be installed. The monorail can cope with 60m as the minimum curve radius. This performance can minimize the land acquisition and resettlement of inhabitants for construction purposes.

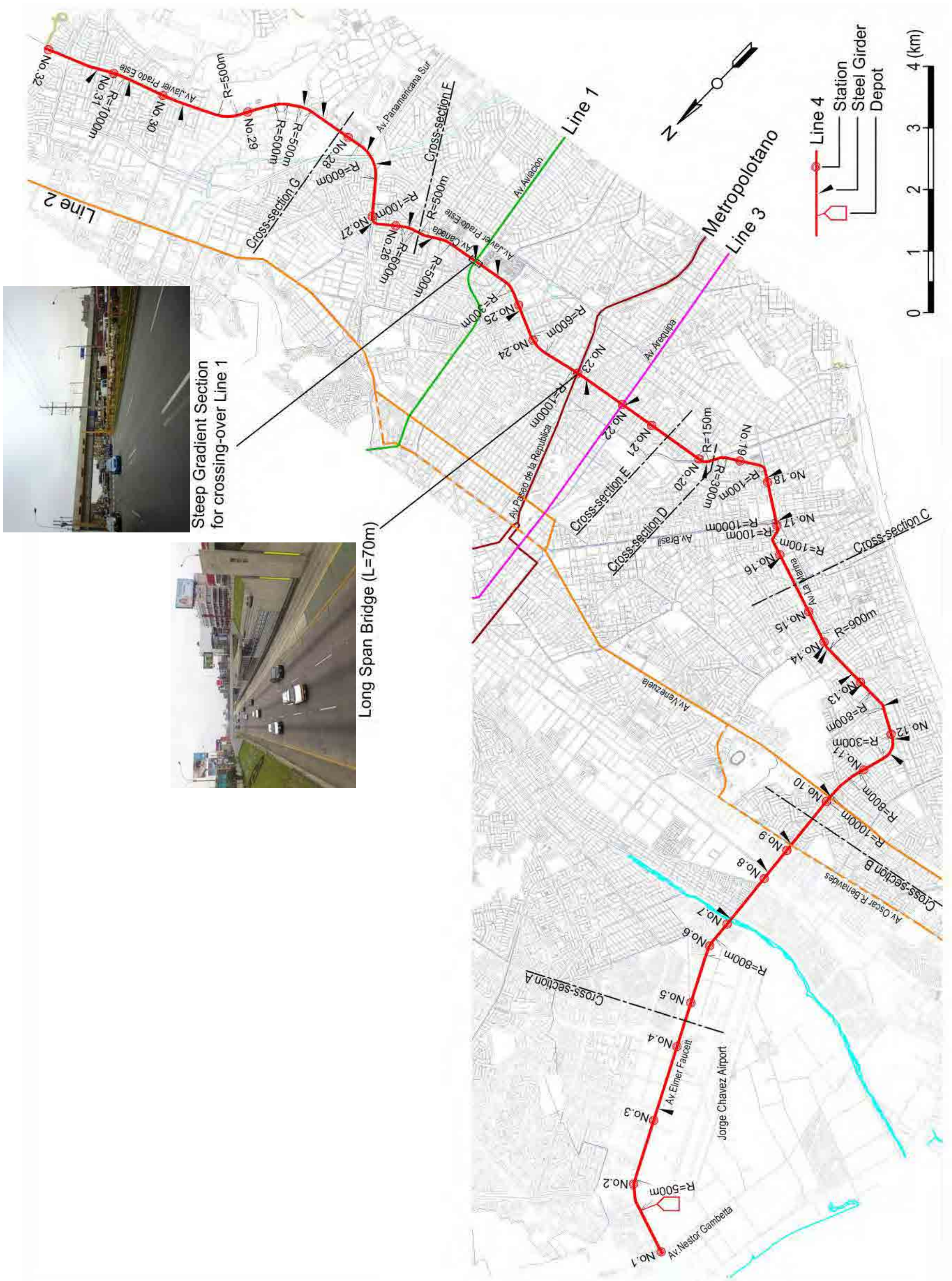
- In Canada Avenue, a steep gradient will be set in order to cross over the viaduct of Metro Line-1. The monorail can cope with 6% as maximum gradient.

- Road width of Ciclovia Salaverry Avenue and Jose Pardo De Zela Avenue is relatively narrow. Existence of the structure of the monorail will no more affect the city landscape than that of other systems that have a slab structure.

- A 6 car-train of the monorail in which train length is 90m can cover the demand of 35,000phpdt.

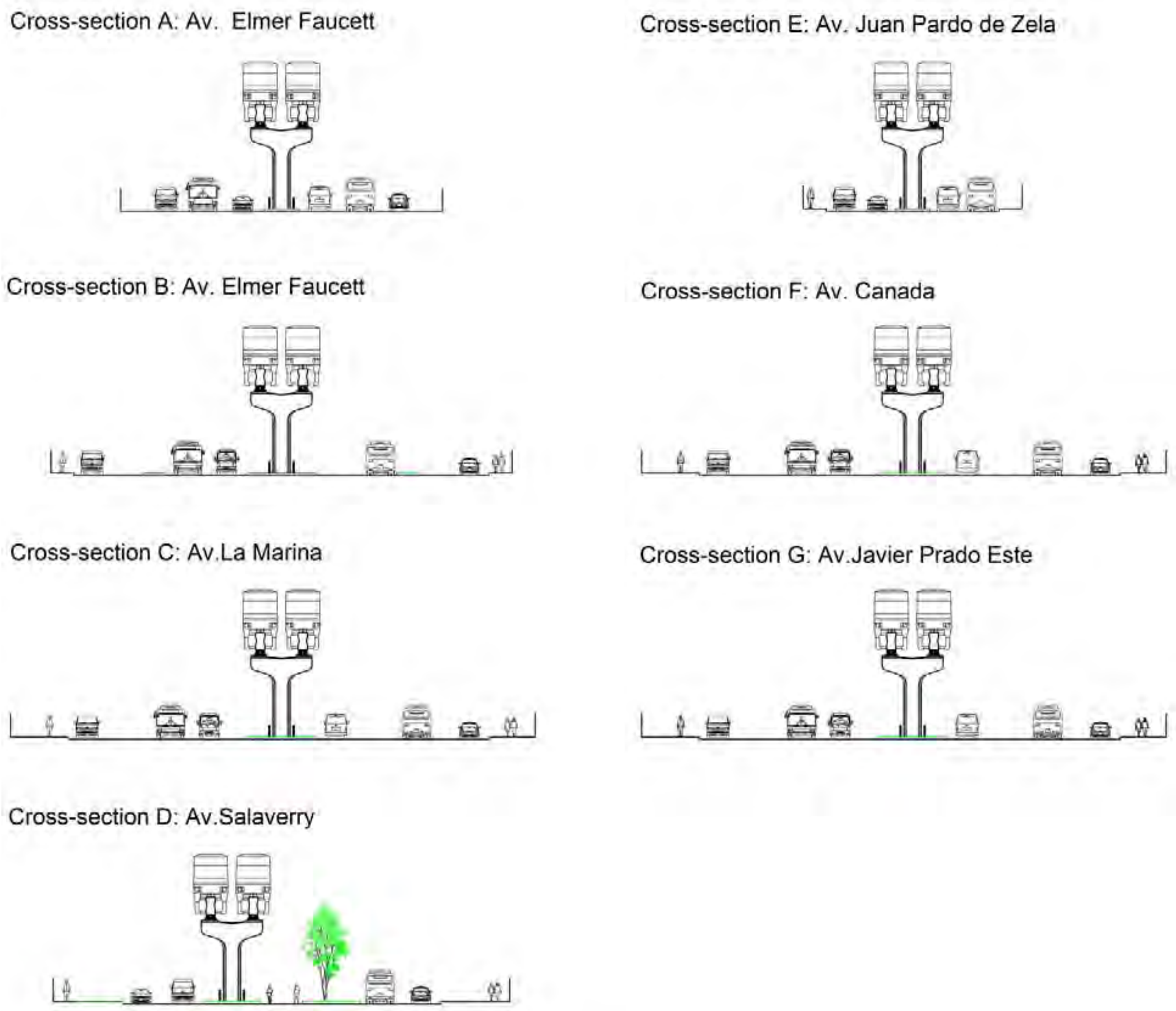
Meanwhile, when the monorail is selected as the system of Line-4 instead of a conventional elevated railway, the following disadvantages will appear.

- Direct train service between Metro Line-2 and Line-4 is impossible. For passengers' easy and smooth transfer, a transfer station shall be designed appropriately.
- Dedicated monorail depot is required.



Source: JICA Study Team

Figure 6.26 Line-4 Monorail Route



Source: JICA Study Team

Figure 6.27 Cross-section of typical section of Line-4

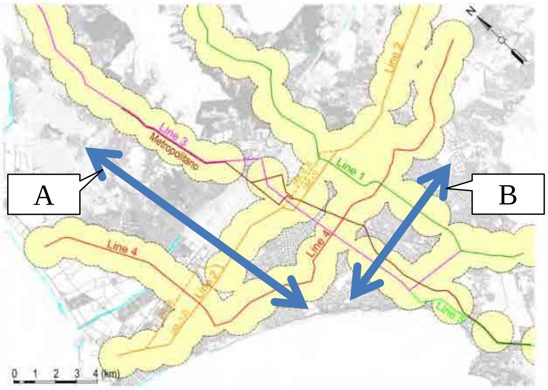
6.5.4 New Proposed Route (Metro Line-6)

(1) Procedure for Route Selection

In addition to Line-4, a proposed route described below is included in the target routes of the concept study of the medium capacity transit system. The proposed route is selected from the routes which will contribute to improvement of urban transport in the Lima and Callao Metropolitan Area, of which the expected demand is between 10,000 and 30,000 phpdt. The main line should be an elevated double track line. Basically, the track of the main line should be constructed within the public space above road.

The proposed route was selected by the procedure shown in Table 6.10.

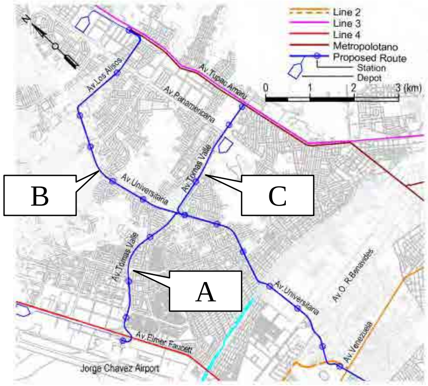
Table 6.10 Procedure of Proposed Route Selection



Upon checking the blank areas of the public transport which are not covered with the effective area of Metro lines, the following 2 blank areas were found.

A) area along Av. Universitaria (North-South axis)
B) area along Av.Angamos Este (East-West axis)

Based on this, a proposed route was set on Av. Universitaria and Av. Angamos Este.
(In this figure, the effective area was assumed as 1km from each station.)



As alternatives to the northern-end of the route, the following 3 routes were considered.

A) Approach to Naranjal station of Metropolitano.
B) Approach to Airport Jorge Chavez
C) Long distance bus terminal (Gran Terminal Terrestre)

Based on the evaluation of passenger demand forecast, alternative B was selected.

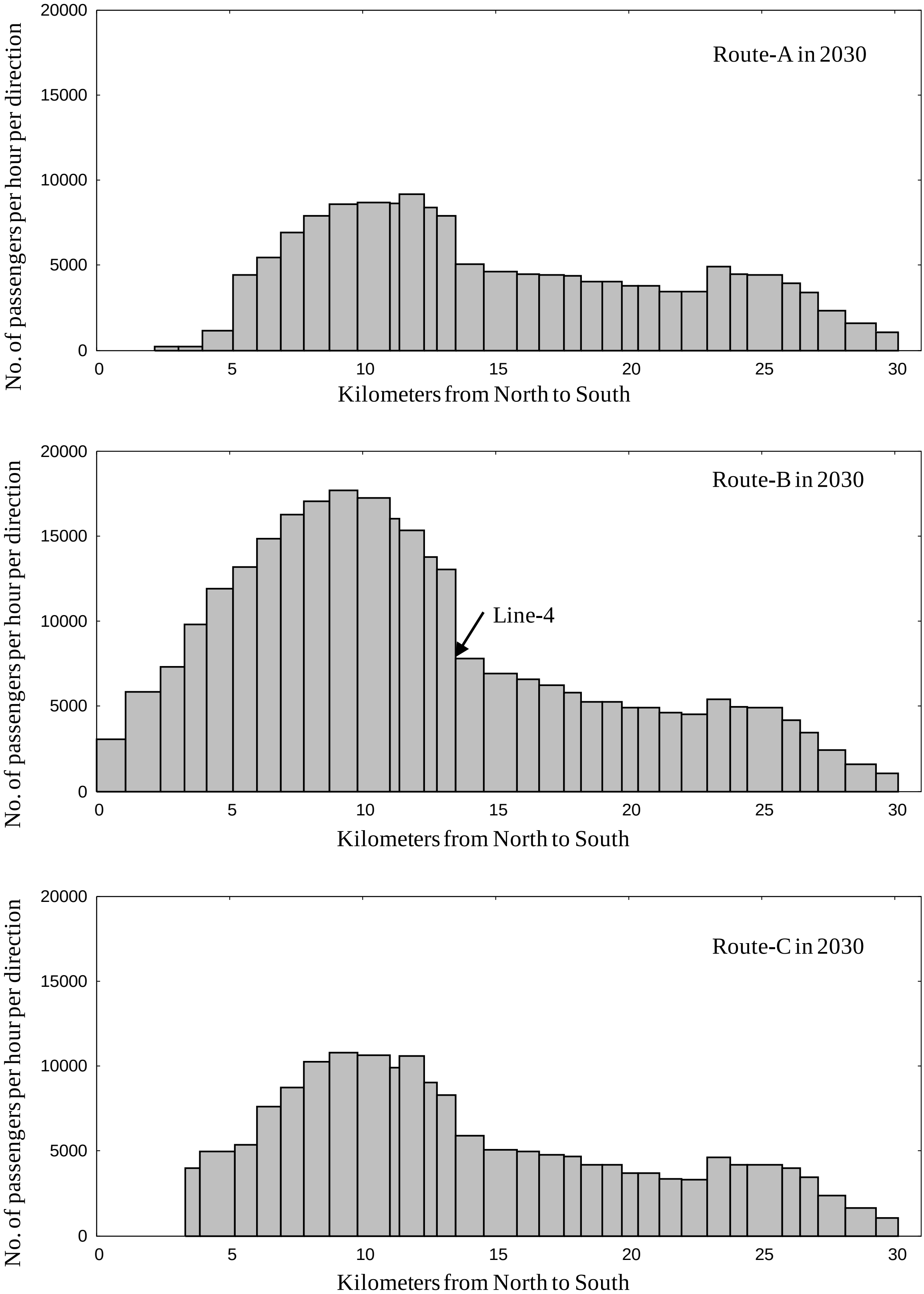
Source: JICA Study Team

(2) Passenger Demand

Passenger demand forecast was carried out for the three alternatives of Route-A, B, and C. The same network, OD matrices, and parameters in Chapter 5 were employed. The mass transit network of the demand forecast consists of Metropolitano, five metro lines in the metro plan in 2010, and each alternative route of Metro Line-6. It is assumed that the fare system of Line-6 is the flat fare of S/. 1.5, allowing free transfer to other metro lines.

Figure 6.28 shows the passenger flow each alternative in the morning peak hour for the peak direction. The peak direction is from north to south for all alternatives. The peak passenger flow of Route-A is less than 10,000 phpdt while that of Route-C exceeds 10,000. In case of Route-B, the peak passenger flow is approximately 18,000. The demand of Route-A is small because the airport access does not necessarily contribute the morning peak traffic. The demand of Route-C will be larger than that of Route-A because it is connected to the long distance bus terminal. Route-B can collect many passengers along University Road, and the peak flow will reach approximately 18,000.

Passenger flow drops at the transfer station to Line-4. In case of Route-B, passenger flow from the transfer station to the south and Av. Angamos Este will be 5,000 – 8,000.



Source: JICA Study Team

Figure 6.28 Passenger Demand Forecast of Line-6 Alternatives

(3) Description of Route

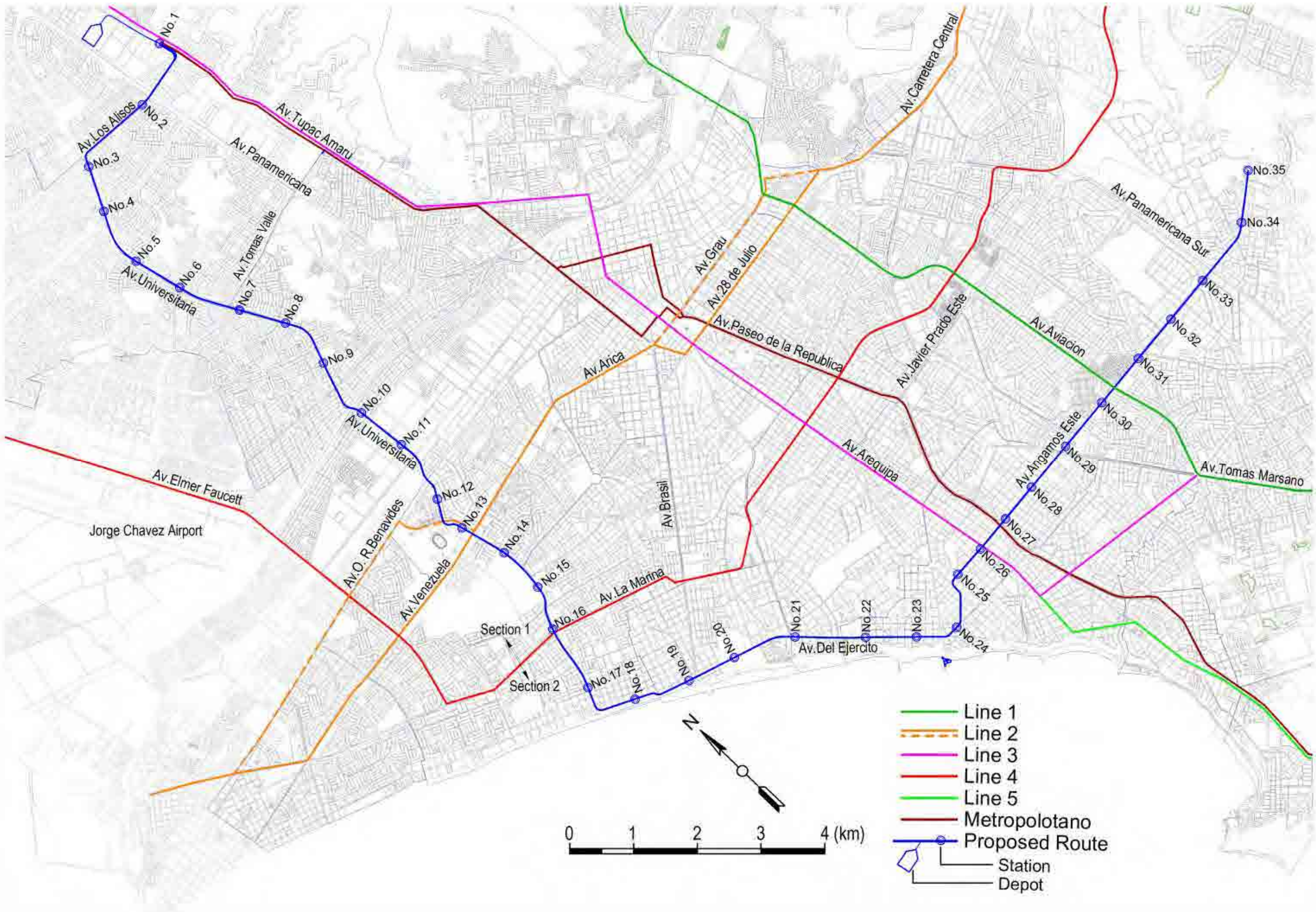
The proposed route consists of two sections as shown in Figure 6.29.

Section-1 is on a South-North axis and connects the Naranjal station of Metropolitano and La Marina Avenue, passing through Los Allsos Avenue and Universitaria Avenue. This section has a length of 13.69km and four junction stations to Metropolitano, Line-2, Line-3 and Line-4 will be allocated.

Section-2 is on an East-West axis located in the coastal area and on Angamos Este Avenue. This section extends from La Marina Avenue to the eastern side of Panamericana Sur Avenue where the university is located, via Bertolotto Avenue, Del Ejercito Avenue, Jose Pardo Avenue and Angamos Este Avenue. This section has a length of 16.46km and will contribute to the tourism industry in the coastal area. In Angamos Este Avenue, three junction stations to Line-3, Line-1 and Metropolitano will be allocated.

As a practical measure to facilitate construction, phasing can be considered. In this case, since a depot will be located on the north side of Narranjal station which belongs to a section-1, the section-1 has a high priority for construction. Moreover, land acquisition is required for some areas in section-2, and it may take time.

When this route is constructed by phasing, section-1 corresponds to phase 1 and section-2 is phase 2.



Source: JICA Study Team

Figure 6.29 Proposed Route (Ultimate)

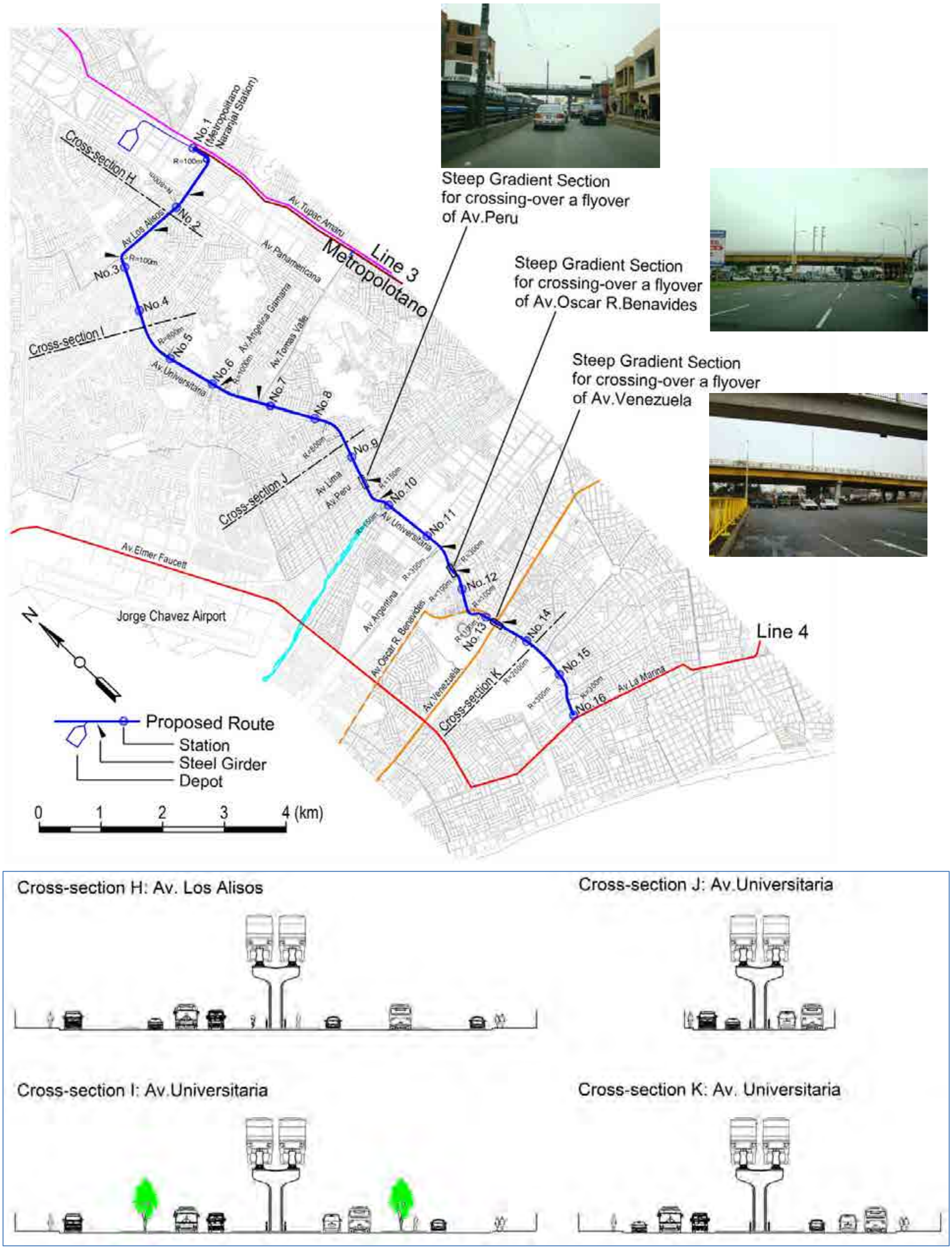
Table 6.11 shows the outline of the proposed route.

Table 6.11 Outline of Proposed Route

Item	Phase 1	Ultimate (Phase 1+2)
Route Alignment		
Route Length	13k690m	30k150m
Number of Stations	16 stations	35 stations
Small curve radius section (less than 300m)	100m: 5 sections 150m: 2 section 300m: 4 sections	100m: 12 sections 150m: 2 sections 300m: 4 sections
Steep Gradients section (i=6%)	3 sections	5 sections
Steel girder section	10 sections	22 sections
Long span bridge 1 bridge	None	1 bridge
Service		
Estimated demand	16,000 phpdt	18,000 phpdt
Schedule speed	35km/h	35km/h
Train configuration	6-car train	6-car train
Headway	3.3 minutes	3 minutes
Transport capacity	17,000 phpdt	18,920 phpdt

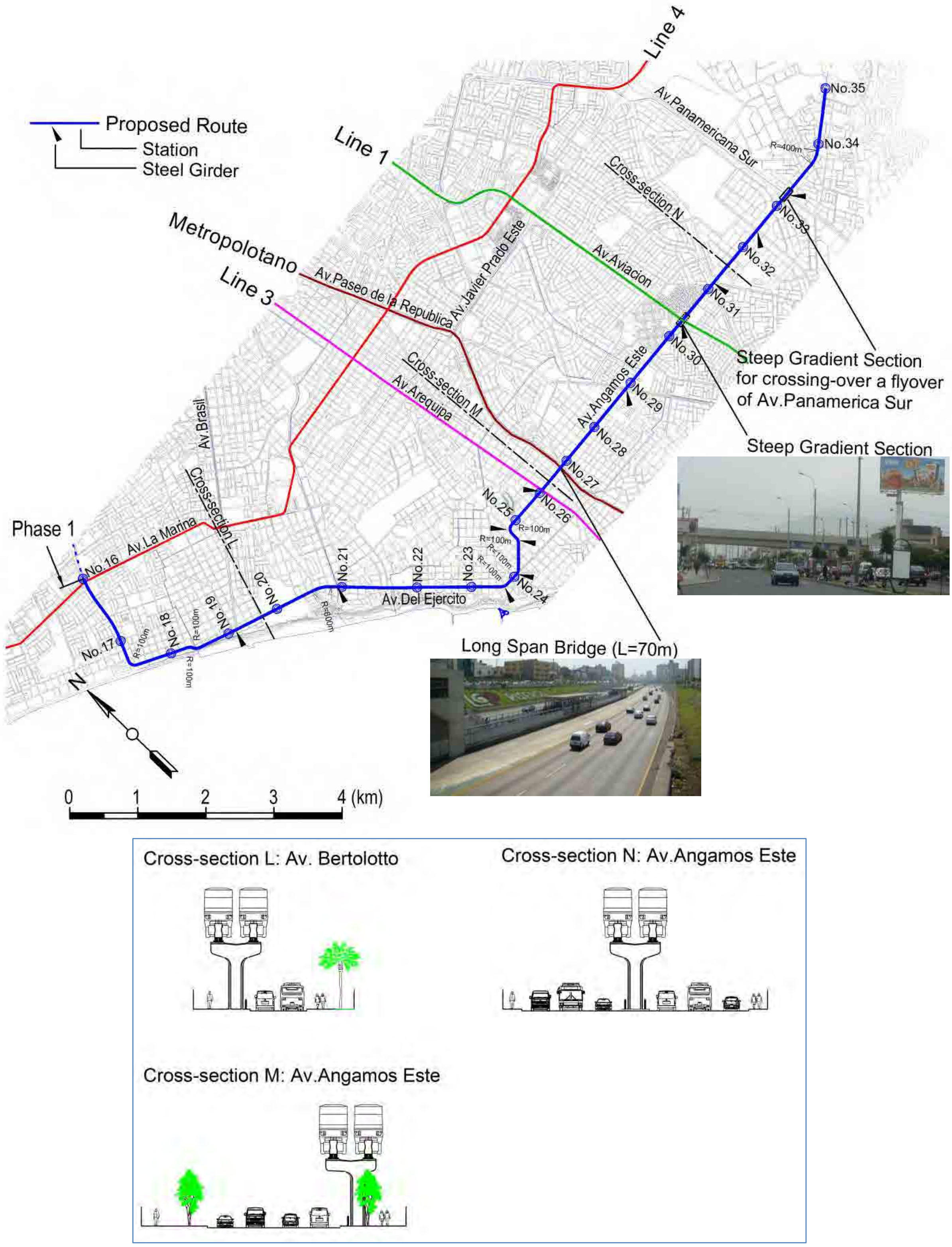
Source: JICA Study Team

Figure 6.30 and Figure 6.31 illustrate the alignment and cross sections of the proposed route in Phase-1 and Phase-2, respectively.



Source: JICA Study Team

Figure 6.30 Proposed Route Phase 1



Source: JICA Study Team

Figure 6.31 Proposed Route Phase 2

(4) Advantages of a Monorail in the Proposed Route

1) In phase 1, 11 small curves with a radius of less than 300m will be installed. There exist already three flyovers over which the monorail should cross. The monorail will be able to cope with this alignment condition.

2) Universitaria Avenue on the north side of the Rimac River consists of 4 lanes with the narrow center median and narrow sidewalks. The road width of the 1km long trunk road section between No.9 and No.10 stations, on which the elevated transit system is installed, is narrow. The monorail structure will mitigate the impact on the city landscape and land acquisition compared with that of other systems.

3) In phase 2, land acquisition is required in some section along the road between No.17 and No.25 stations because the road width is narrow. Since the applicable minimum curve radius of monorail is smaller than that of conventional railway, the area of land acquisition can be minimized.

6.6 Preliminary Cost Estimate

The project cost was estimated based on the unit costs of other related projects, which were converted to the price in March 2012. As for the indirect cost, the following figures were applied in this Study.

1) Contingency: Direct cost x 5%
2) Administration cost: Direct cost x 5%
3) Engineering cost: Direct cost x 10%

The costs of land acquisition including the depot area, utility relocation and compensation for resettlement are not included in this estimate.

The project cost estimate prepared on the basis of the above conditions is shown in Table 6.12. Note that this is a preliminary cost estimate based on the route kilometer and the locations of major structures for the analysis of the possibility to introduce the monorail system, and a further study will be necessary for the decision making.

Table 6.12 Preliminary Cost Estimate

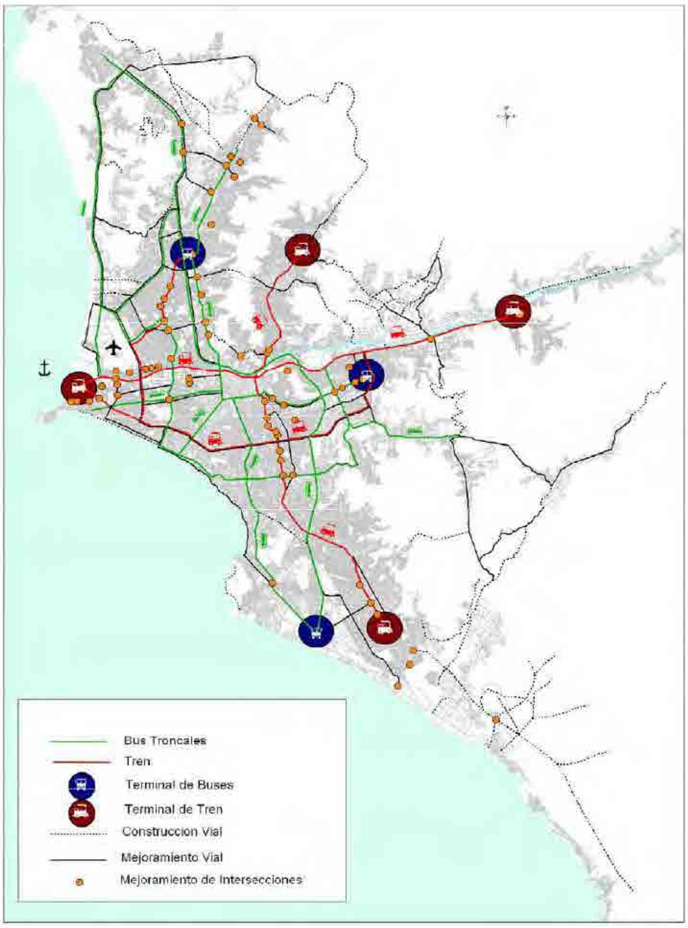
Item	Unit	Unit Cost (USD '000)	Line 4 Monorail Quantity	Line 4 Monorail Cost (USD '000)	Proposed Route Altimate Quantity	Proposed Route Altimate Cost (USD '000)	Proposed Route Phase 1 Quantity	Proposed Route Phase 1 Cost (USD '000)
		Length	29.5 km		30.2 km		13.7 km	
		Stations	32 stations		35 stations		16 stations	
		Demand	25,000 PHPDT		18,000 PHPDT		16,000 PHPDT	
Direct Cost								
Civil Engineering Cost								
PC Beam including Bearing (L=22r	beam	93	2,570	239,000	2,660	247,400	1,210	112,500
Steel Girder (L=40m)	span	801	31	24,800	22	17,600	10	8,000
Substructure	nos	98	1,168	114,500	1,192	116,800	536	52,500
Switch Bed	nos	666	4	2,700	4	2,700	3	2,000
Long Span Bridge (L=70m)	bridge	3,360	1	3,400	1	3,400	0	0
Station (L=90m)	station	2,588	32	82,800	35	90,600	16	41,400
Depot(for 336 cars)	lot	91,338	1	91,300				
Depot(for 234 cars)	lot	54,803			1	54,800		
Depot(for 66 cars)	lot	18,268					1	18,300
Subtotal of Civil works				558,500		533,300		234,700
E&M								
Signaling System	km	2,409	29.5	71,100	30.2	72,800	13.7	33,000
Telecommunication System	km	1,543	29.5	45,500	30.2	46,600	13.7	21,100
Power Supply System	km	5,783	29.5	170,600	30.2	174,600	13.7	79,200
Switch Machine (Main line)	nos	1,900	8	15,200	6	11,400	6	11,400
Depot Facilities(for 336 cars)	lot	56,250	1	56,300				
Depot Facilities(for 234 cars)	lot	37,500			1	37,500		
Depot Facilities(for 66 cars)	lot	18,750					1	18,800
Subtotal of E&M				358,700		342,900		163,500
Rolling Stock	car	2,600	336	873,600	234	608,400	102	265,200
Direct Cost Subtotal				1,790,800		1,484,600		663,400
VAT		18%		322,344		267,228		119,412
Direct Cost with VAT				2,113,144		1,751,828		782,812
Indirect Cost								
Contingency		5%		105,657		87,591		39,141
Administration cost		5%		105,657		87,591		39,141
Engineering cost		10%		211,314		175,183		78,281
Subtotal of Indirect cost				422,628		350,365		156,563
Grand Total				2,535,772		2,102,193		939,375
Cost per km (million USD / km)				86.0		69.6		68.6

Note: Unit costs were taken from similar studies and information on the Metro Line-1. The quantities were calculated from the route length.
Source: JICA Study Team

Chapter 7 Review of PMTU-2025

7.1 Summary of PMTU-2025

The Urban Transport Master Plan for the Lima and Callao Metropolitan Area (PMTU) 2025 was formulated in 2005 by Transport Council of Lima and Callao (CTLC) and JICA. A Person Trip Survey in which more than 34,000 households were interviewed was conducted for the analysis of the present condition and the future scenarios. The master plan was formulated for four sectors, namely, 1) Road Facilities, 2) Railway, 3) Trunk Bus System, and 4) Traffic Management. Figure 7.1 shows the project map of the master plan.



Source: PMTU-2025

Figure 7.1 PMTU-2025

The master plan focused on the following three issues.

a) The public transport system is very poor for the city with the population of approximately 8 million (2004).

b) The heavy traffic congestions have been occurred on the major trunk roads and on the major intersection, due to the rapid increase in traffic and very poor public transport system.

c) The environmental problem, especially air pollution will worsen because of the rapid increase in traffic volume.

To deal with above issues, a public transport priority policy was introduced as the basic policy in the master plan, and the following four policies were identified under the basic policy.

a) To Improve Poverty's Life Conditions
b) To Maintain Good Environmental Aspects
c) To Control of Traffic Demand
d) To Increase Transport Facilities Capacity

Urban transport strategies were formulated to achieve the policies, and goals were also identified under each policy as shown in Table 7.1.

Table 7.1 Policies, Strategies, and Goals in PMTU-2025

Policies	Strategies	Goals
To Improve Poverty's Life Conditions	a) To insured usefulness public transport system b) To improve public transport tariff c) To accommodate free public transport system	a) To achieve faster travel time compared with existing condition. b) To achieve cheaper transport tariff compared with existing condition. c) To achieve shorter walking distance compared with existing condition. d) To achieve more safety transport system
To Maintain Good Environmental Aspects	a) To make the best use of CNG energy b) To transfer user from car to public transport c) To insure traffic safety and to decrease traffic accidents d) To improve bus fleets	a) To achieve better air pollution compare with existing conditions b) To create modern transport facilities c) To achieve safety transport system and facilities.
To Control of Traffic Demand	a) To reinforce public transport system (to introduce mass rapid transit system) b) To improve bus transport system c) To transfer user from car to public transport d) To introduce traffic demand management (TDM) system	a) To achieve faster travel time compared with existing condition. b) To achieve cheaper transport tariff compared with existing condition. c) To achieve shorter walking distance compared with existing condition. d) To create more comfort and convenience transport system e) To achieve more safety transport system
To Increase Transport Facilities Capacity	a) To reinforce road network b) To improve road facilities c) To improve public transport system	a) To mitigate traffic congestion compared with existing conditions b) To achieve more smooth traffic flows compared with existing conditions

Source: PMTU-2025

The master plan study analyzed many scenarios of road facilities, railways, bus trunk lines, and traffic management programs based on the determined policies, strategies, and goals.

PMTU-2025 proposed 68 projects with an investment cost of USD 5,535 million as shown in Table 7.2. The proposed projects consist of road facilities, railways, bus trunk lines, and traffic management programs.

Table 7.2 Number of Projects and Costs by Sector

	Road Facilities	Railways	Bus trunk lines	Traffic management programs	Total
No. of projects	33	7	18	10	68
Cost USD million	2,374	2,024	981	156	5,535

Source: PMTU-2025

7.2 Socio-economic Framework

The study of PMTU-2025 estimated the future population of the Lima and Callao Metropolitan Area. The population in 2004 was 8.0 million according to PMTU-2025, and the study estimated the population at 8.85 million for the year 2010 and 10.6 million for 2025. The actual population in 2010 was 9.16 million. The population projection was revised in this Study. The revised population is larger than the previous projection. This difference is attributed to the projection of the population in 2004. Although the study estimated the population in 2004 at 8.0 million, the actual population was 8.5 million in 2005.

Table 7.3 Population Projection in PMTU-2025

(million)

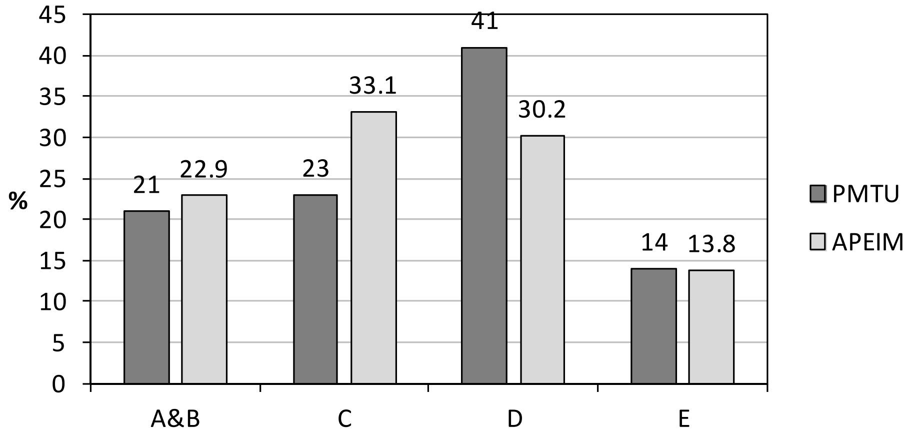
	2010	2015	2020	2025
Projection in PMTU-2025	8.85	9.48	10.06	10.57
Revised in this Study	9.16	9.90	10.69	11.48

Source: PMTU-2025 and JICA Study Team

The master plan assumed that the population in the central area would increase, but in fact the population in the central area has decreased from 2004. The actual population growth was higher than the projection in suburban areas and lower than the projection in the central areas.

Peru achieved high economic growth recently. PMTU-2025 estimated the annual growth rate of the real GDP from 2005 to 2010 at 4% while the growth rate of the five years was 7.2%. The growth rate of GDP per capita was estimated at 2.0%, although it was 6.0%.

PMTU-2025 estimated the population by socio-economic level in the future periods. The socio-economic level in Peru is classified into 6 categories (A to E) in Peru. “A” represents the highest income group while “E” represents the lowest. Figure 7.2 shows the difference of the projection and the actual proportion. Population of Level C has increased more than the figure projected by PMTU.

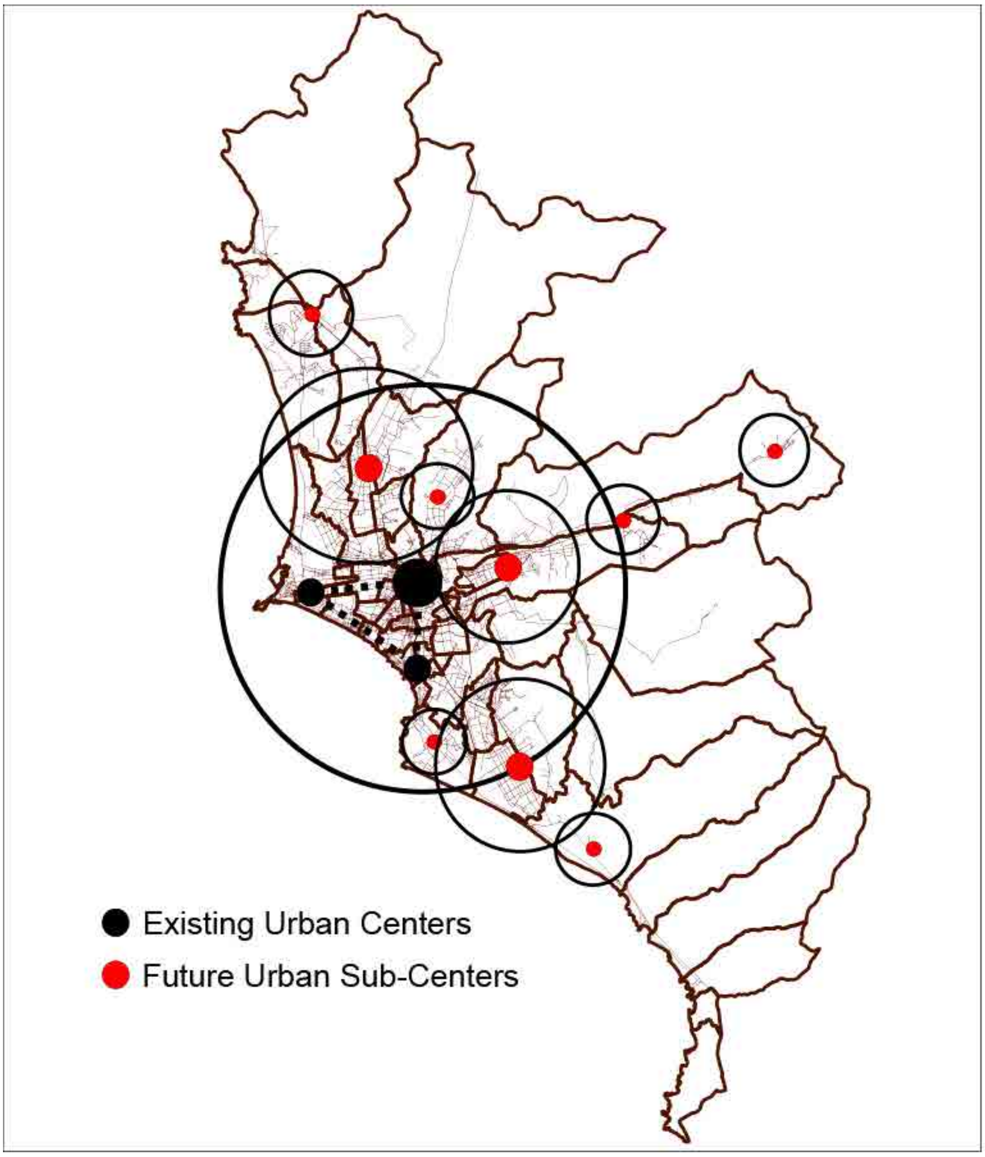


Source: PMTU-2025 & APEIM

Figure 7.2 Proportion of Population by Socio-economic Level (2010)

Figure 7.3 shows the locations of the proposed urban centers and urban sub-centers. The master plan applied the poly-centric decentralized development pattern and established the land use policies including 1) To consolidate the Metropolitan Services in the Central Area, and 2) To Promote Decentralization of Urban Services in Sub-Centers. The population in the central area was 2.24 million in 2004, and the master plan estimated the population in the central area at 2.42 million for the year 2010. On the other hand, the population in the area in 2012 was 1.87 million.

The reason that the study of PMTU 2025 projected population increase in the central area where it was actually decreasing probably because the study of PMTU-2025 "assumed" that the urban structure in Figure 7.3 would be realized. Based on the future land use, the total population was distributed to each traffic zone by applying ideal population density by land use pattern in the study of PMTU-2025.



Source: PMTU-2025

Figure 7.3 Existing Urban Centers and Future Decentralized Urban Sub-Centers

7.3 Demand Analysis

A four-step demand forecast model, which is a traditional style of traffic demand forecast, was developed from the traffic survey. The model was prepared for 4 socio-economic groups (Estrato) such as Estrato-AB, Estrato-C, Estrato-D, and Estrato-E. Trip purposes are categorized into 1) To Work, 2) To School, 3) Business, 4) Private, and 5) To Home. The demand forecast model consists of 1) trip production model, 2) trip generation/ attraction mode, 3) trip distribution model, and 4) modal split model.

1) A trip production rate is the number of trips per person per day. The total number of trips in the metropolitan area was estimated from trip production rates by Estrato.

2) Trip generation and attraction models by Estrato by purpose were developed by using linear regression analysis. The variables in the models were (i) population, (ii) number of students in their residential zone, (iii) number of students at school place, (iv) number of employees at work place, (v) number of the service sector employees at work place, (vi) number of workers in their residential zone, and (vii) number of the service sector workers in their residential zone.

3) Voorhees type gravity models were developed to estimate the number of inter zonal trips by Estrato by purpose. The travel time was used for the transport cost. Interzonal trip model was also developed for each Estrato and each purpose.

4) Transport modes were classified into 3 modes in the modal split model: car, taxi, and public transport. Multinomial logit models were developed for the modal split by Estrato by purpose based on the Stated Preference Survey conducted in the study. The modal split of public transport was estimated by traffic assignment.

In total, there were 94 models in the demand forecast model.

The results showed that the traffic demand in 2025 would be 1.48 times the demand in 2004 (from 12.1 to 18.0 million trips per day). The change in the modal share was estimated as shown in Table 7.4.

Table 7.4 Projection of Modal Share

	2004	2025
Car	15.3%	22.5%
Taxi	7.4%	7.0%
Public Transport	77.3%	70.5%

Source: PMTU-2025

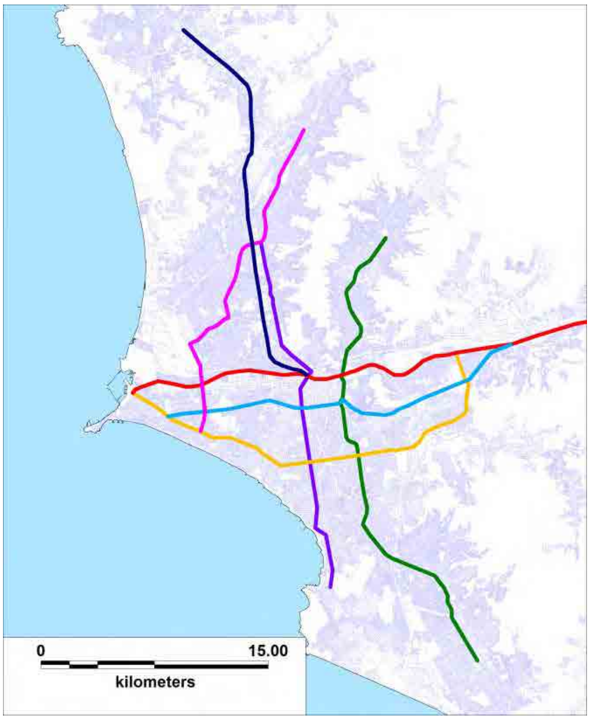
The master plan study analyzed the future situation in the case where no action would be taken place, in which the average travel speed was projected to decrease from 16.8km/h to 7.5km/h, and the average commuting time was projected to increase from 44.9 minutes to 64.8 minutes.

7.4 Public Transport Planning

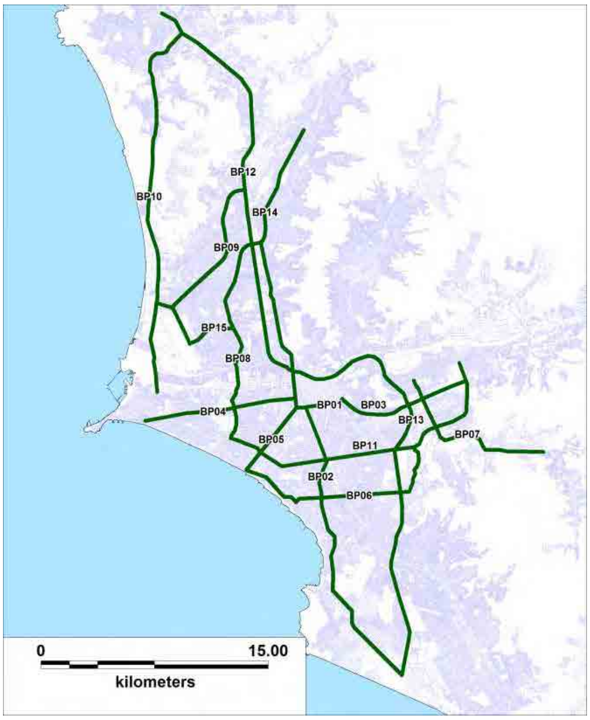
7.4.1 Network Alternative Analysis

The previous study analyzed 16 network scenarios. These scenarios were prepared from combinations of 4 railway networks and 4 trunk bus networks. A railway network was elaborated from 7 railway lines that were proposed by AATE, while a trunk bus network was from 17 trunk bus lines that were proposed by the JICA Study Team of PMTU (Figure 7.4). The same road network with 33 projects was used for all the analyses. Only railway and trunk bus systems were considered in the previous planning. It was assumed that a truck bus system has a capacity of 15,000 passengers per hour per direction at maximum.

The criteria of the alternative analyses are 1) population covered by the network, 2) benefit, 3) benefit to cost ratio, 4) net present value of the benefit, 5) the average speed on roads, 6) ratio of distance with a volume capacity ratio of over 1.0, and 7) reduction of CO2. These values were calculated for all the alternatives, and a point (0 to 15) was given to each alternative by criterion according to the rank.



Railway Network



Trunk Bus Network

Source: PMTU-2025 (Illustrated by JICA Study Team)

Figure 7.4 Base Network for the Alternative Setting in PMTU-2025

The scenario of the highest score was selected as the master plan network. The largest bus network was selected among the 4 bus alternative networks while the medium size network was selected for the railway system. It can be said that the master plan gave more priority to the bus network than the railway network.

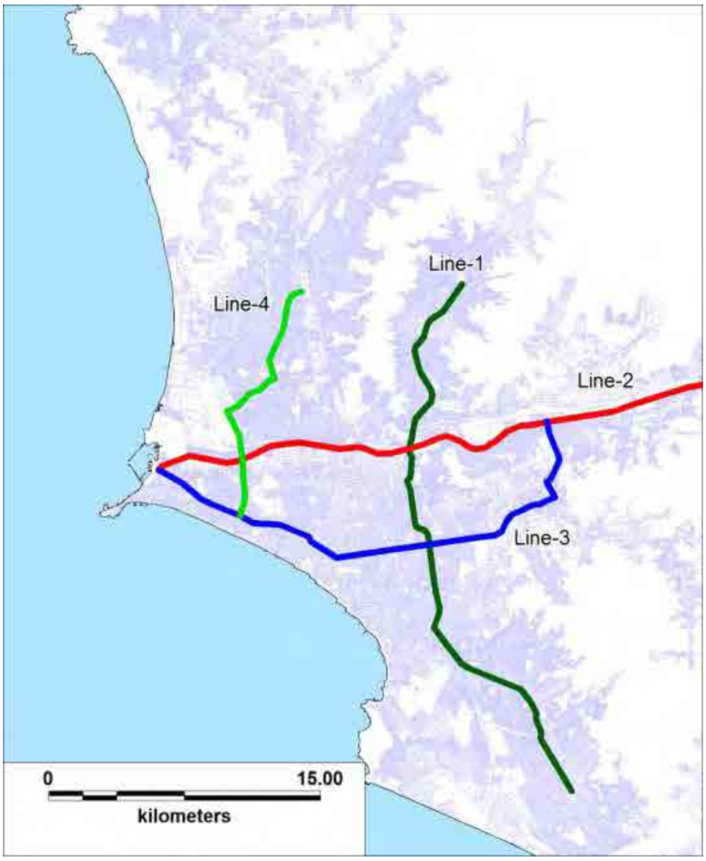
7.4.2 Railway Plan

After the demand forecast analysis, the previous study concluded that light rail transit would not satisfy the demand due to its capacity. However, the proposed railway system was surface type railway system, which has a lower capacity than the elevated or underground system. Figure 7.5 shows the railway network in the master plan. Only Line-1, whose structure was already constructed as an elevated type at the time of the master plan study, was proposed as an elevated system. The reason for applying at-grade structure instead of elevated type is not clear because it is not mentioned in the master plan reports. Since "utilization of existing railway infrastructure and facilities" was one of the major concepts for the planning of the railway network of the master plan, reduction in the project cost was probably an important consideration in the master plan. Table 7.5 shows the projected demand in 2025 of each line by segment.

Table 7.5 Passenger Demand of the Railway System

Railway Route Segments	Length	Demand (Passengers per peak hour per direction)		Structure
		Inbound	Outbound	
Line-1 (Constructed)	9.2km	39,000	37,000	Elevated
Line-1 (Atocongo- Hospital 2 de Mayo)	11.7km	55,000	61,000	Elevated
Line-1 (Hospital 2 de Mayo - Bayovar)	13.0km	35,000	59,000	At grade
Line-2	29.0km	65,000	59,000	At grade
Line-3 (Garibaldi - Javier Prado)	16.2km	35,000	22,000	At grade
Line-3 (Javier Prado - S. Industrial)	11.9km	19,000	16,000	At grade
Line-4	24.6km	42,000	17,000	At grade

Source: PMTU-2025



Source: PMTU-2025 (Illustrated by JICA Study Team)

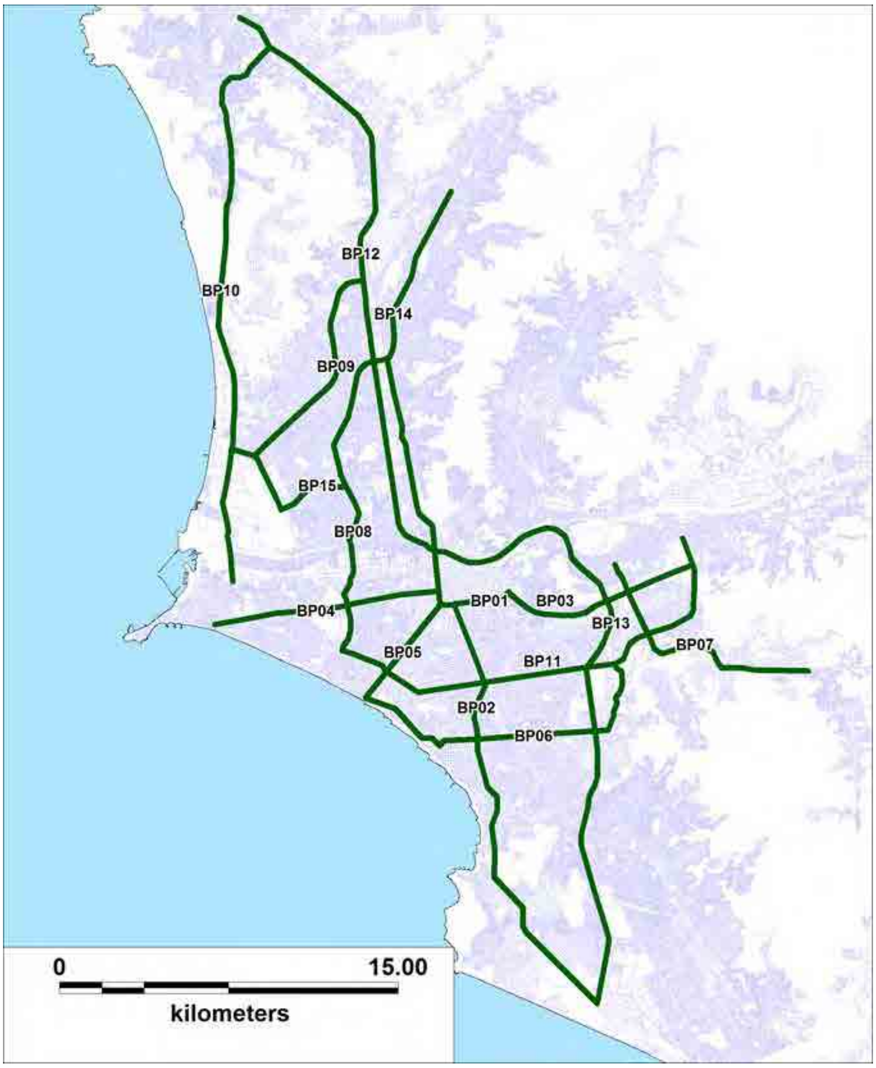
Figure 7.5 Railway Plan in PMTU-2025

7.4.3 Trunk Bus Transport Plan

The master plan study identified 17 trunk bus lines, although the type of the busway was not identified in the plan. The master plan proposed three types: 1) Trunk busway, 2) Exclusive bus lane, and 3) Bus priority lane. A trunk busway is partially or fully segregated from other traffic, while an exclusive bus lane is separated from other lanes with paint marking on roads. The articulated bus with 150-200 passengers per bus was proposed for these lanes. On the other hand, a bus priority lane is used for buses only at peak hours. The single unit bus with a capacity of 80-100 passengers was proposed for the bus priority lanes.

The capacity of a trunk busway was designed at 25,000 passengers per hour per direction. After the alternative analysis with the demand forecast, 15 trunk bus lines were selected. Among the 15 trunk bus lines, only the COSAC Project was implemented as the BRT system, which was opened in 2010.

In 2007, JICA conducted the feasibility study for the East-West Corridor (Av. Venezuela Trunk Busway, Av.Grau Trunk Busway, and Carretera Central Trunk Busway). However, this corridor was identified as a railway system (Line-2) in the notification by the Government in 2010.



Source: PMTU-2025 (Illustrated by JICA Study Team)

Figure 7.6 Trunk Bus Plan in PMTU-2025

7.4.4 Evaluation of Public Transport Plan

The mass transit network in PMTU-2025 consists of a dense network of Trunk Bus System and four railway lines in which three lines are at-grade, the capacity of which is lower than elevated and underground railways. Since the demand forecast shows that high capacity transit systems will necessary for the north-south and east-west directions, the public transport plan should be reorganized based on the metro plan (D.S. 059-2010-MTC) in which high demand corridors are identified as metro lines.

PMTU-2025 considered that the trunk bus system could be implemented in a short term period, but the recent progress shows that formulation of 15 trunk bus routes will take much time than expected in PMTU-2025. It is recommended that the trunk bus network be reviewed based on the cost and benefit analysis as adopted in the study in PMTU-2025.

When updating the public transport plan, the concept of medium capacity transit system should be considered instead of formulating the network by bus and rail systems only in view of optimal investment.

Several trunk bus routes are proposed to be reorganized as Metro “Line-6” in Chapter 6.

7.5 Road Plan

7.5.1 Projects in PMTU-2025

In PMTU-2025, road network plan was formulated for three (3) road categories: 1) National and Regional Expressway Network, 2) Metropolitan Expressway Network, and 3) Arterial and Collector Road Network. The network development plan consists of 1) road construction and improvement, 2) road widening, and 3) construction of new roads in new housing areas. In addition, improvement of 62 intersections is proposed. Projects were grouped into short-term, mid-term, and long term projects. Figure 7.7 shows the road network plan in 2025 and Table 7.6 gives a summary of road projects in PMTU-2025.

Source: PMTU-2025

Figure 7.7 Road Network Plan in PMTU-2025

Table 7.6 Summary of Road Projects in PMTU-2025

Project Component	Road Class	No.	Length (km)
Road Construction	National and Regional Expressway	8	173.5
	Metropolitan Expressway	4	28.3
	Arterial and Collector	6	4.1
Road Improvement	National and Regional Expressway	3	31.7
	Metropolitan Expressway	3	46.9
	Arterial and Collector	1	2.7
Road widening	-	-	230
Intersection Improvement	-	62	-
Road construction in new housing areas	-	-	202.8
Rehabilitation	Expressway	-	100
	Arterial	-	567
	Collector	-	691

Source: PMTU 20205

7.5.2 Demand Forecast Analysis

Construction of Av. La Costa Verde, which was planned as a medium term project, has already been implemented. The demand forecast shows that this expressway plays an important role to release the congestion of roads.

The major difference of the demand forecast between PMTU-2025 and this study is population distribution in the future. PMTU-2025 estimated that population in the center of the city will increase while this study has estimated that it will decrease a little in the future based on the past trend. On the other hand, the population growth in the suburban area in this study is larger than that of PMTU-2025. For example, PMTU-2025 estimated the population of San Juan de Lurigancho District in 2025 at 842,551 while the population of the district has already exceeded 1 million by 2012. From this, arterial roads connecting the center of the city and suburban areas will be more congested than was estimated in PMTU-2025. Figure 7.8 shows the daily traffic flow in 2025 which was estimated in PMTU-2025. The demand forecast in this Study is shown in figures in Chapter 5. Traffic volume in San Juan de Lurigancho District shows a large difference between the two projections.

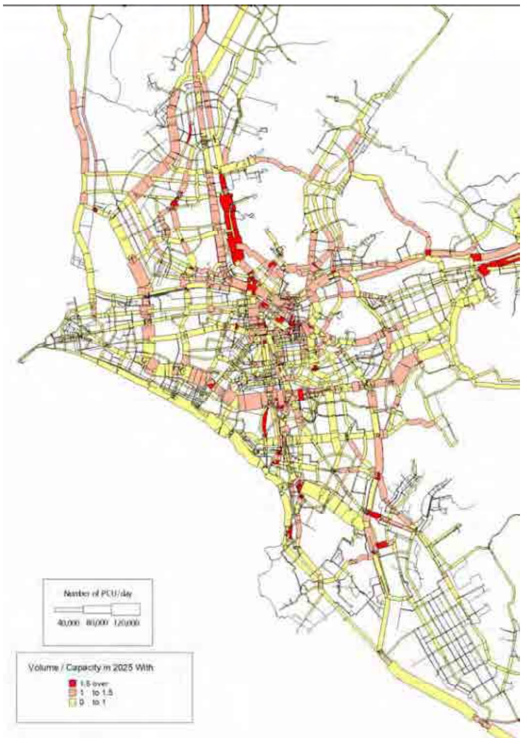
The demand forecast of this study indicates that the following project is important.

1) Vía de Periférica,

2) Av. Paseo de la República Sur, and

3) Autopista Ramiro Prialé

It is necessary to review the design of Av. Paseo de la República Sur because the demand of the road will be high.



Source: PMTU-2025

Figure 7.8 Future Demand Forecast in PMTU-2025

7.5.3 Other Road Projects

(1) Linea Amarilla (Yellow Line)

This is a road construction project along Rimac River for 9km in length, including a tunnel section along the river. The project is already in the construction stage. The demand forecast shows that this project will contribute to release traffic congestion of the road along Rimac River.

Source: Illustrated by JICA Study Team based on Linea Amarilla Project

Figure 7.9 Location of Linea Amarilla

(2) Bicycle Network

Lima has a bicycle lane network with a total length of 325km. The municipality of Lima has developed bicycle lanes recently. However, the bicycle network plan was not included in PMTU-2025 because a master plan study on bicycle transport was being conducted by FORNAM (Fondeo Nacional del Ambiente Peru) at the time of the study of PMTU-2025.

7.6 Traffic Management Plan

The objectives of the traffic management plan in PMTU-2025 were:

a) To achieve a smooth traffic flow
b) To reduce traffic accidents
c) To divert the excessive traffic demand made by private vehicles to public transport
d) To create "pedestrian-friendly" facilities

The master plan includes 10 projects for the traffic management sector as follows.

1) Improvement Plan of Traffic Signal Control System
2) Improvement Plan of Intersections
3) Plan of Traffic Demand Management System (TDM)
4) Improvement Plan of Traffic Safety Facilities
5) Improvement Plan of Parking Control System
6) Plan of Traffic Safety Education System
7) Plan of Traffic Accident Monitoring System
8) Improvement Plan of Vehicle Inspection System
9) Area Traffic Control System and Traffic/ Road Information System
10) Bus Location Information System and Bus Priority Signal Control System on Trunk Roads

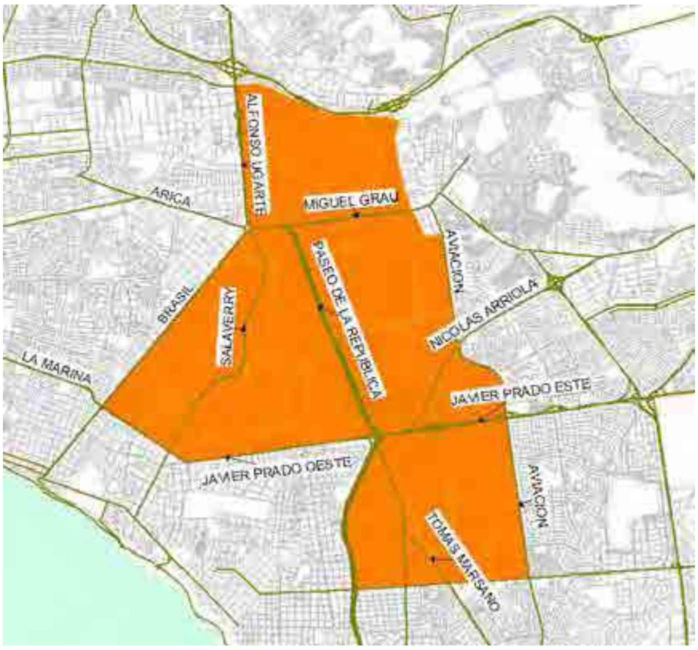
Items No. 9 and 10 were proposed as parts of middle and long term plans while others were proposed as parts of the short term plan.

The synchronized traffic control system, which was a part of Item No. 1, has been implemented along Av. Arequipa, Ave. Canada, Av. Petit, Av. Tourars, and Av. Arenales.

The traffic management plan was studied further in the subsequent feasibility study, and the following five action plans were prepared.

1) Road Safety Education and Campaign Program
2) Road Accident Monitoring Plan
3) Intersection Improvement Plan
4) Traffic Demand Management (TDM) Plan
5) On-street Parking Improvement Plan

The above plans were proposed for the short term. In the TDM Plan, the study evaluated 12 typical TDM measures and concluded that the license-plate numbering system would be the most applicable measure for the metropolitan area, although the area licensing system (ALS) was finally selected as the TDM project in response to the technical committee of the study. Figure 7.10 shows the proposed control area of the ALS. Vehicles entering the area need to pay an entrance charge in ALS. The ALS has not been implemented, although it was proposed as a short-term project. Since the ALS discourage people to use their cars, an alternative public transport system is essential.



Source: PMTU-2025

Figure 7.10 Control Area of the Area Licensing System

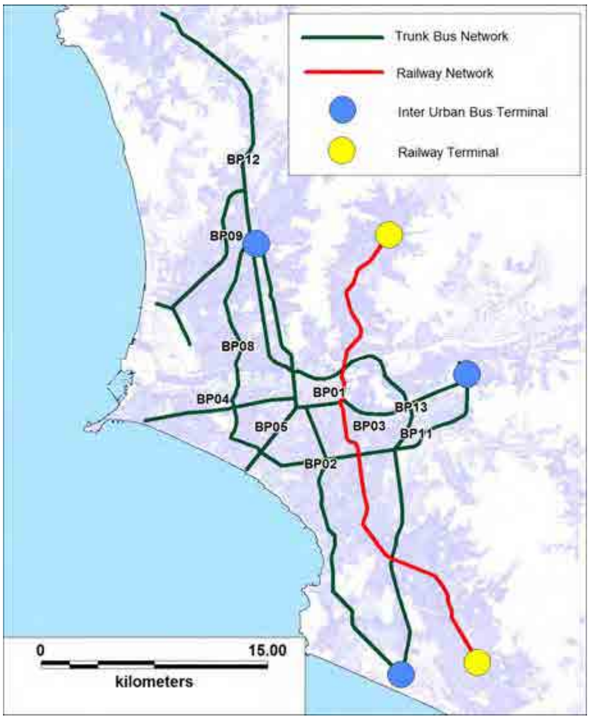
The demand forecast shows that the capacity of arterial roads in the center of the city does not necessarily small compared to the commuter traffic demand, except for Centro area, although the roads are congested in the morning peak hours. This means that traffic congestion in the central area occurs due to improper traffic management.

7.7 Short-term Plan

7.7.1 Short-term Projects in PMTU-2025

The study of PMTU-2025 formulated a short-term plan consisting of 33 projects for the period of 2005-2010, by identifying priority projects based on six criteria of the master plan projects. The criteria are (1) transport planning policy, (2) economic effect, (3) traffic improvement effect, (4) characteristics and conditions of the project, (5) progress of the on-going projects, and (6) balance of investment cost every year. The total project cost was estimated at US$ 1,295 million, accounting for 24% of the master plan cost by 2025.

Figure 7.11 shows the location of railway and trunk bus projects in the short-term plan. In the short-term projects, “high priority projects” were selected in view of the peak hour travel demand and the cost benefit analysis. The selected high priority projects were Metro Line-1, Trunk Bus of East-West Corridor (BP01, 03, and 04), and Trunk Bus on Ave. Panamericana (BP11 and 12).



Source: PMTU-2025 (illustrated by JICA Study Team)

Figure 7.11 Short-term Railway and Trunk Bus Projects in PMTU-2025

7.7.2 Implementation of Short-term Projects

In the short term plan, two important projects were implemented: railway line-1 and COSAC project. Only Line-1 was proposed in the short term plan for the railway sector. On the other hand, 10 corridors were proposed as truck bus projects in which only COSAC project was implemented.

There were two road construction projects (RP-13 and RP-19) in the short term plan, but neither of them was implemented. Improvement of Av. Elmer Faucett (RP-15) was implemented. Details of RP-31 (Expressway Rehabilitation) are not given in the master plan report.

The progress of the road projects was confirmed based on information of the Municipality of Lima, supplemented by site surveys and Google Earth image. Only two roads were constructed among 25 roads in PR-30 (Construction of Roads in New Housing Area). The widening project (RP-28) shows approximately 30% progress.

Table 7.7 shows the current status of the short-term projects. Only six projects out of 33 projects have been implemented. The result can be explained by the following reasons:

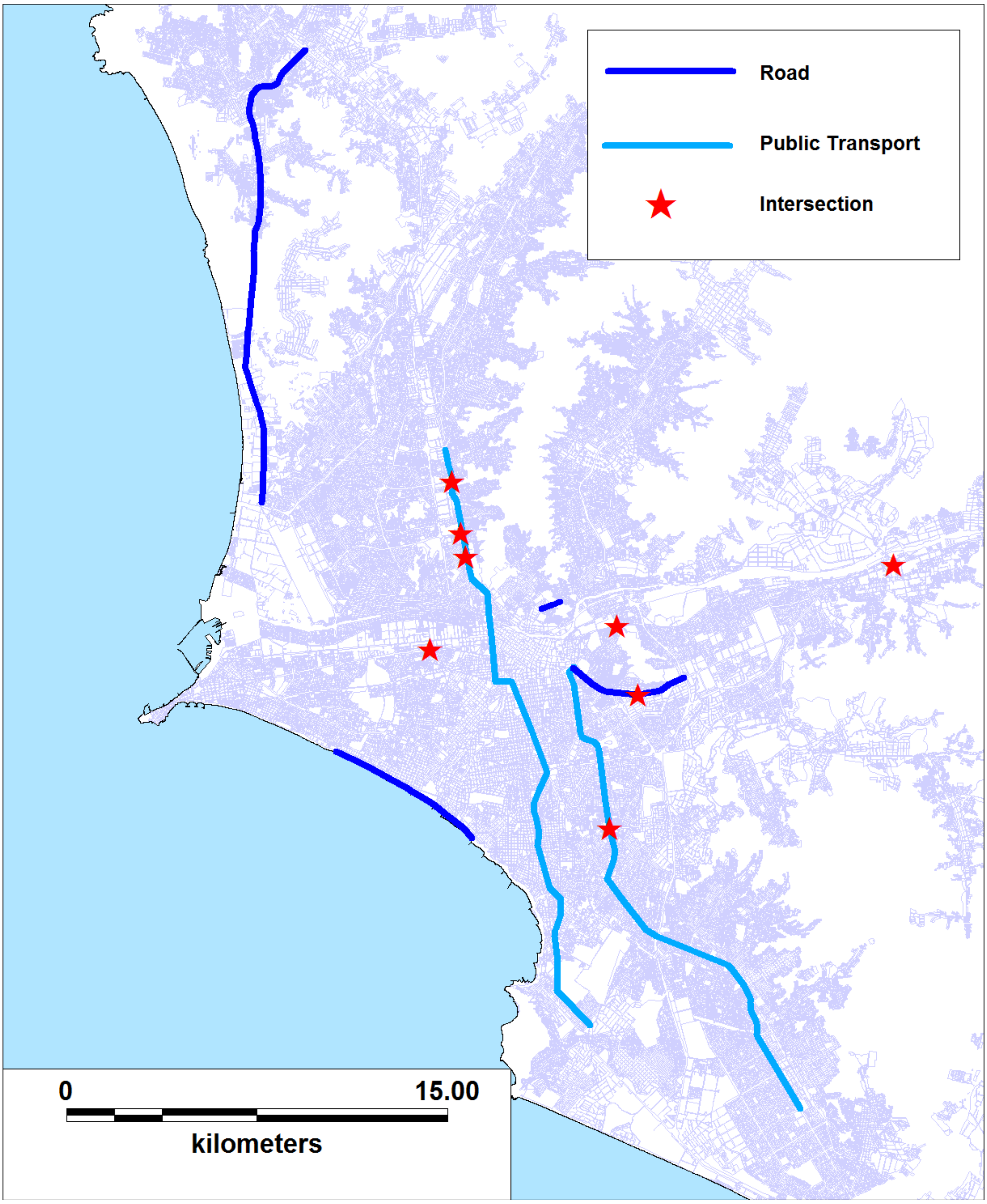
- Too many trunk bus projects were included. Although a trunk bus project can be implemented in a shorter period than railway system, the period of five years is too short to implement the all the projects shown in Figure 7.11.
- There were other priority projects. Some mid-term projects in PMTU-2025 were implemented in the short-term period. Development of the bicycle lane network has been a priority project.
- “Planning” was the content of some traffic management projects, and the plan of traffic management projects was proposed in the subsequent JICA F/S in 2007.

Table 7.7 Status of Short-term Projects

Sector	Code	Project	Remark	Status
Railway	TP01	Line-1 (Section-2)	11.7km	Y
	TP02	Line-1 (Section-3)	13.0km	Y
Trunk Bus	BP01	Av. Grau	2.3km (F/S in 2007)	N
	BP02	COSAC Project	29.0km	Y
	BP03	Carretera Central	8.4km (F/S in 2007)	N
	BP04	Av. Venezuela	9.1km (F/S in 2007)	N
	BP05	Av. Brasil	4.8km	N
	BP08	Universitaria Sur	12.7km	N
	BP09	Av. Callao-Canta	9.1km	N
	BP11	Av. Javier Prado	21.1km	N
	BP12	Av. Panamericana Norte	23.9km	N
	BP13	Av. Panamericana Sur	25.6km	N
	BP18	Terminal A	North	N
	BP19	Terminal-B	East	N
	BP20	Terminal-C	South	N
Road	RP13	Construction of Extension of Av. Paseo de República in the South	5.0km	N
	RP15	Improvement of Av. Elmer Faucett	5.6km	Y
	RP18	Improvement of Av. Universitaria	2.7km	Y
	RP19	Construction of Av. Póceres de Independencia – Av. Grau	3.3km	N
	RP25	Intersection Package-1	19 intersections	N
	RP28	Widening of existing roads in Built Up Area	161km	N
	RP30	Construction of Roads in New Housing Area	202.8km	N
	RP31	Expressway Rehabilitation	100km	N
	RP32	Arterial Rehabilitation	567km	N
	RP33	Collector Rehabilitation	691km	N
Traffic Management	MP01	Traffic Signal Control	Area Traffic Control System Synchronized Traffic Control System	Y
	MP02	Intersection Improvement	Part of MP-01	N
	MP03	Plan of TDM	Making master plan of TDM	N
	MP04	Improvement Plan of Traffic Safety Facilities	Planning of (1) Pedestrian bridges and (2) scramble pedestrian crossing	N
	MP05	Parking Control	Installation of charged on-street parking lots	N
	MP06	Plan of Safety Education System	Planning including overseas training	N
	MP07	Plan of Accident Monitoring	Traffic Safety Audit System (TSAS)	N
	MP08	Vehicle Inspection	Mandatory Inspection	N

Note: Status Y = implemented, N = not implemented, P= partially implemented
Source: JICA Study Team based on PMTU-2025

Figure 7.12 shows the locations of the implemented projects in PMTU-2025.



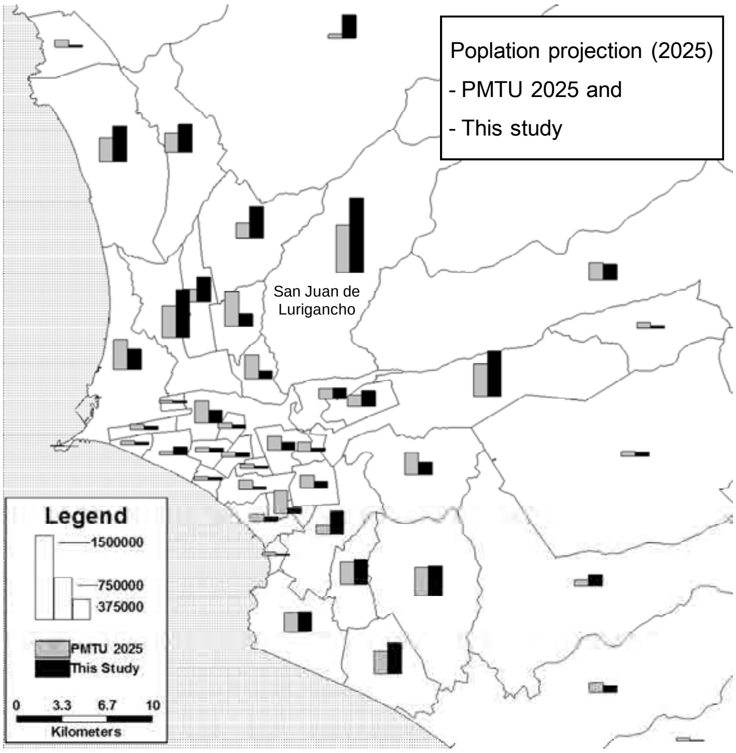
Source: JICA Study Team based on PMTU-2025

Figure 7.12 Implemented Projects in PMTU-2025

7.8 Urban Transport Issues

7.8.1 Urban Expansion

PMTU-2025 was formulated based on the distribution of the future population which was estimated from the future land use plan, but the real urban development trend has been different from the plan. The JICA Study has reviewed the population projection and revised the distribution of the future population reflecting the actual trend of the urban development. Figure 7.13 shows the comparison of the population projection in PMTU-2025 and the revised one. As can be seen, districts in the north area, such as San Juan de Lurigancho, will have a larger population than projected in PMTU-2025. From this, infrastructure development in suburban areas, especially in the north area, is more important than in PMTU-2025. Furthermore, population recovery in the central area, which was assumed in PMTU-2025, is effective to reduce long distance travel demand, so the actions for the population recovery will be necessary.



Source: PMTU-2025 and JICA Study Team

Figure 7.13 Population Projection of PMTU-2025 and the Revision

7.8.2 Increase in Commuter Time

According to the Person Trip Survey, the average commuter time ("To Work") of all modes is approximately 45 minutes. The average travel time by bus is approximately 50 minutes. It is expected that the travel time will be longer according to the expansion of urbanized area. Since travel time reduction is an important issue for bus passengers as shown in the passenger interview survey, it is necessary to provide high speed transit system especially for people living in suburban areas.

7.8.3 Increase in Passenger Car

Presently, modal share of public transport in motorized transport is as high as 70% in Lima. Although the number of cars will increase in the future as estimated in Chapter 4, the JICA Study Team estimated that the modal share in peak hours will not change because the mass transit network in the future will improve public transport services while the congestion on arterial roads will remain. However, there is a possibility that the car share will be higher than the estimation due to the rapid expansion of the urban area. Presently, car ownership in the suburban areas is lower than in the central area. Since income level is increasing, car usage will increase if proper public transport system is not provided.

7.8.4 Capacity Limit of Metropolitano

After the inauguration in 2010, Metropolitano has greatly improved the urban mobility in Lima, running through high demand corridor. Presently, its service area is larger than that of Metro Line-1 as described in Chapter 3. According to the demand forecast, the future demand will exceed the capacity of Metropolitano unless other mass transit system is implemented.

7.8.5 Modal Shift

According to the passenger interview survey, 95% of passengers of Metropolitano and Metro Line-1 shifted from public transport modes such as bus and combi to the mass transit systems. Passenger car users concentrate on the central area of the city as shown in Chapter-3, where cars are more convenient than public transport. Public transport network should form a dense network to attract passenger car users. The demand forecast shows that congestion on arterial roads will remain in the future even if all lines in the metro plan in 2010 are implemented. Promoting modal shift from private mode to public mode is necessary to improve the road congestion. Park and ride facilities should be considered in the planning of metro lines.

7.8.6 Intermodal Transportation

Metropolitano attracts many passengers by the feeder bus system with large scale terminal stations. In the demand forecast, transfer between bus and railway lines (or monorail) is assumed to be convenient. Since boarding demand from feeder buses at the terminal station of metro lines of the metro plan is expected to be very large, proper development of the intermodal facilities is an important issue. In addition, fare integration with feeder bus systems and metro lines should be considered because the additional payment to metro lines is one of the reasons that bus demand will remain high in the future.

7.8.7 Station Transfer

The demand forecast shows that transfer demand between metro lines at the crossing stations will be very high as described in Chapter 5. Reduction in walking time and distance between the stations is an important issue as well as the capacity of the stations.

7.8.8 New Transit Corridor

This study proposed Metro “Line-6” along the corridors which were identified as parts of Bus Truck System routes in PMTU-2025. The concept study shows a monorail system will be the best system for the route. It is recommended to include the new route in the metro plan.