12.5. EVALUATION AND SELECTION OF ALTERNATIVE TRANSPORT NETWORK PLAN

12.5.1. EVALUATION PROCESS

(1) Evaluation Method

In section 12.4, the 15 master plan alternative networks are formulated in the combination of railway and trunk bus projects. In this section, a master plan network will be chosen from among those alternatives, and projects proposed in the master plan are studied for line facilities, operation system, project work volume, cost, etc. in the next project sector plan.

Figure 12.5-1 shows a flowchart of evaluation process, which illustrates a process of choice for the master plan network. The evaluation to select from 15 alternatives was made based on tangible and intangible items. The tangible items are composed of traffic and passenger demand in 2025, a cost-benefit analysis, population covered by the alternative networks, and environmental impact. There are some social impacts as an intangible item derived from the implementation of the Master Plan project. However, it is difficult to carry out a detailed evaluation for those impacts in the Master Plan study. Therefore, the general social impacts are evaluated in the intangible items.

The comprehensive evaluation of the alternatives was made by the manner of matrix form, which shows the interrelation between alternatives and evaluation items. Through the evaluation, two master plan networks were selected as a candidate of master plan and then, the alternative-N was chosen as a master plan taking into account the line capacity of the trunk bus system and railway system in 2025 and later year.

(2) Project Cost and Length of Alternatives

Table 12.5-1 shows project cost and length of the alternatives in which busway, bus facilities such as bus stop and terminals, bus fleets for the trunk bus system, and infrastructure, stations, track, Electric works, operation control center, coach, deposit and equipment for railway system. Those construction works and its cost data are referred to the data from AATE for railway and Protransporte for the trunk bus.

As can be seen, the total length of full project case, Alternative-O is approximately 270km, in which 133km are for railway and 140km are for trunk bus system. Its total cost is approximately 6,000 million US$ in which 2,370 million US$ are road construction cost, 2,800 million US$ are railway and 780 million US$ are trunk bus.

Table 12.5-1 Project Cost and Length of Alternatives

Alternative Case	Project Length (km)			Project Cost (1000US$)			Total Cost including Road
	Railway	Trunk Bus	Total	Railway	Trunk Bus	Sub-Total	
Base Case	0	0	0	0	0	0	0
Alternative-A	53.7	0.0	53.7	1,345,050	0	1,345,050	3,718,775
Alternative-B	96.3	0.0	96.3	2,024,900	0	2,024,900	4,398,625
Alternative-C	133.0	0.0	133.0	2,844,200	0	2,844,200	5,217,925
Alternative-D	0.0	64.8	64.8	0	552,480	552,480	2,926,205
Alternative-E	40.7	64.8	105.5	1,016,100	540,480	1,556,580	3,930,305
Alternative-F	96.3	77.4	173.7	2,024,900	540,040	2,564,940	4,938,665
Alternative-G	133.0	53.5	186.5	2,844,200	387,690	3,231,890	5,605,615
Alternative-H	0.0	133.7	133.7	0	878,795	878,795	3,252,520
Alternative-I	53.7	122.4	176.1	1,345,000	716,405	2,061,405	4,435,130
Alternative-J	96.3	91.3	187.6	2,024,000	594,730	2,618,730	4,992,455
Alternative-K	133.0	67.4	200.4	2,844,200	452,580	3,296,780	5,670,505
Alternative-L	0.0	215.7	215.7	0	1,202,955	1,202,955	3,576,680
Alternative-M	53.7	204.5	258.2	1,345,000	1,156,515	2,501,515	4,875,240
Alternative-N	96.3	192.8	289.1	2,024,900	950,640	2,975,540	5,349,265
Alternative-O	133.0	140.0	273.0	2,844,200	780,700	3,624,900	5,998,625

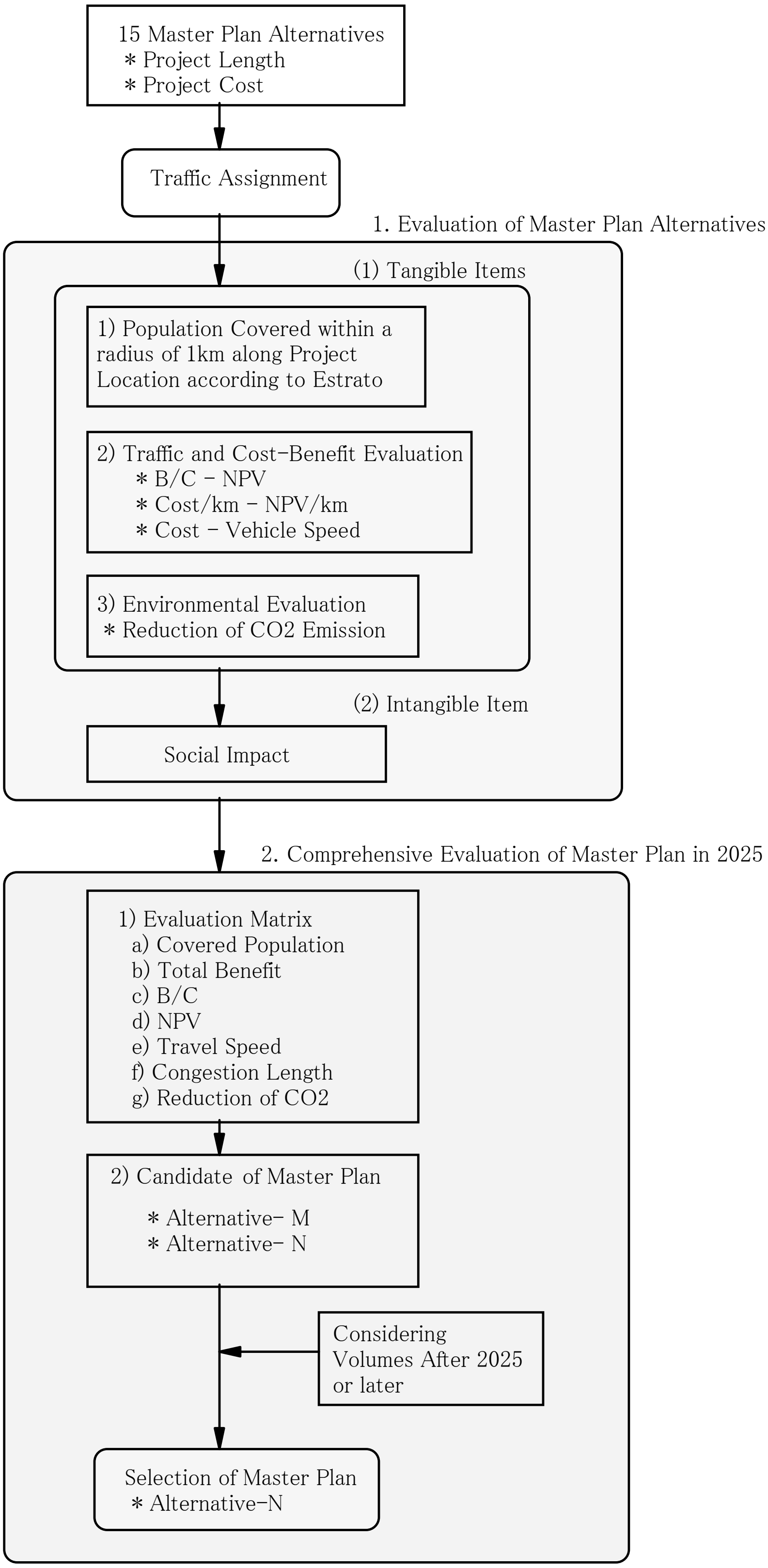


Figure 12.5-1 Evaluation Process of Master Plan Alternatives

12.5.2. EVALUATION OF MASTER PLAN ALTERNATIVES

(1) Tangible Item

1) Covered Population

Figure 12.5-2 shows a covered population ratio to the total according to the alternative networks, which is the population covered within a radius of 1km along project location according to Estrato. As can be seen, the covered population ratio is increase against an alternative network distance. Alternative-N is maximum in the population ratio at approximately 80%, while the alternative-A is 30%. The full network alternatives-M, N and O cover 70-80% of total population. As for Estrato E, approximately 50% of the total population of Estrato E are covered in Alternative-M, N and O.

Figure 12.5-3 shows the covered population per alternative network length, which divided the covered population by the alternative network length. As can be seen, the longer the alternative network length is, the lower the covered population is. The covered populations of alternatives-M, N and O are approximately 28,000, 27,000 and 29,000, respectively.

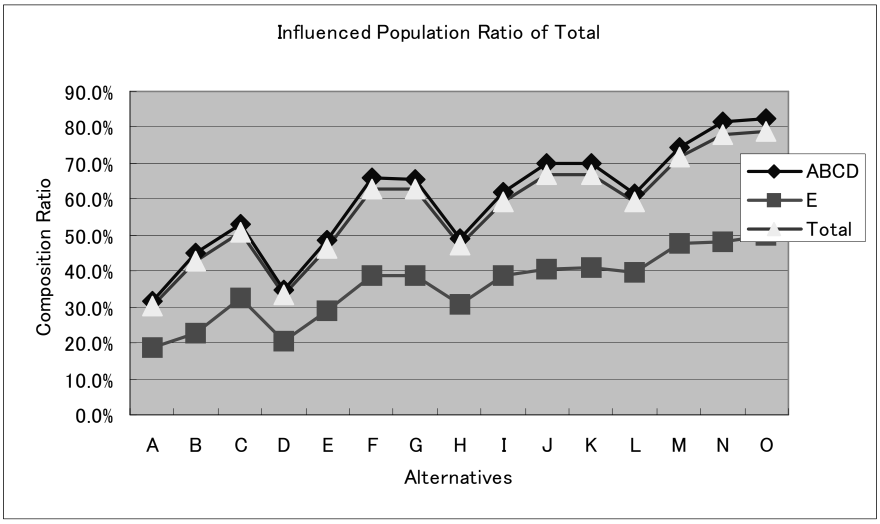


Figure 12.5-2 Population Ratio Covered by Alternatives

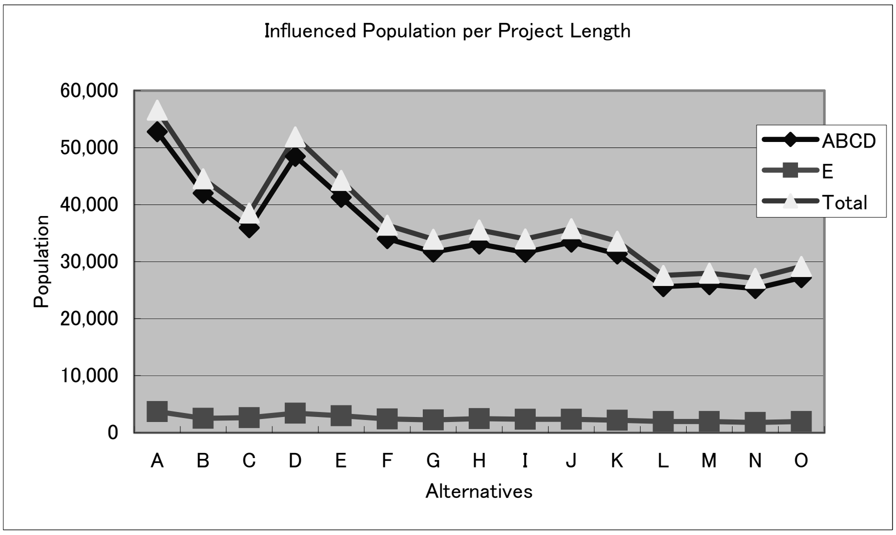


Figure 12.5-3 Covered Population per Alternative Network Length

2) Traffic and Cost-Benefit Evaluation

Traffic and cost-benefit evaluation factors are as followings.

- Travel speed
- Passenger-km
- Passenger-hour
- PCU-km
- PCU-hour
- Number of dispatched buses and trains
- Cost and benefit analysis

Table 12.5-2 shows the results of cost and benefit analysis by the alternatives, which are analyzed based on above traffic and transport indices. As for the measurement of benefit, the difference of VOC and TTC between a base case which is the 2025 project network with only road project, and alternative case which is the 2025 network with road and public transport projects is measured as a benefit. This means that the benefit is measured only for the public transport project composed of trunk bus and railway systems. The unit values of VOC and TTC refer to the data of AATE and Protransporte. In the cost and benefit analysis, the economic cost is estimated from the project cost, which is 80% of the financial cost.

Evaluation of the alternative uses following indices:

- B/C - NPV
- Cost/km – NPV/km
- Cost – Vehicle speed

Figure 12.5-4 shows relationship between B/C and NPV in which NPV shows on the horizontal X-axis against B/C on the vertical Y-axis. NPV is difference between benefit and cost and B/C is a ratio between benefit and cost. As can be seen, the alternatives with higher B/C ratio and large NPV are alternatives-I, J, M, and N. From among these alternatives, the alternatives-I and M are higher in B/C ratio due to trunk bus oriented-project. This is because the cost of trunk bus project is lower than that of the railway.

On the other hand, since alternatives-N orients to the railway project, the cost is higher than that of the trunk bus. The B/C ratio is somewhat low, while NPV is higher. The railway-oriented alternatives are higher in benefit volume and somewhat low in the B/C ratio.

Figure 12.5-5 shows relationship between investment cost and private vehicle speed in which the cost shows on the horizontal X-axis against the speed on the vertical Y-axis. The vehicle speed indicates private vehicle speed on roads. In the trunk bus and railway systems, due to the fact that trunk busway is constructed on the median, the trunk bus is not operated on a mixed traffic lane on which private vehicles, conventional and feeder buses run. Therefore, in this system, the vehicle speed on the mixed lane will be increase. As can be seen, the speed gradually increases against the railway-oriented alternatives. In comparison to the “without” case, which is no improvement in the transport network, the speed in the alternative cases is dramatically higher.

The private vehicle service level in the alternatives-M, N and O is more improvement, comparing to the trunk bus oriented alternatives-H and L.

Figure 12.5-6 shows relationship between cost and NPV per km. In the figure, an alternative, which is a small investment cost/km as well as a large NPV/km, is more efficiency as a master plan alternative. As can be seen, those alternatives are Nos. I, M and N.

Figure 12.5-7 shows a ratio of distance with a volume-capacity ratio of over 1.0 to total road distance against the project investment cost. This means a congestion distance ratio on roads. As can be seen, the higher the investment cost is, the lower the ratio of road distance with traffic congestion is. The ratios in the alternative Nos. M and N are 12.7, respectively. On the other hand, the alternative Nos. I and J in which the railway project distance is short comparing to the alternative Nos. M and N, are higher at 14.6% and 14.0% in the congestion distance ratio. This means that the road congestion level in the alternative Nos. I and J become worse, comparing to the alternative Nos. M and N. Figure 12.5-21 and Figure 12.5-23 show the traffic volume and the volume-capacity ratio on road by private vehicle and conventional bus in alternative Nos. I and J. Figure 12.5-27 and Figure 12.5-29 show for alternative Nos. M and N. Those figures illustrate the congestion segments on roads.

Table 12.5-2 Cost and Benefit Analysis

Case	Total Benefit (VOC+TTC) (1000US$)	B/C	NPV (1000US$)	Speed on Road (km/h)	Ratio of Distance with a volume-capacity ratio of over 1.0
Alternative-A	1,435,259	1.75	2,416,859	14.2	18.0%
Alternative-B	1,794,881	1.79	3,131,629	15.0	16.5%
Alternative-C	2,234,520	1.82	3,986,212	15.8	15.2%
Alternative-D	823,549	1.37	880,613	13.7	20.4%
Alternative-E	1,658,260	1.90	3,095,709	14.5	16.5%
Alternative-F	2,141,494	1.86	3,919,179	15.4	14.5%
Alternative-G	2,366,578	1.78	4,090,762	15.9	14.4%
Alternative-H	1,242,229	1.80	2,182,227	14.6	18.2%
Alternative-I	2,249,086	2.22	4,884,849	16.0	14.6%
Alternative-J	2,363,344	2.03	4,736,875	16.2	14.0%
Alternative-K	2,368,678	1.76	4,029,323	15.8	14.1%
Alternative-L	1,741,423	2.24	3,803,889	15.5	15.6%
Alternative-M	2,523,754	2.23	5,495,861	17.2	12.7%
Alternative-N	2,604,114	2.07	5,303,624	17.5	12.7%
Alternative-O	2,577,306	1.79	4,500,058	16.7	12.9%

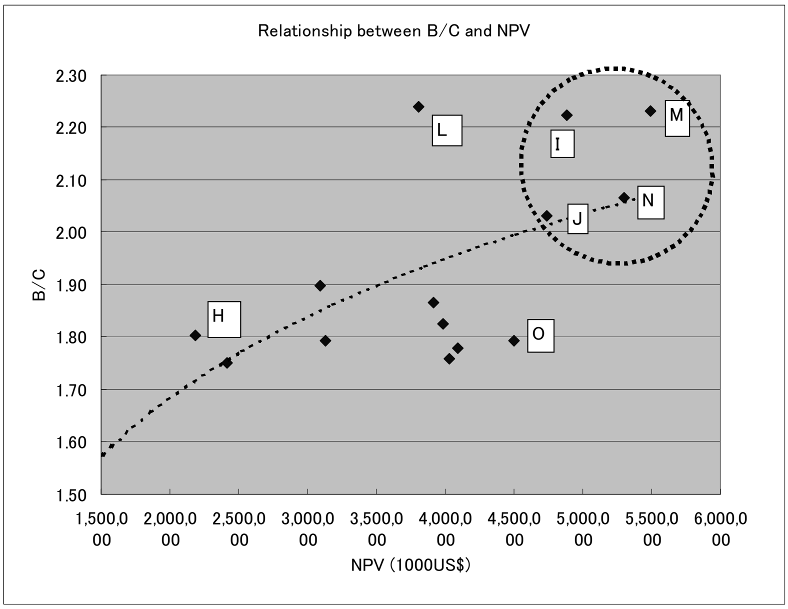


Figure 12.5-4 Relationship between B/C and NPV

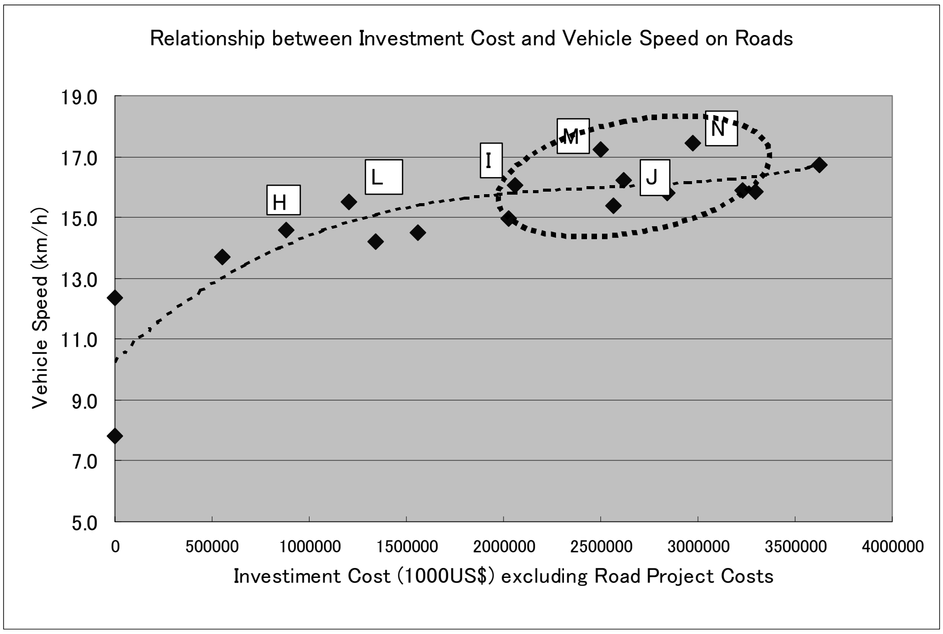


Figure 12.5-5 Relationship between Investment Cost and Vehicle Speed

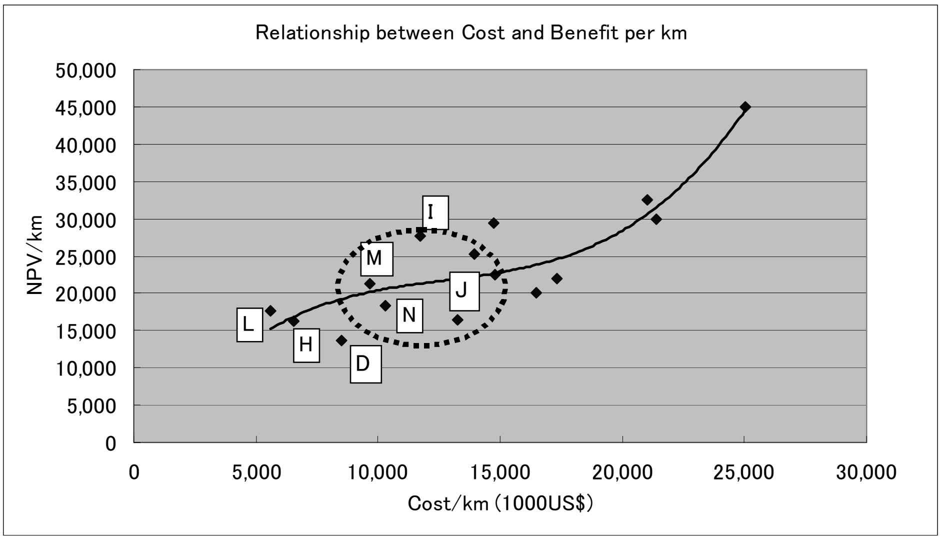


Figure 12.5-6 Relationship between Cost/km and NPV/km

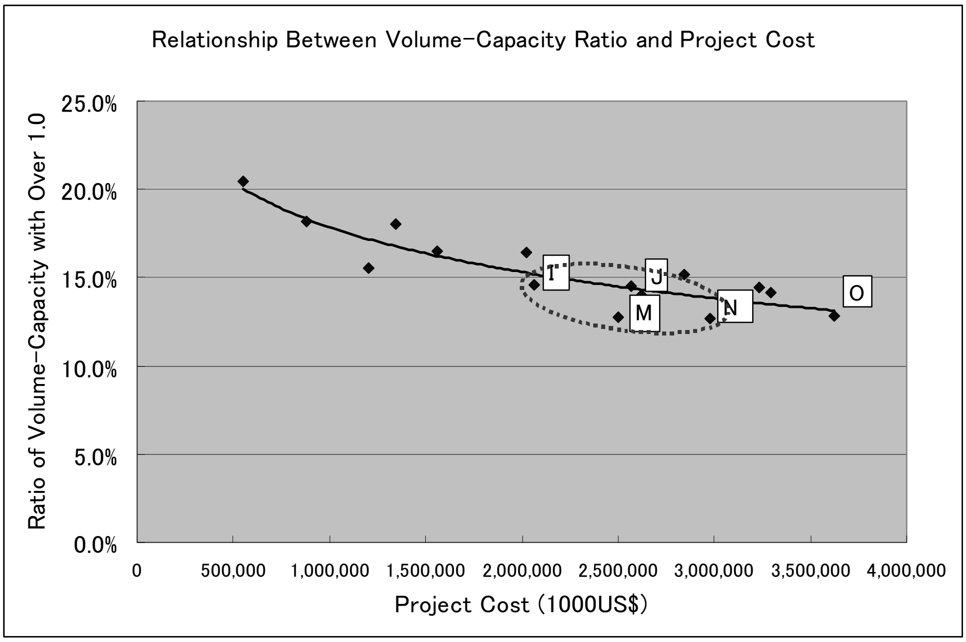


Figure 12.5-7 Relationship between Investment Cost and Volume-Capacity Ratio

Figure 12.5-8 shows daily number of dispatched buses and railway coaches according to the alternatives. The dispatched conventional buses in alternatives-H and I are approximately 65% of the total in which the conventional bus is operated on the mixed lanes. The balance is the trunk bus and railway. In the alternatives-M, N and O, the conventional bus ratio is decrease at 45-60%, while the trunk bus ratio is increase at 35-50%.

In the future transport conditions, the trunk bus and railway transport shares in the alternatives-M, N and O are increase, while the conventional bus share in the alternatives-H and I is higher.

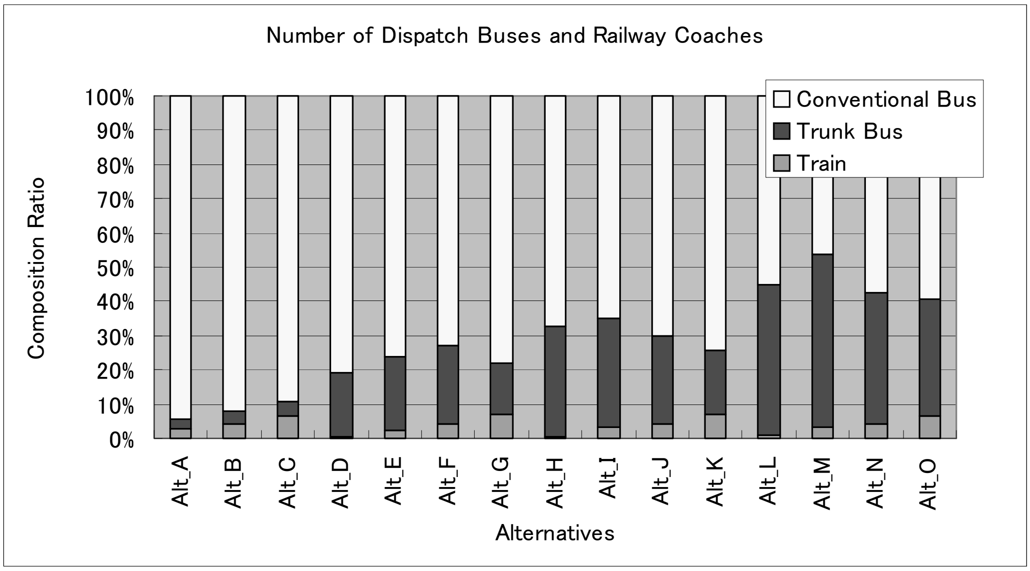


Figure 12.5-8 Daily Number of Dispatched Buses and Railway Coaches

3) Environmental Evaluation (Preliminary Vehicular Emission Study)

The purpose of this study is to evaluate the amount of vehicular emissions to be generated by the regional future traffic and transport conditions around the Lima and Callao Metropolitan Area, and carry out a comparative study under the following two scenarios; i.e., **with-** and **without** proposed new roads, trunk bus and railway system project in the Year 2025. Here, the emission of the carbon dioxides (CO_2) is of concern.

a) <u>Computation of Vehicular Emissions</u>

The daily amount of the total emission loading of pollutants, $\mathbf{W_s}$, is computed by,

$$\mathbf{W_s = \Sigma\, E_s \;\cdot CK} \qquad (1)$$

where $\mathbf{E_s}$ is the vehicle-type air pollution emission factor of targeted pollutants, and **CK** is the computational results (vehicle times kilometers) of the future traffic and transport demand forecast, that are carried out under sixteen different development scenarios (see Chapter 12 of this report for more detailed information). Here, four different vehicle types such as passenger car, taxi, truck and bus are considered.

Recently, a series of studies on the vehicular emissions have started in Peru (Air Quality Steering Committee for Lima and Callao, 2002). However, no the information and/or parameter of CO_2 emission factors haveare not been summarized yet. So, vehicular emission factors summarized in current study reports[1] are used within this study. In general, the order of the magnitude of the CO_2 emission factor of old vehicles tends to be larger than that of those of the new ones. However, due to the lack of precise information of the vehicle age by the vehicle type, only one type of emission factor is used for each vehicle types within this estimation. No long-term vehicle maintenance/inspection programs that will specify the future vehicle type and the vehicular emission condition exist yet in Peru, so it is assumed that no significant change in the vehicular condition will occur until the Year 2025.

The estimation of the environmental benefit to be caused by the operation of the proposed transport project is carried out by evaluating the amount of the reduction of the emitted CO_2 loading that is caused by the change of vehicle-kilometer of the entire transport situation.

b) <u>Results and Discussions</u>

Based on the evaluation procedures mentioned above, the calculation of the regional amount of CO_2 - vehicular emission loading in the Year 2025 is carried out. Figure 12.5-9 and Figure 12.5-10 show the computational results of total CO_2 vehicular emission loading and the environmental benefits (i.e. the reduction of the emitted CO_2 loading) to be caused under different scenarios, respectively. Figure 12.5-11 shows the computational results of CO_2 vehicular emission loading by the vehicle type. From these figures, it can be seen that the vehicular emission loading of the taxi will be the most significant under each **With**- and **Without**-scenarios. The amounts of the vehicular emission-reduction of CO_2 to be caused by the operation of the proposed transport project in the Year 2025 are varyied between 22,526 ton/day (59 %-reduction: Alt-M) and 16,900 ton/day (44 %- reduction: Alt-D).

This reduction can be explained by the following reasoning. After the operation of the proposed new mass transit system beginswill start, the entire public transport by bus or railway system will be improved greatly in comparison with current non-organized transport conditions. Then, some of commuters by car will switch to use the proposed mass transit system, provided that both bus and railway fares of the proposed mass

[1] Environmental Bureau, Tokyo Metropolitan Municipality, Study on Vehicular Emission for Future Traffic Demands in the Metropolitan Area, 2000.

transit system are reasonably set for the public transport system users. Eventually, traffic volumes of several major roads around the Lima and Callao Metropolitan Area will be lessened due to this modal shift, and the severity eness of current traffic conditions (e.g., traffic jams, road safety and so on) will be alleviated to some extents. As a result, the entire traffic condition and roadside environment around the Lima and Callao Metropolitan Area will be improved (more detailed discussions of traffic transport benefits to be caused by the proposed transport project can be found in Chapter 12 of this report).

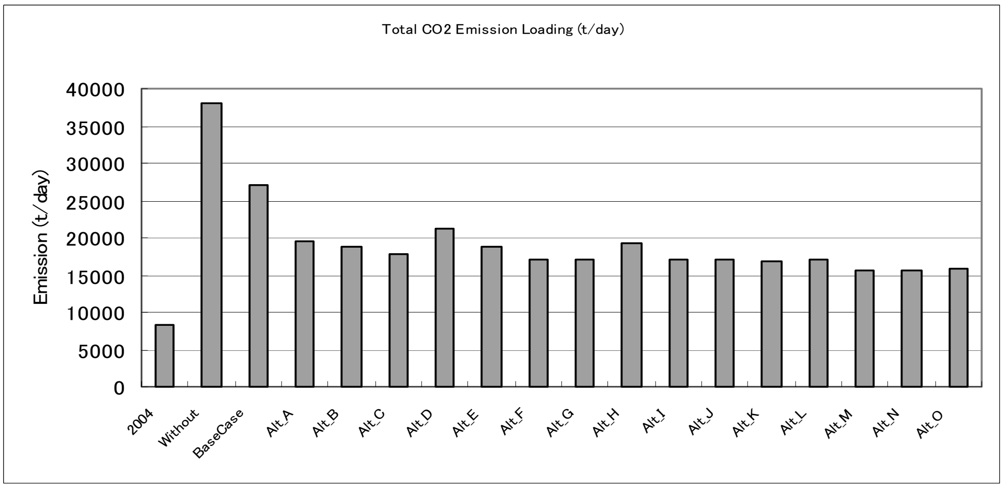
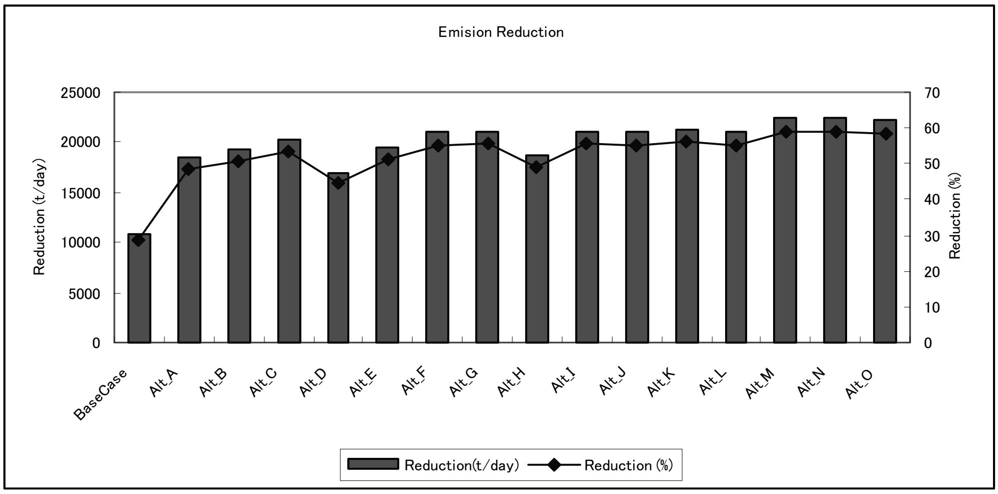


Figure 12.5-9 CO_2 Vehicular Emission Loading



Note: Reduction (%) = 100 x (Emission without - Emission with)/(Emission without)

Figure 12.5-10 Environmental Benefit (Reduction of CO_2 Vehicular Emission Loading)

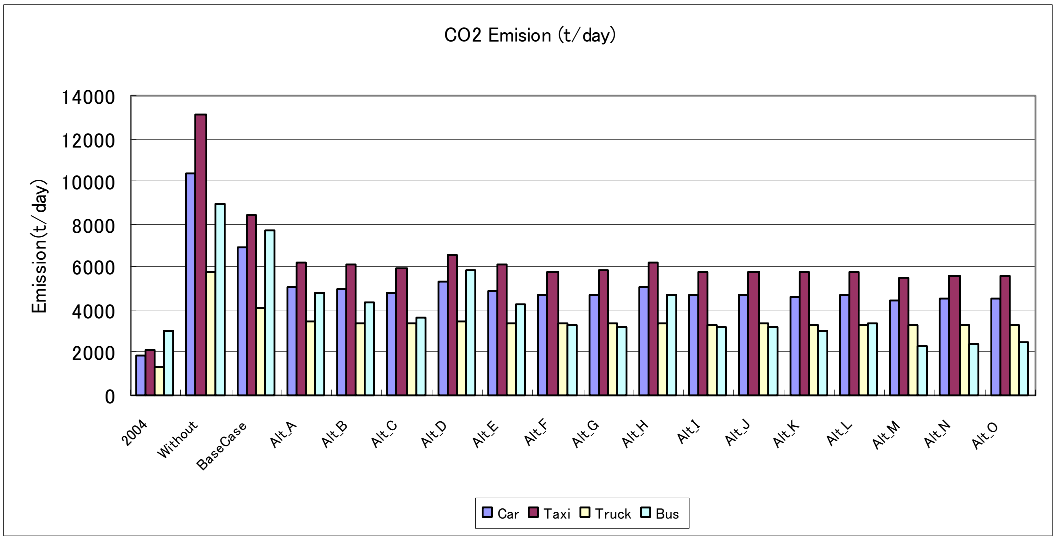


Figure 12.5-11 CO_2 Vehicular Emission Loading by Vehicle Type

(2) Intangible Item

The evaluation of the Master Plan alternatives was made based on the tangible items, which are composed of traffic and passenger demand in 2025, a cost-benefit analysis, population covered by the alternative networks, and environmental impact. They are the most objective items to indicate the effectiveness of project investment. However, there are many items to consider the evaluation of project investment in exclusive of these tangible items. Those items are difficult to measure from the socioeconomic viewpoint. One of those items is social impact derived from the implementation of the Master Plan project. The social impacts in exclusive of the socioeconomic items are important in the evaluation of the Master Plan.

However, it is difficult to carry out the detailed evaluation for those impacts in the Master Plan study. Therefore, the general social impacts are intangibly evaluated due to difficulty of conversion to the value of money.

The alternative projects in the Master Plan are the railway, trunk bus system and road projects. The proposed plans include hardware and software as mainly shown below.

a) To introduce a large articulated bus with a higher capacity to alleviate a traffic congestion and problems for air and noise pollution caused by bus fleets
b) To integrate a bus route
c) To reorganize a private bus organization
d) To construct a busway network segregated a private vehicle to actualize a higher bus operation speed
e) To prepare a bus facility such as bus terminal and bus stop
f) To propose a new tariff system
g) To prepare a feeder bus route
h) To construct new roads

Since the intensity of social impacts derived from the above plans is similar by alternative projects, the social impacts are examined, not by the alternatives. Therefore, the social impact is not employed in the evaluation of the alternatives.

The social impacts are classified into two: direct and indirect effectiveness. Those impacts are shown below.

1) Direct Effectiveness

a) Impact of introduction of the large articulated bus

The trunk bus system introduces a large articulated bus with a higher capacity. According to the introduction of the articulated bus, the total number of operated buses is decrease and effectiveness of bus operation improves. The situations to shift toward the small bus are stopped in accordance with the direction of bus improvement plan in DMTU, which plans the introduction of large bus instead of small bus against future passenger growth. The small buses (Micro bus and Camioneta rural) with a bus age of 10 years or less will be operated on the feeder bus routes. The reduction of number of small buses operated on major roads alleviates traffic congestion.

In Lima, the average bus ages of Omnibus, Microbus and Camioneta are approximately 20 years, 18 years and 15 years, respectively. Omnibus, which uses over 15 years accounts for 78% of the total. Therefore, the old buses are close to a scrap due to not enough for maintenance of those buses. This is because bus company and owner can not afford the expenses of the bus maintenance and prefer to expense the survival of company. As the results of the situations, the environment conditions become worse. Especially, the air and noise pollution are severe. The introduction of the articulated bus will improve the conditions of air and noise pollution. Bus passengers desire the scrap of old bus according to the bus passenger opinion survey.

Since the new articulated bus is clean in board, the security in bus fleet is improved. The bus passenger opinion survey indicates that the security problem is higher rank in the current bus problem.

b) Impact of integration of a bus route

The bus route in the Lima and Callao municipalities is too many in numbers and too long in distance. At the same time, the route configuration and the route distance change in route location and route length. And then, the bus service level such as service frequency is gradually lower due to the increase of operation cost. In general, it is said that short route distance is better in operation efficiency. From the viewpoint, the operation efficiency becomes worse in Lima.

When the trunk busway is constructed on major roads, conventional bus routes assigned on those roads must be rerouted by cutting those which overlap with trunk bus lines, as well as small demand routes. On the cut and integrated bus routes from among the conventional bus routes, the conventional bus is operated. The integration of the route will improve the operation efficiency. At the same time, the integration of the route influences to bus users at first, and then gradually satisfies sooner or later.

The operation of trunk bus system, which can offer high performance and special operational measures are required. It is necessary to consider a metropolitan transport management organization to be created or reformulated for the operation of the trunk bus system. The trunk bus system operating companies will propose a candidate trunk bus routes or lines in the trunk bus system under public bidding. Under the situation, the reorganization or consortium of the trunk bus operating companies will be reformulated. The large-scale companies and consortiums will be prepared in future and strengthened for financial condition.

At the present, the bus companies are forced to operate bus under keen competition with other companies. This means that the efficiency of bus operation become worse. The bus company is hard in management such as income and expenditure balance. Under the trunk bus system, since the new bus fare system is introduced, the bus driver does not scramble the passengers at bus stop. Therefore, the keen competition with other companies in the operation will disappear and a traffic safety will improve.

In this condition, the income balance will become better. The financial conditions under the trunk bus system operation will be done in the feasibility study.

c) Impact of introduction of railway and trunk bus system

The introduction of the railway and trunk bus system influences the employees of transport company. The drivers and conductors of bus fleets will lose their jobs due to the reduction of operating buses. However, in order to accomplish high performance in the trunk and feeder bus system, an efficient ticketing system is needed. There is off-board ticketing system as an intelligent ticketing system. It offers the possibility to reduce passenger service time and thereby to reduce bus dwelling time and increase commercial speed.

The ticketing system proposes to sale the ticket at shops outside a bus fleet such as kiosks, newspaper stands, and bus stop. The system will need a ticket examiner at railway station and bus stop whose facility provides the ticket gates and ticket window to divide passengers and others. The new system needs a reshuffling of personnel according to the operation system. It is indispensable to shifts excess personnel of drivers and conductors to new working positions.

From the above discussion, it will be possible to control the impact for employment.

d) Impact of preparation of a feeder bus route for poor people

In the proposed trunk and feeder bus system, the feeder bus service is indispensable. Especially, a feeder bus network and a fare rate system for a poor people are an important issue according to result of the poor people survey carried out in the study.

According to the survey, the travel of the poor people within walking distance is done by walking, not use other modes because of fare rate and poor bus route. The walking distance is longer than other people. The demand for the bus transport is mainly two: one is to improve bus route and the other is to be fare problem. Therefore, the proposal for the poor people is two: one is to prepare the feeder bus route network to answer their demand, and the other is to propose a lower fare rate of feeder bus.

The preparation of the feeder bus route with a lower fare rate extends the behavior of a street vender who walks about an average of 20 minutes or more. Their daily travels will be improved.

As for the fare rate of the feeder bus, it is necessary to carry out a further study.

e) Impact of traffic accidents by the Master Plan

The implementation of the Master Plan projects reduces traffic accidents in the whole study area. In the Master Plan study, it is difficult to estimate quantitatively the reduction of the accidents. This is because the analysis of the relationship between the ratio of accidents generated and traffic conditions on the basis of past data is difficult.

However, the reduction of traffic accidents generally be found according to the contents of the projects as shown below.

- To reduce traffic accidents between trunk buses and private vehicles because the trunk bus is operated on the busway segregated the buses from private vehicles.
- To reduce traffic accidents between trunk buses because the trunk bus is operated on the segregated busway on which the bus cannot overtaken other buses.
- To reduce traffic accidents for passengers and pedestrians because trunk bus stops at a bus stop facility. At the present, bus passengers boards and alights buses everywhere where bus stop facility exists or not, when bus passengers raise his/her hand as a signal at sidewalk on roads with the approach of bus due to no

facility of bus stop in exclusive of particular roads. Therefore, under the trunk bus system, the potential of traffic accidents will be lower when boarding and alighting.

2) Indirect Effectiveness

a) Impact of employment by construction

The employment by construction for the projects will be promoted. Especially, the employment by construction and its material companies increase when the Master Plan projects will be implemented. Since the demand on the construction workers increases as an economic measure against poor people, the unemployment problem will be alleviated.

The estimation of volume of construction workers for related projects will be carried out in the feasibility study.

b) Impact of development of railway station and bus terminal

The Master Plan projects construct railway stations and bus terminals near the end of bus routes. The construction of those facilities accelerates the development of commercial facility near those areas, and the employment of service industry. The area surrounding those facilities will be developed to residential area and population will increase, as well as travel demand will increase. As a result, the value of the property will rise.

12.5.3. Comprehensive Evaluation of Master Plan in 2025

(1) Evaluation Matrix

The alternatives of the Master Plan networks are comprehensively selected from the viewpoint of traffic (improvement of travel speed, alleviation of traffic congestion), economic (cost-benefit analysis) and environmental effectiveness (reduction of CO2).

In order to show a clear procedure of selection method, the tangible evaluation items is shown in the manner of matrix form, which is interrelation between alternative scenarios and evaluation items. The evaluation items are shown below:

a) Covered population
b) Total benefit
c) B/C
d) NPV
e) Travel speed on road
f) Congestion Length
g) Reduction of CO2

Table 12.5-3 summarizes the evaluation items by the alternative Scenarios of which those items are already shown in the related sections. Table 12.5-4 shows the evaluation matrix, in which the maximum value from among the alternatives in each item gives 15 points and the next rank gives 14 points. The minimum value gives 1 point. The summation of 7 items without weight factor is defined as a comprehensive evaluation.

As can be seen, the highest evaluation is the alternative-N, which gets 99 points. The next highest is the alternative-M with 98 points.

Table 12.5-3 Evaluation Items by Alternative Scenarios

Alternatives	Total Cost including Road (1000US$)	Covered Population	Total Benefit (VOC+TTC) (1000US$)	B/C	NPV (1000US$)	Speed on Road (km/h)	Ratio of Distance with a volume-capacity ratio of over 1.0	Reduction of CO_2 Vehicular Emission	
								Ton/day	Reduction Ratio (%)
Alternative-A	3,718,775	3,036,540	1,435,259	1.75	2,416,859	14.2	18.0%	19,532	48.7
Alternative-B	4,398,625	4,289,224	1,794,881	1.79	3,131,629	15.0	16.5%	18,786	50.7
Alternative-C	5,217,925	5,127,367	2,234,520	1.82	3,986,212	15.8	15.2%	17,743	53.4
Alternative-D	2,926,205	3,363,241	823,549	1.37	880,613	13.7	20.4%	21,178	44.4
Alternative-E	3,930,305	4,670,322	1,658,260	1.90	3,095,709	14.5	16.5%	18,663	51.0
Alternative-F	4,938,665	6,328,780	2,141,494	1.86	3,919,179	15.4	14.5%	17,072	55.2
Alternative-G	5,605,615	6,326,776	2,366,578	1.78	4,090,762	15.9	14.4%	16,981	55.4
Alternative-H	3,252,520	4,751,466	1,242,229	1.80	2,182,227	14.6	18.2%	19,327	49.2
Alternative-I	4,435,130	5,987,184	2,249,086	2.22	4,884,849	16.0	14.6%	16,957	55.5
Alternative-J	4,992,455	6,712,582	2,363,344	2.03	4,736,875	16.2	14.0%	17,040	55.2
Alternative-K	5,670,505	6,729,820	2,368,678	1.76	4,029,323	15.8	14.1%	16,736	56.0
Alternative-L	3,576,680	5,948,597	1,741,423	2.24	3,803,889	15.5	15.6%	17,094	55.1
Alternative-M	4,875,240	7,220,887	2,523,754	2.23	5,495,861	17.2	12.7%	15,553	59.2
Alternative-N	5,349,265	7,834,618	2,604,114	2.07	5,303,624	17.5	12.7%	15,688	58.8
Alternative-O	5,998,625	7,954,125	2,577,306	1.79	4,500,058	16.7	12.9%	15,817	58.5

Table 12.5-4 Evaluation Matrix by Alternative Scenarios

	1) Covered Population	2) Total Benefit (VOC+TTC)	3) B/C	4) NPV	5) Speed	6) Ratio of Distance with a volume-capacity ratio of over 1.0	7) Reduction of CO2 (Ton/day)	Total 1) to 7)	Rank
Alternative-A	1	3	2	3	2	3	2	16	14
Alternative-B	3	6	5	5	5	5	4	33	12
Alternative-C	6	8	8	8	8	7	6	51	10
Alternative-D	2	1	1	1	1	1	1	8	15
Alternative-E	4	4	10	4	3	4	5	34	11
Alternative-F	10	7	9	7	6	9	8	56	8
Alternative-G	9	11	4	10	10	10	10	64	7
Alternative-H	5	2	7	2	4	2	3	25	13
Alternative-I	8	9	13	13	11	8	11	73	5
Alternative-J	11	10	11	12	12	12	9	77	4
Alternative-K	12	12	3	9	9	11	12	68	6
Alternative-L	7	5	15	6	7	6	7	53	9
Alternative-M	13	13	14	15	14	14	15	98	2
Alternative-N	**14**	**15**	**12**	**14**	**15**	**15**	**14**	**99**	**1**
Alternative-O	15	14	6	11	13	13	13	85	3

(2) Selection of Master Plan

Two (2) candidates of master plan network alternatives are Nos. M and N, which are trunk bus and railway combination plans. Considering volumes after 2025 or later, **alternative-N** is chosen as a master plan network. The alternative-N is further studied in the peak hour traffic demand and the master plan is formulated.

Figure 12.5-12 to Figure 12.5-30 show daily passenger volumes on the trunk bus and railway systems in 2025 in the alternatives-A to O. In those figures, the traffic volume on each transport facilities is drawn by a narrow band whose width is proportional to the assigned passenger volume. A green color shows daily railway passenger volumes and a red color is daily trunk bus passenger volumes.

The major reasons for the selection of Alternative-N (Alt-N) of the Transport Network Plan are summarized as follows,

a) By the vehicular emission reduction comparison study between the With Project case and Without Project case, Alternative–N presents a high reduction percentage (57%) in comparison to the Without Project case among 15 Alternatives. The evaluation of the other natural and social environmental impacts are almost same value among 15 alternatives.

b) From the benefit-cost ratio (B/C) analysis, Alternative-N presents a high (B/C=2.07) ratio among 15 Alternatives.
c) Alternative-N presents the highest benefits (B), as well as the next highest Net Present Value (NPV) among the 15 Alternatives.
d) Alternative-N presents the highest running speed on the roads among 15 Alternatives.

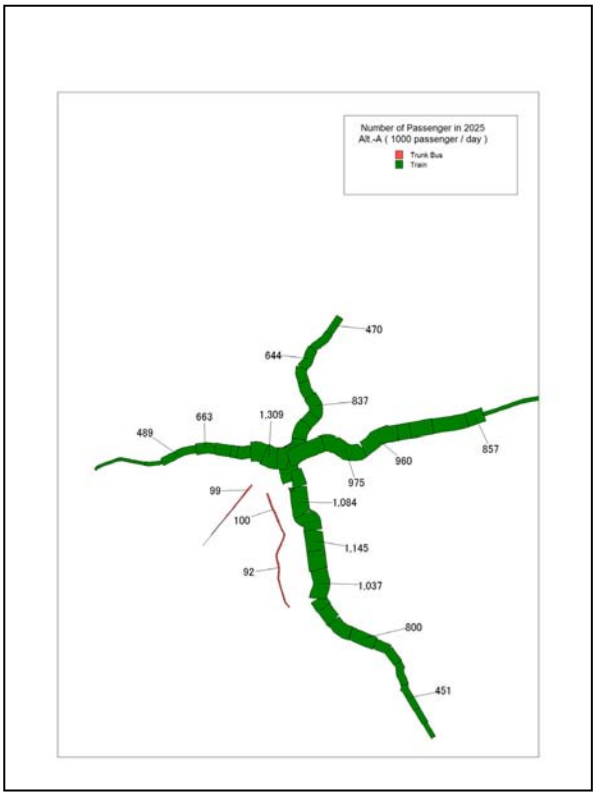


Figure 12.5-12 Daily Passenger Volumes in Alternative-A

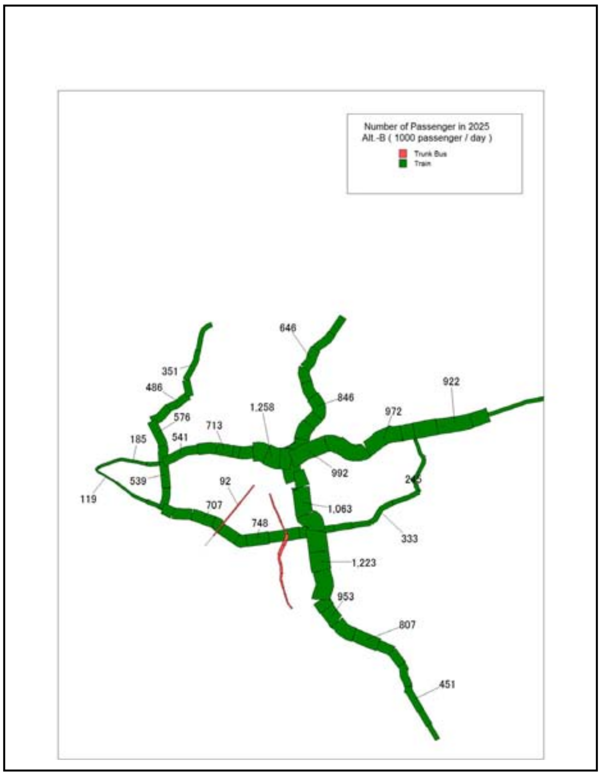


Figure 12.5-13 Daily Passenger Volume in Alternative-B

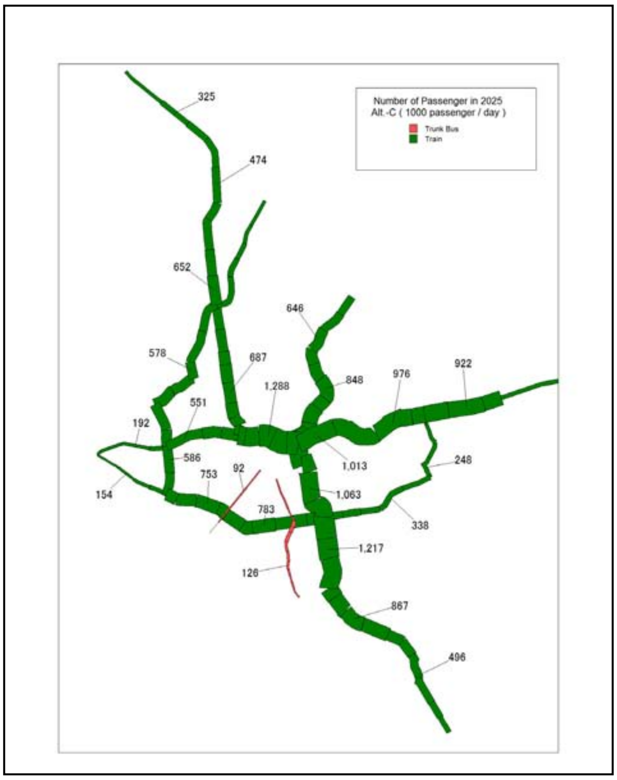


Figure 12.5-14 Daily Passenger Volumes in Alternative-C

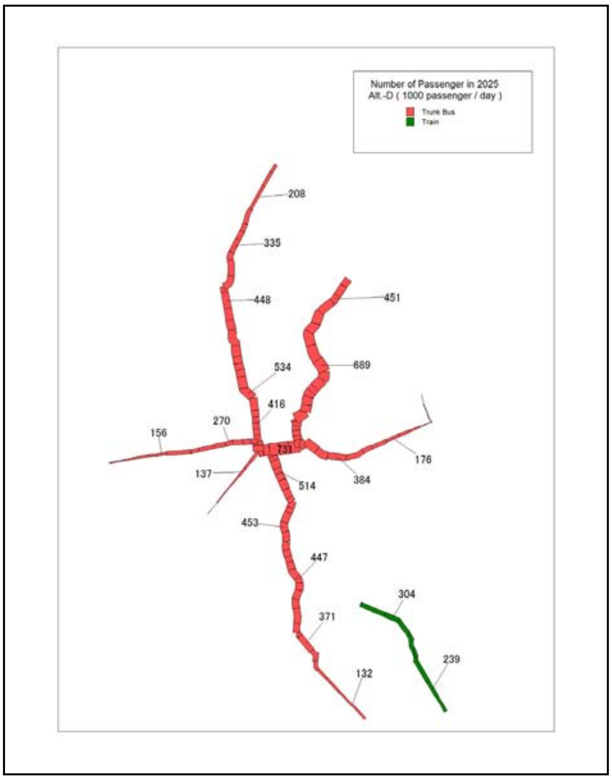
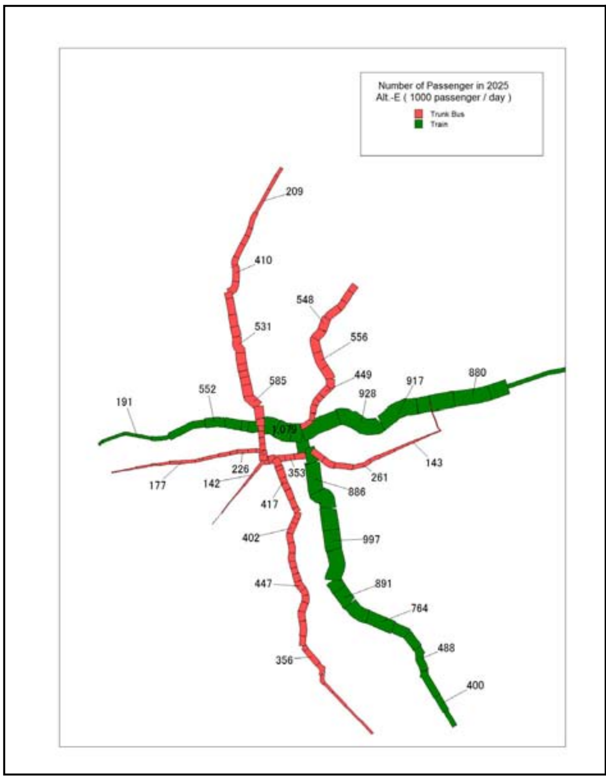


Figure 12.5-15 Daily Passenger Volumes in Alternative-D



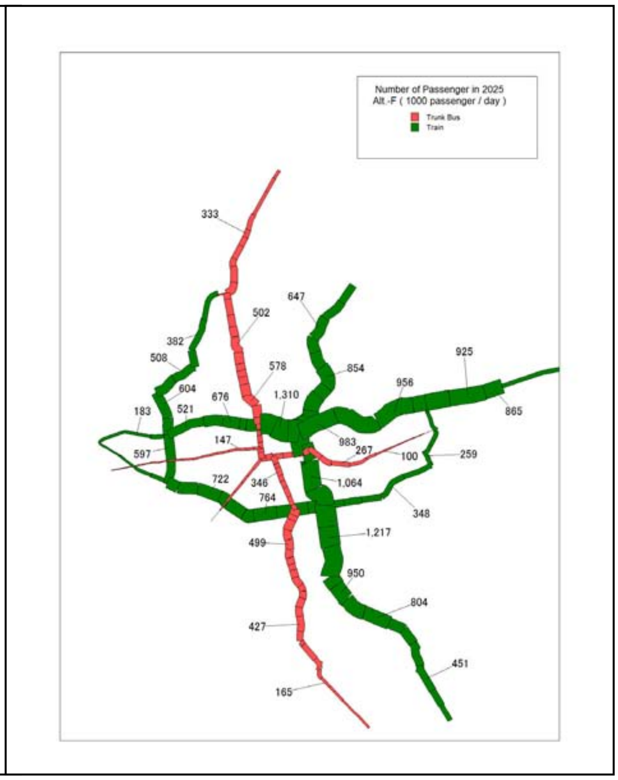
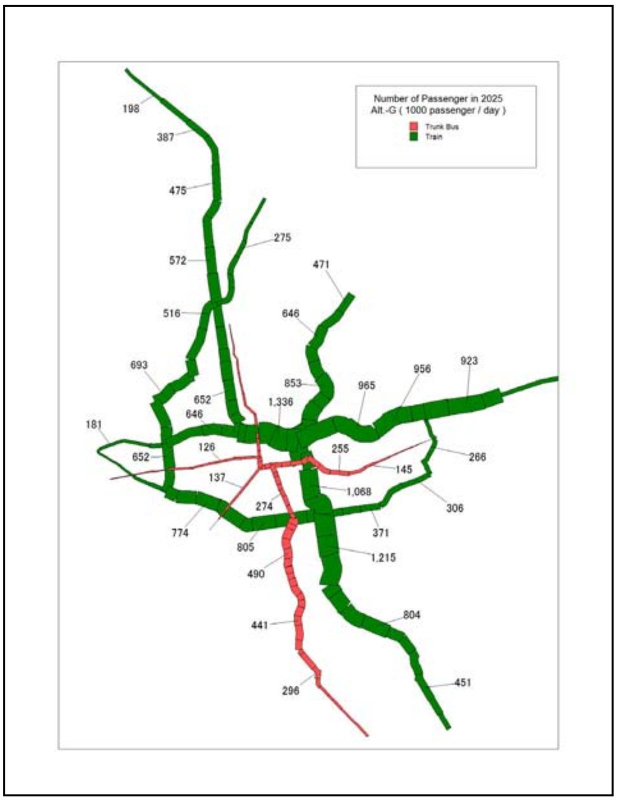


Figure 12.5-16 Daily Passenger Volume in Alternative-E

Figure 12.5-17 Daily Passenger Volume in Alternative-F



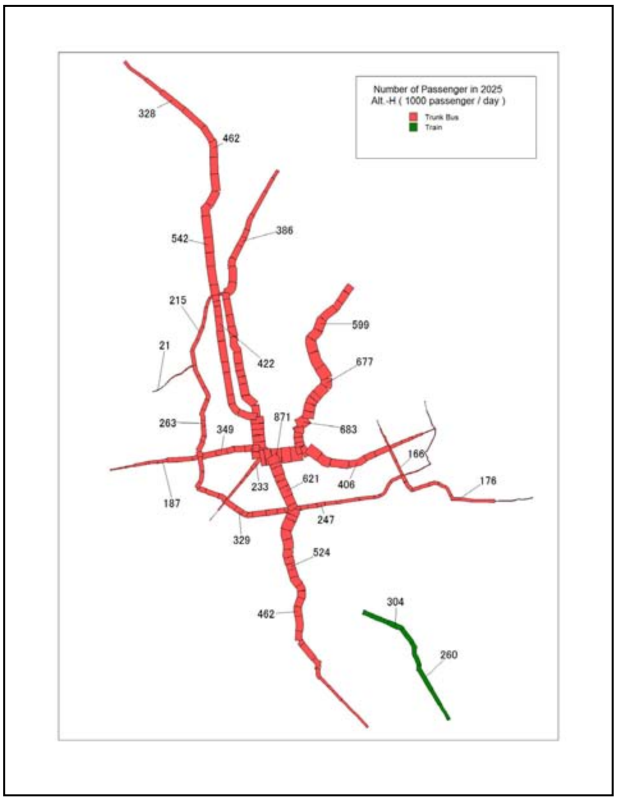


Figure 12.5-18 Daily Passenger Volume in Alternative-G

Figure 12.5-19 Daily Passenger Volume in Alternative-H

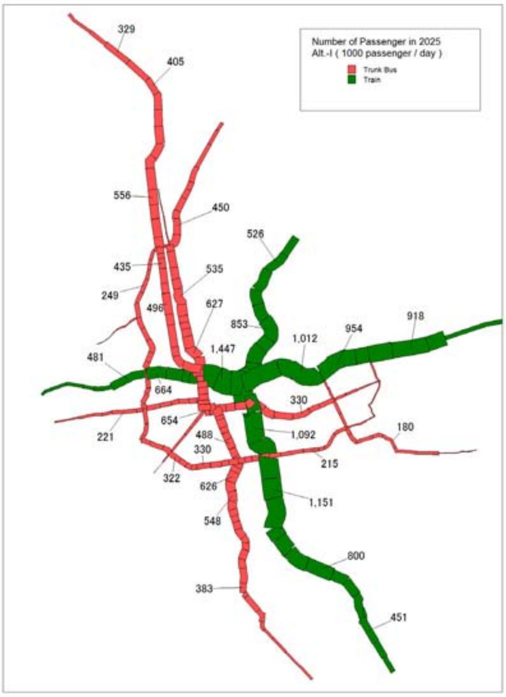


Figure 12.5-20 Daily Passengers Volume in Alternative-I

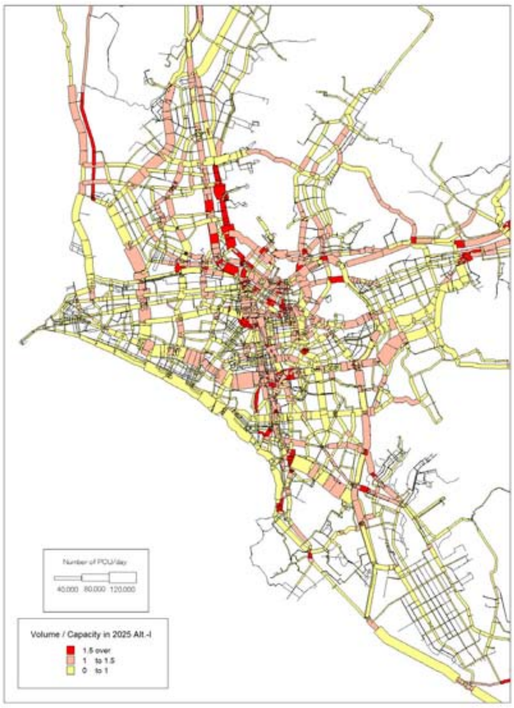


Figure 12.5-21 Daily PCU Volumes on Road in Alternative-I

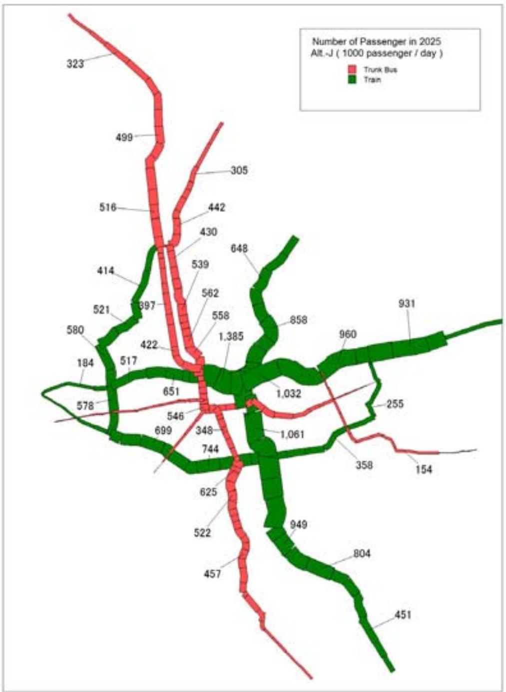


Figure 12.5-22 Daily Passenger Volumes in Alternative-J

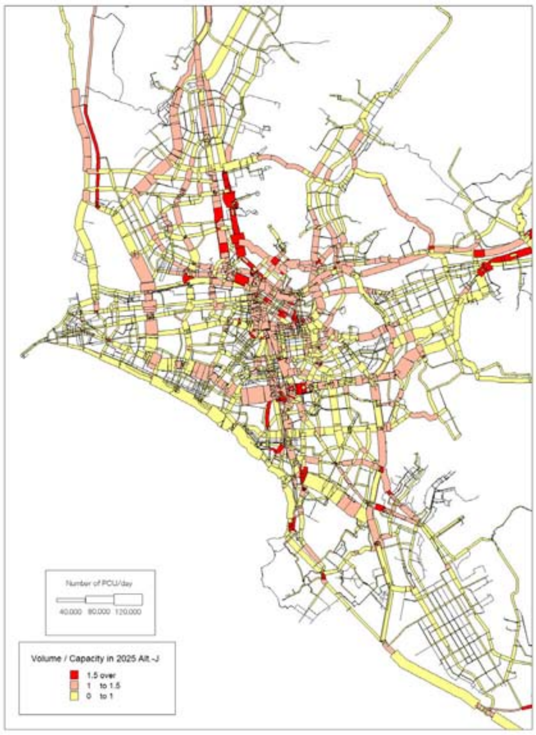


Figure 12.5-23 Daily PCU Volumes on Road in Alternative-J

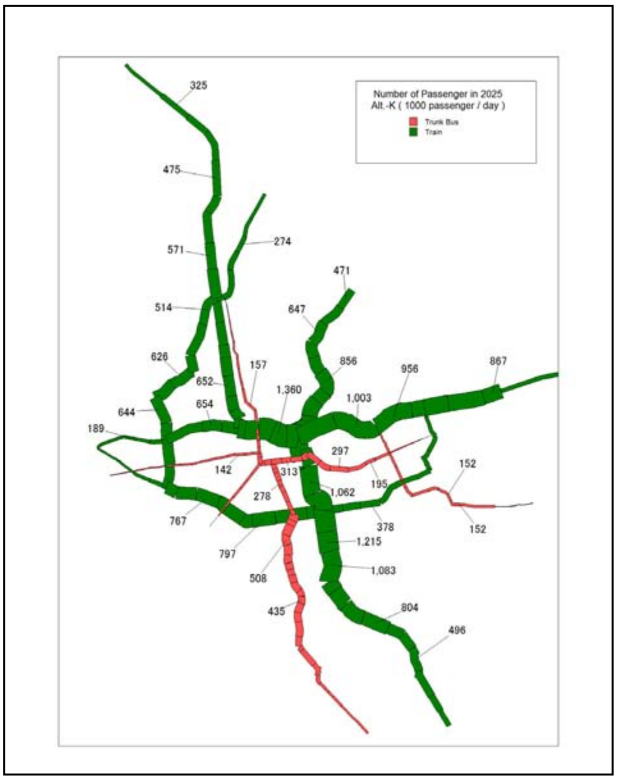


Figure 12.5-24 Daily Passenger Volumes in Alternative-K

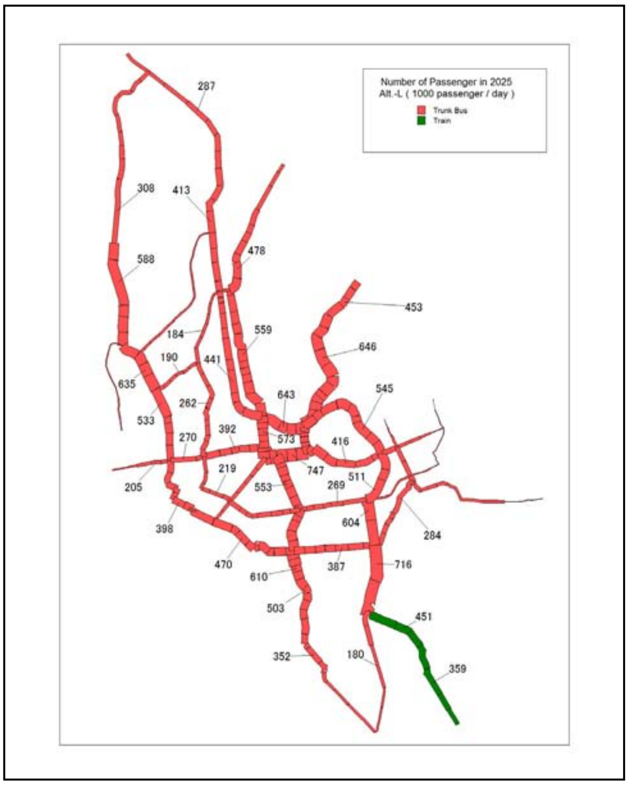


Figure 12.5-25 Daily Passenger Volumes in Alternative-L

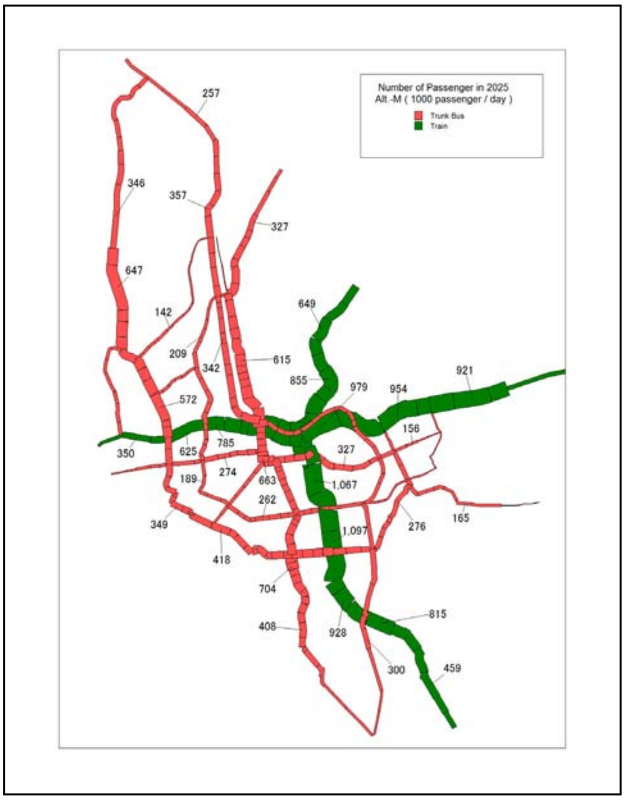


Figure 12.5-26 Daily Passenger Volumes in Alternative-M

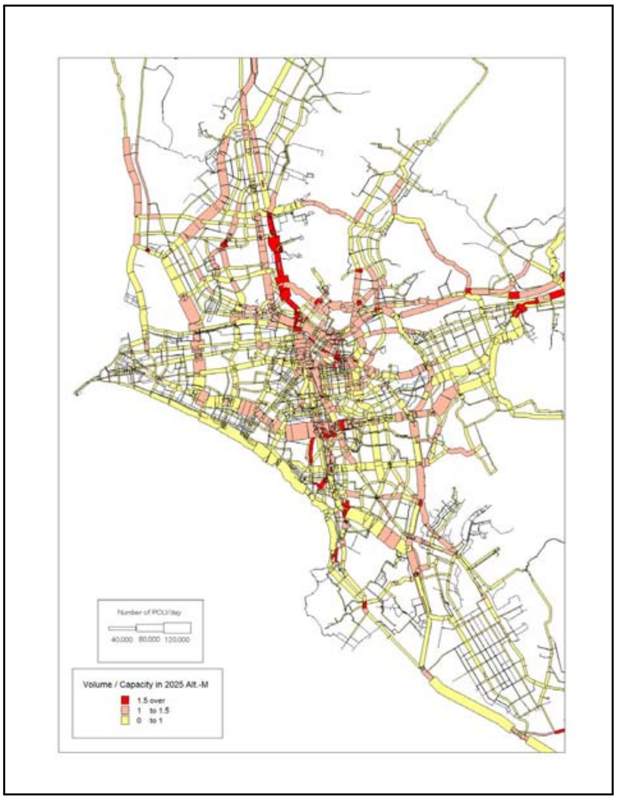


Figure 12.5-27 Daily PCU Volumes on Road in Alternative-M

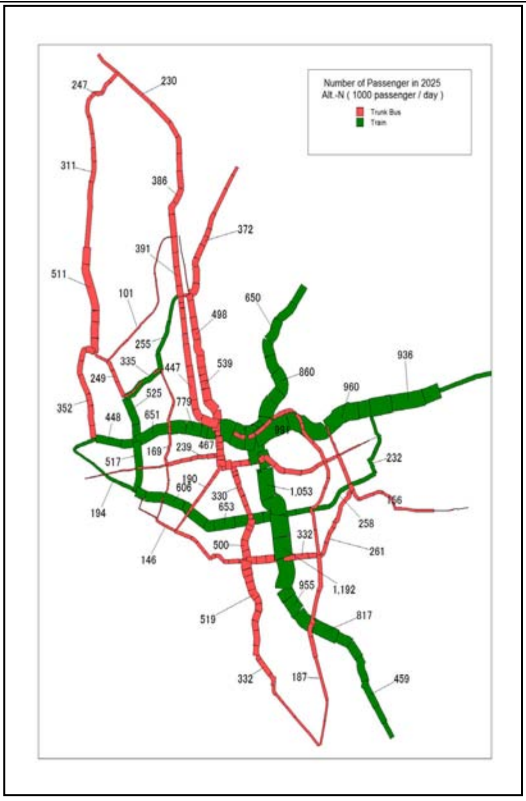


Figure 12.5-28 Daily Passenger Volumes in Alternative-N

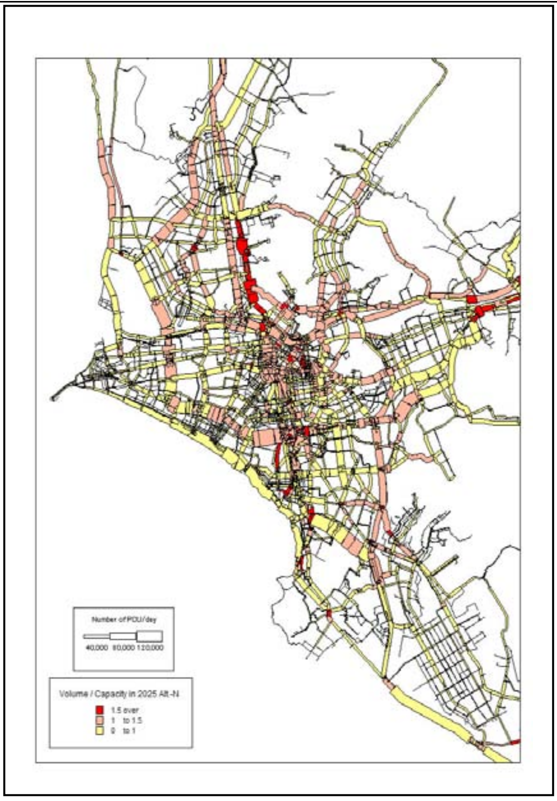


Figure 12.5-29 Daily PCU Volumes in Alternative-N

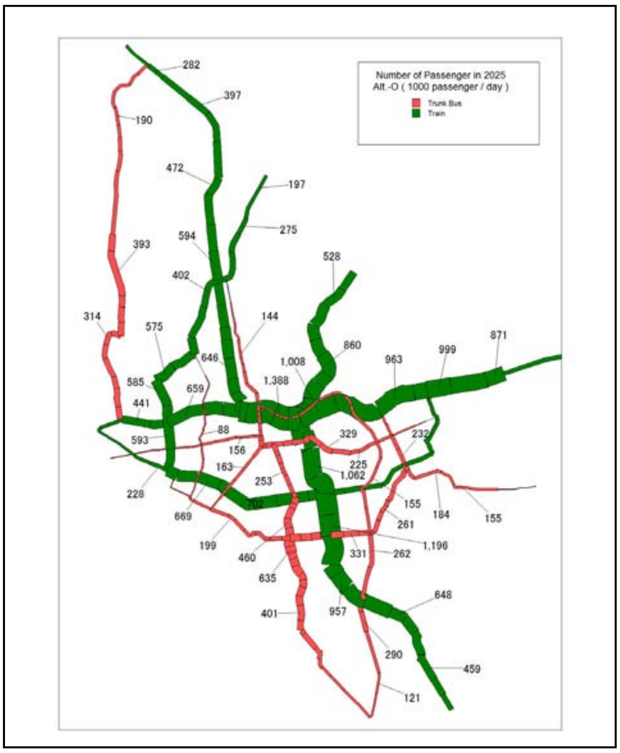


Figure 12.5-30 Daily Passenger Volumes in Alternative-O

12.5.4. VERIFICATION FOR EVALUATION OF ALTERNATIVE TRANSPORT NETWORK BY GIS ANALYSIS

(1) Introduction

1) Evaluation in Master Plan Study

In a Master Plan study, a person trip survey is one of popular tools that provide the information about the trips traveled in a study area. The trip data obtained by a person trip survey, in general, is aggregated into a zone in order to make Origin and Destination (OD) matrixes that are used for demand forecasts. The zones applied in the Study divide the districts into an average of seven to eight areas. On the other hand, in the previous section 12.5.2, the Alternative Transport Network study is conducted based on the wide range of analysis and evaluation, such as selection of project alignment, demand forecast, balance between demands and supply, project feasibility in revenue, etc. In some cases, the analysis not only needs the aggregated information, such as OD matrixes, but also more detailed spatial information. GIS (Geographic Information System) analysis has been attracting attention from this viewpoint because it can provide spatial information and visual presentation. Prior attempts to supply more detailed analysis using GIS system and information provided based on GIS system have been done in this Study.

2) Database Provided

The following database are prepared for the analysis

a) Network
b) Origin and Destination Matrix
c) Information in Grid

A network data represents an existing and planned transport structure for a city, in which there are links and nodes. The nodes represent the position in the network, such as an intersection, on/off ramp, station, etc., and the links represent the connection between nodes, such as a road sections, etc. Therefore, indicators, travel time or travel distance between nodes can be measured by searching the shortest route on the network.

Travel is an activity that takes place from one given geographic place to another. An OD matrix expresses the total volume of travel aggregated in each zone pair. The element of a matrix represents how many trips are traveled between one zone to another. The last database provided for the GIS analysis is the information in Grid. A grid is a system of numbered squares developed on a map covering the whole study area, and has several information. An area of 100 square meters is applied for the analysis in the Study.

3) GIS Analysis Conducted

By using the above-mentioned database, the following analysis is conducted in this section.

a) Evaluation of Transport Network Alternatives
b) Population Covered by Railway Line

An evaluation of transport network alternative attempts to compare the improvement of travel time by using the grid information. This analysis is applied only in the Master Plan network alternative cases of M, N, and O. In the Master Plan, stations are determined on each railway line. Based on the location of tentative planed stations on the railway line, the population covered is examined in this analysis. The covered population seems to be the potential for railway demand. Therefore, the analysis can give an indicator for selecting railway route alternatives.

(2) How to Provide Database

1) Population

The most important information for the GIS analysis is a population in a grid for both the present and the future. This section describes how to provide a population in grid. The estimation of population in grid consists of a two step approach; the estimation of the present population and the estimation of the future population. In the first step, the following figure illustrates the basic idea of formulating the present population in a grid. Thus, the population in each traffic zone is divided into a "manzana" block according to the population by "manzana" block, and then the population in each "manzana" block is broken down to a grid. However, the system of "manzana" areas and their population are based on the Census conducted in 1992. Therefore, the information was updated, especially in Pachacutec city, before it is applied for the approach.

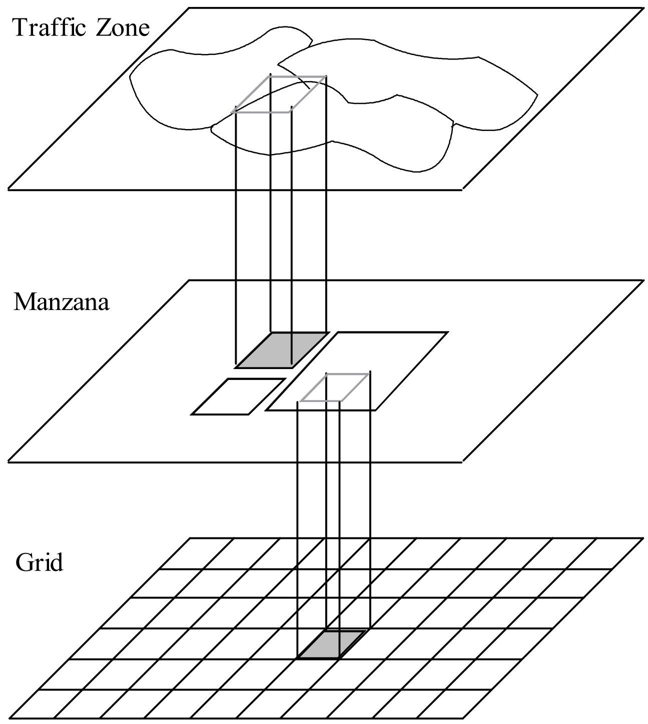


Figure 12.5-31 Formulation of Population in Grid

In the second step, the future population in the traffic zone is divided into the grids, which also cover the future urbanized area considering the discussion conducted for the future framework. Figure 12.5-32 shows the present and the future urbanized grids.

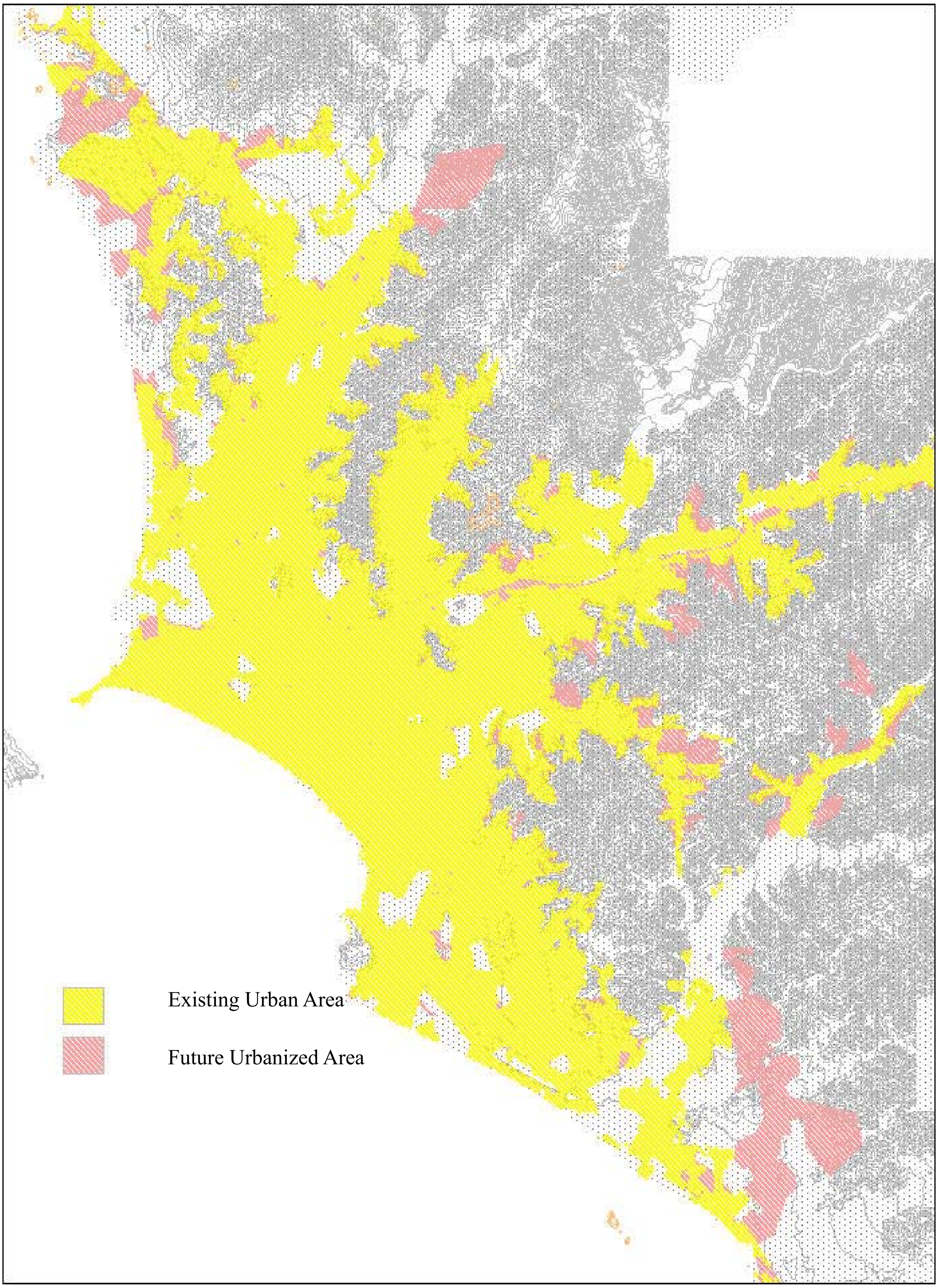


Figure 12.5-32 Future Population in Grid

2) OD Matrix

As explained in the former section, the OD matrix is produced by compiling travel behavior obtained by the person trip survey with traffic zones. Therefore, the OD matrix needs to be divided into grids so that the OD information can be used for the GIS analysis. The following figure illustrates the basic concept to divide the OD matrix into a grid.

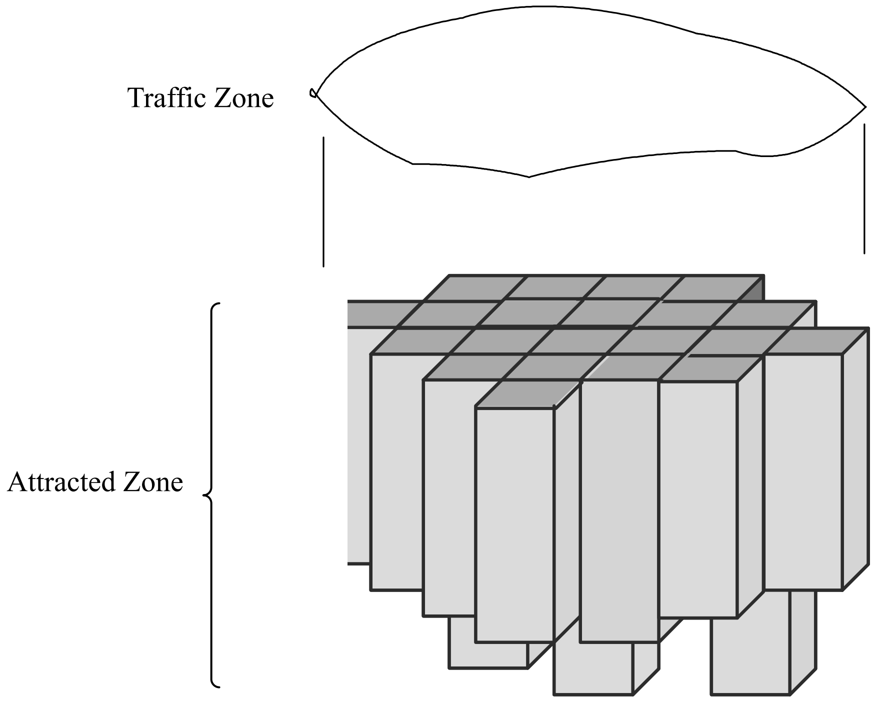


Figure 12.5-33 Formulation of OD Matrix in Grid

In detail, the number of trips between one zone to another is divided into the number of trips according to the following formula.

$$v_j^k = V_{ij} \cdot \frac{P^k}{\sum_l P^l}$$

where, v_j^k : the number of trips traveling from grid k to zone j

V_{ij} : the number of trips traveling from zone i to zone j

P^k : population in grid k

(3) GIS Analysis

In this section, the analysis for the Master Plan Alternative Network and railway lines are discussed using the GIS information mentioned above.

1) Improvement by Master Plan Alternative Network

Travel time is one of the important indicators for comparing and evaluating alternative networks. By this indicator, it is easy to imagine how much the network alleviates the worse condition. Travel time is defined as the following formula in this analysis.

$$t_k = \frac{1}{\sum_j v_j^k} \cdot \sum_j \left(w_{kp} + u_{pj} \right) \cdot v_j^k$$

where, t_k : average travel time starting from grid k based on the future demand

v_j^k : the number of trips traveling from grid k to zone j

w_{kp} : walking time from grid k to the nearest node p on the network

u_{pj} : travel time between node p to attraction zone j

Walking time can be estimated by dividing the distance from the center of a grid to the nearest node in the network by average walking speed, and travel time between the nearest node to the attraction zone can be calculated by searching the shortest route on the network. Moreover, this estimation includes the following assumptions:

a) Walking speed is 3.6km/h
b) Travel speed by train is 50 km/h
c) Travel speed by truck bus is 45 km/h
d) Travel speed by the rest of mode is according to the road network used in assignment

Estimation of travel time in each grid for the Master Plan Alternative Cases, M, N, O, is illustrated through Figure 12.5-34 to Figure 12.5-36, respectively, and the indicators calculated in whole study area are summarized in Table 12.5-5. The Table shows that more than 12% of travel time can be improved with three alternative plans. The reduction of travel times among three alternative plans will not present remarkable differences.

Table 12.5-5 Evaluation of Transport Network Alternatives

Indicators	Existing	Alternative M/P Case		
		Alt - M	Alt - N	Alt - O
Total Travel Time (million hours)	6.88	6.05	6.03	5.99
Improvement	-	12.1%	12.4%	12.9%
Average Travel Time (hour / trip)	0.561	0.493	0.491	0.488

Note: Existing case is calculated considering travel demand in the future and existing network.

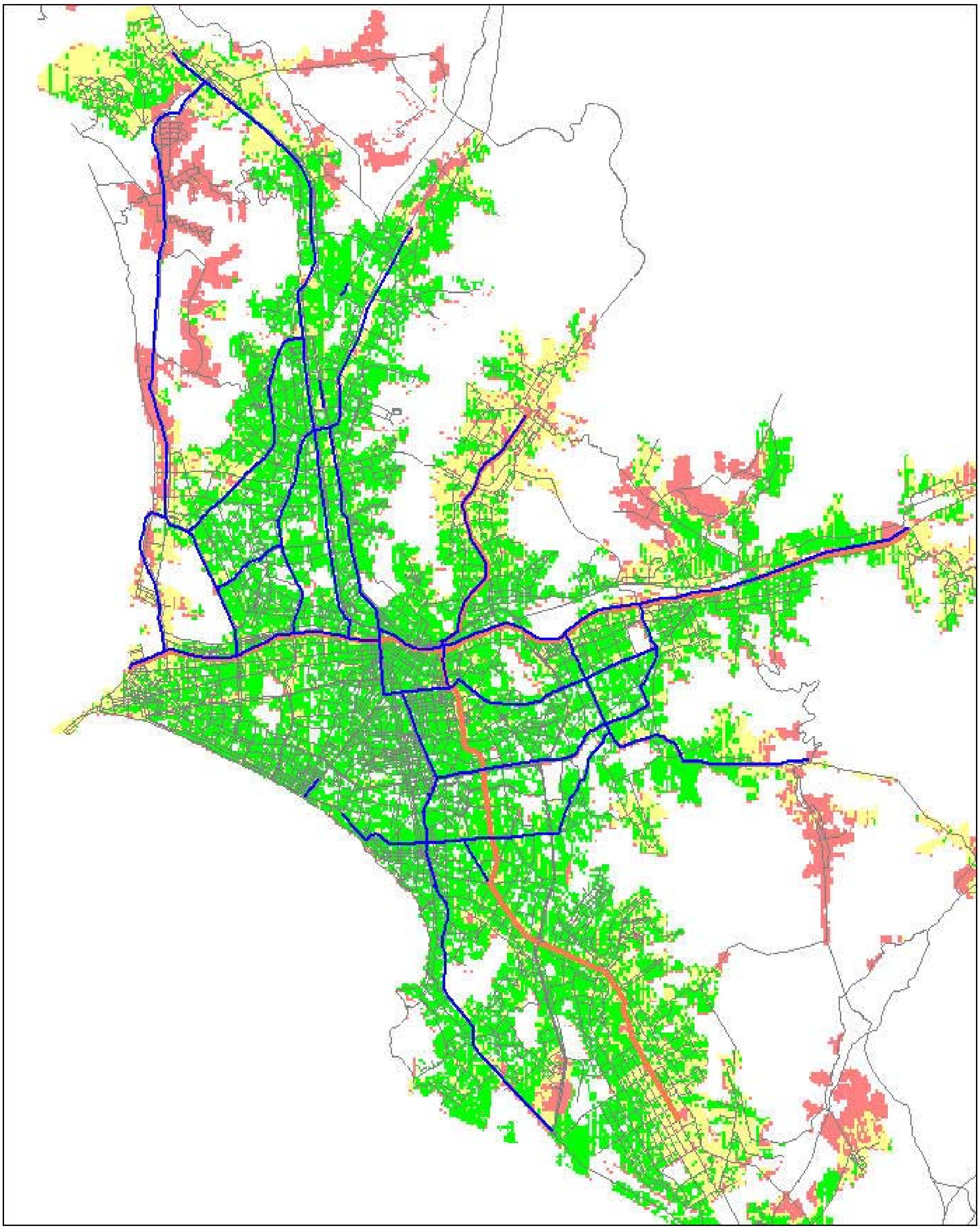


Figure 12.5-34 Master Plan Alternative Alt – M

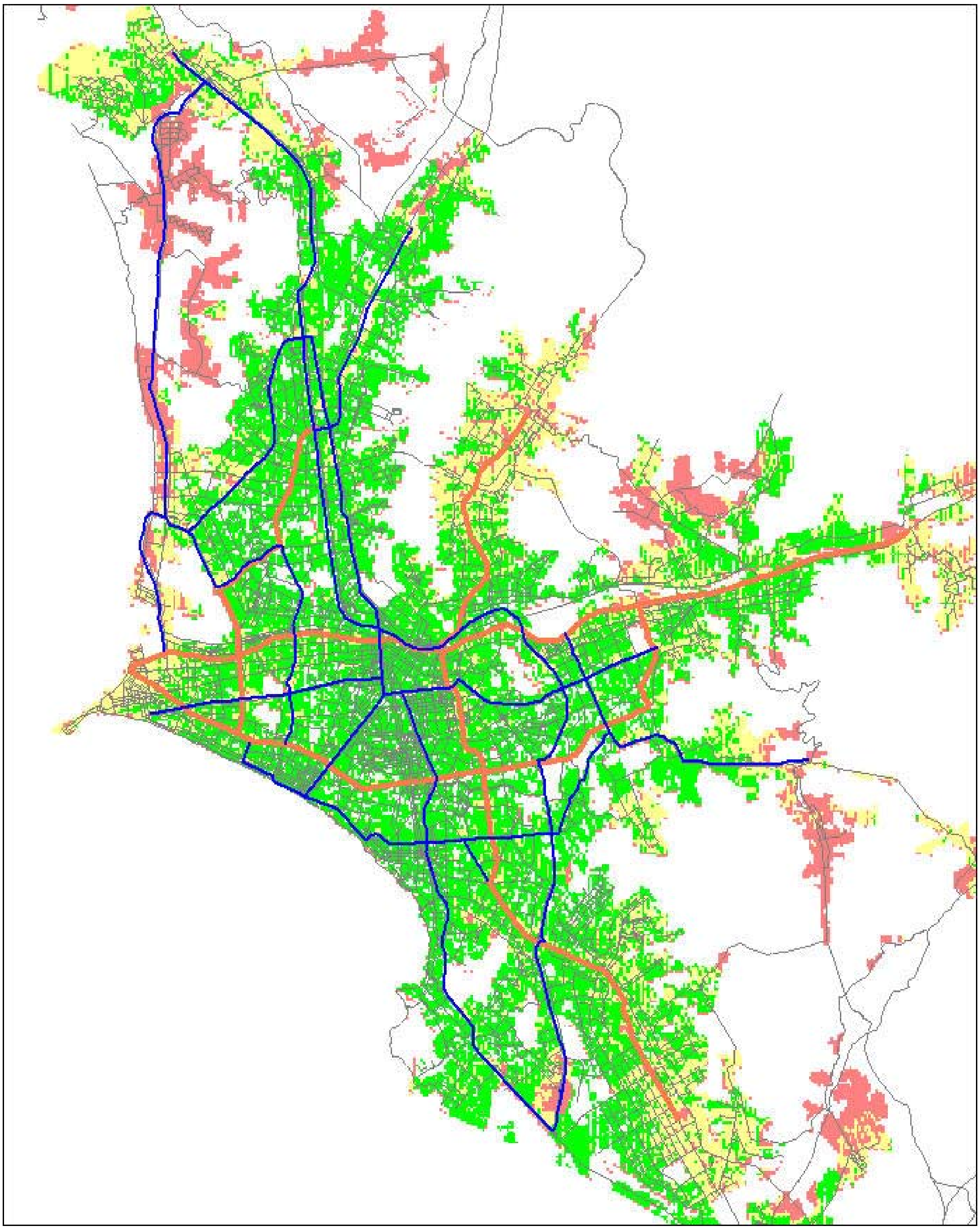


Figure 12.5-35 Master Plan Alternative Alt – N

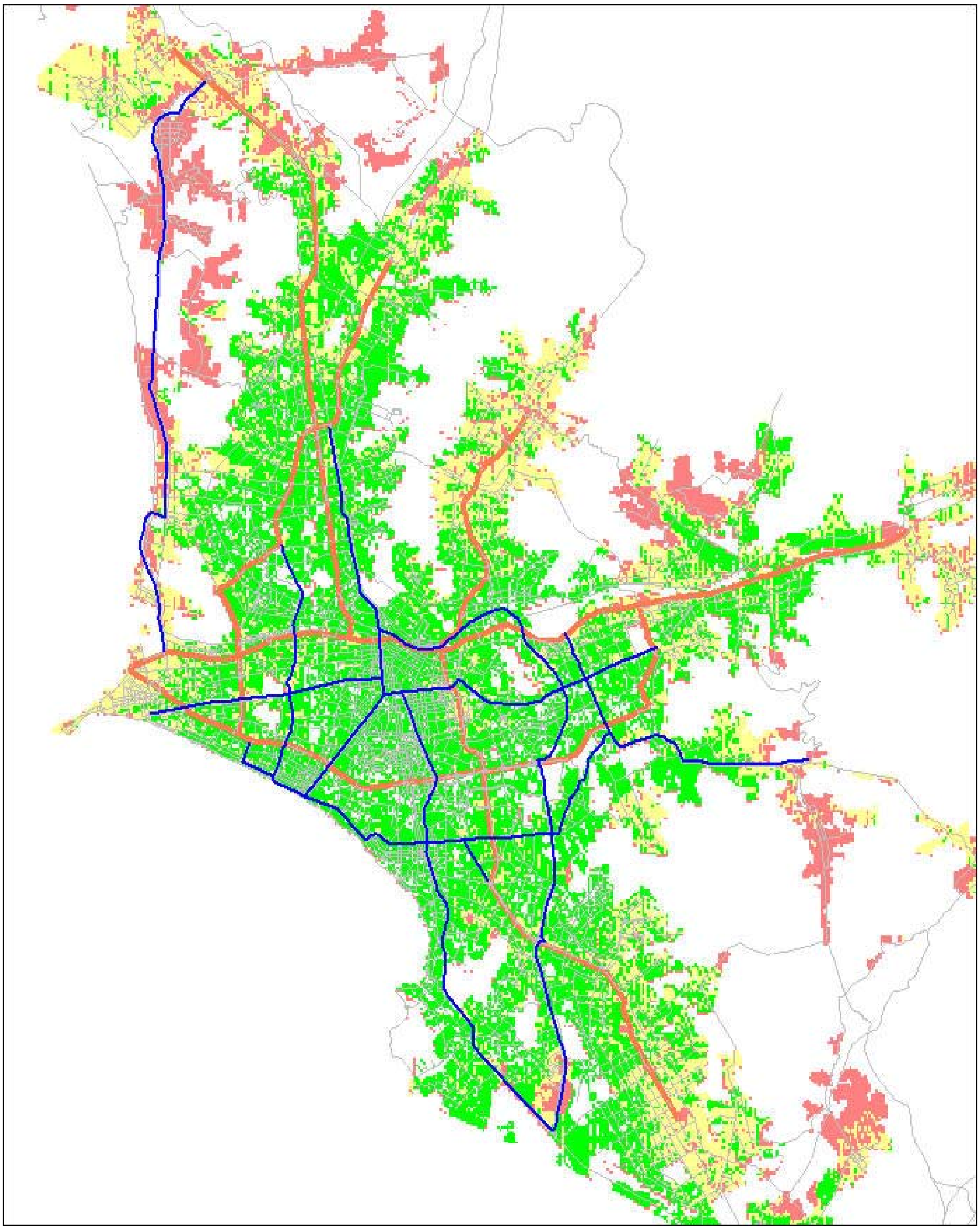


Figure 12.5-36 Master Plan Alternative Alt – O

2) Population Covered by Railway Line

The GIS analysis can provide information regarding the ridership of a railway. If the catchment area of a railway station is supposed to be a circle of 1 km in radius, the number of residents covered by a station on each railway line can be estimated as illustrated in Figure 12.5-37 to Figure 12.5-41. This information is also summarized in the following Table 12.5-6.

Table 12.5-6 Population Covered by Railway Line

Line No.	Total Length (km)	Population Covered (persons)	No. of Stations (Tentative) (volume)	Average Covered Nº of Population by Station (persons)	Average Covered Nº of Population by km (persons)
No. 1	33.9	1,876,000	26	72,000	55,000
No. 2	29.0	1,097,000	18	61,000	38,000
No. 3	28.1	1,273,000	22	58,000	45,000
No. 4	24.6	927,000	14	66,000	38,000
No. 5	40.1	979,000	14	70,000	24,000

Railway line No. 1 covers the largest population according to the above analysis. The covered population is 1.88 million in total, and the average number of population covered by a station indicates 72 thousand. Line No. 3 indicates the second-largest population as 1.27 million. However, it may not suggest that this line attracts the large potential of passengers due to the characteristics of people residing along the line alignment. Based on the result of the analysis, further studies on the railway projects should be conducted.

Figure 12.5-37 Stations on Line Nº 1

Figure 12.5-38 Stations on Line Nº 2

Figure 12.5-39 Stations on Line Nº 3

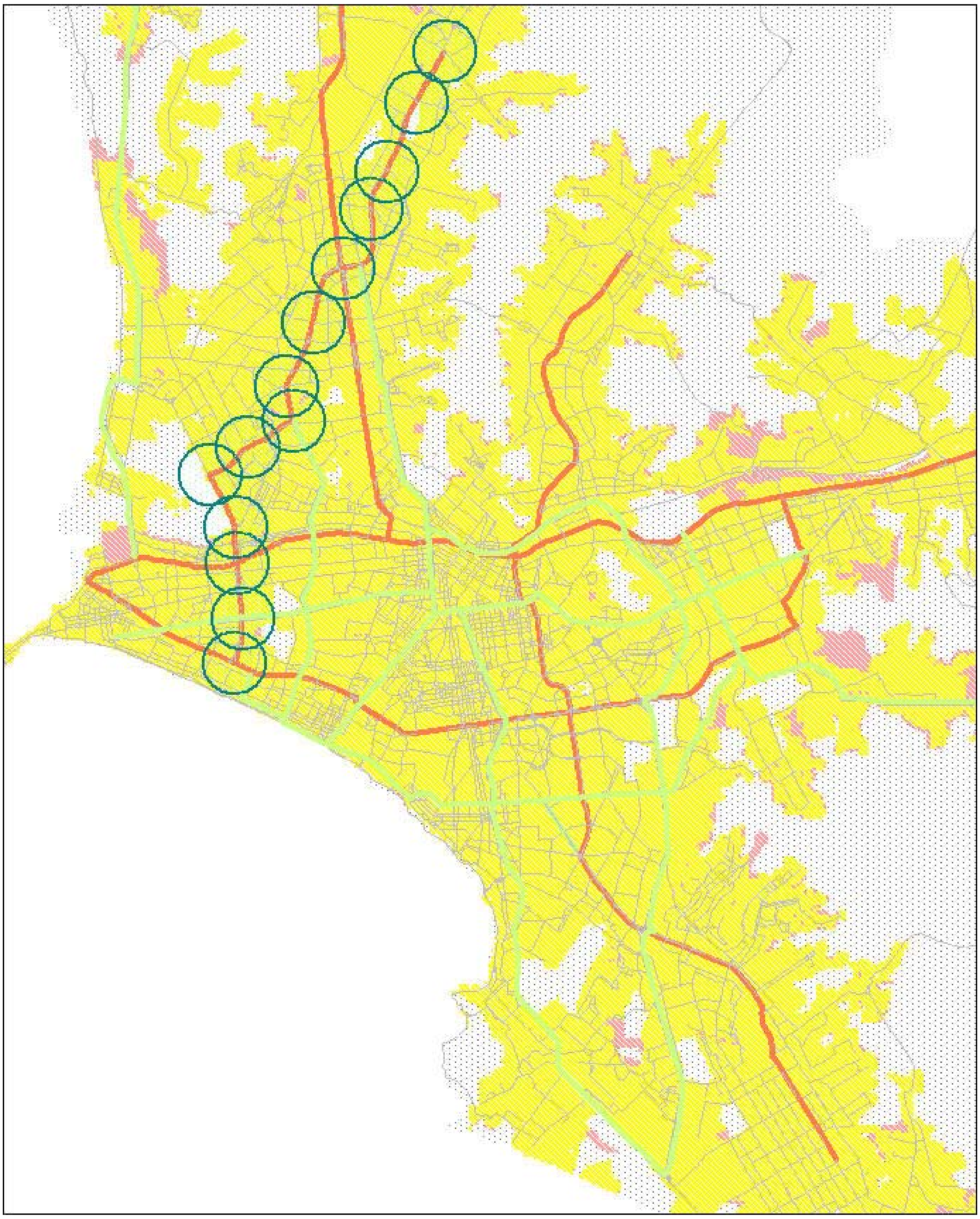


Figure 12.5-40 Stations on Line Nº 4

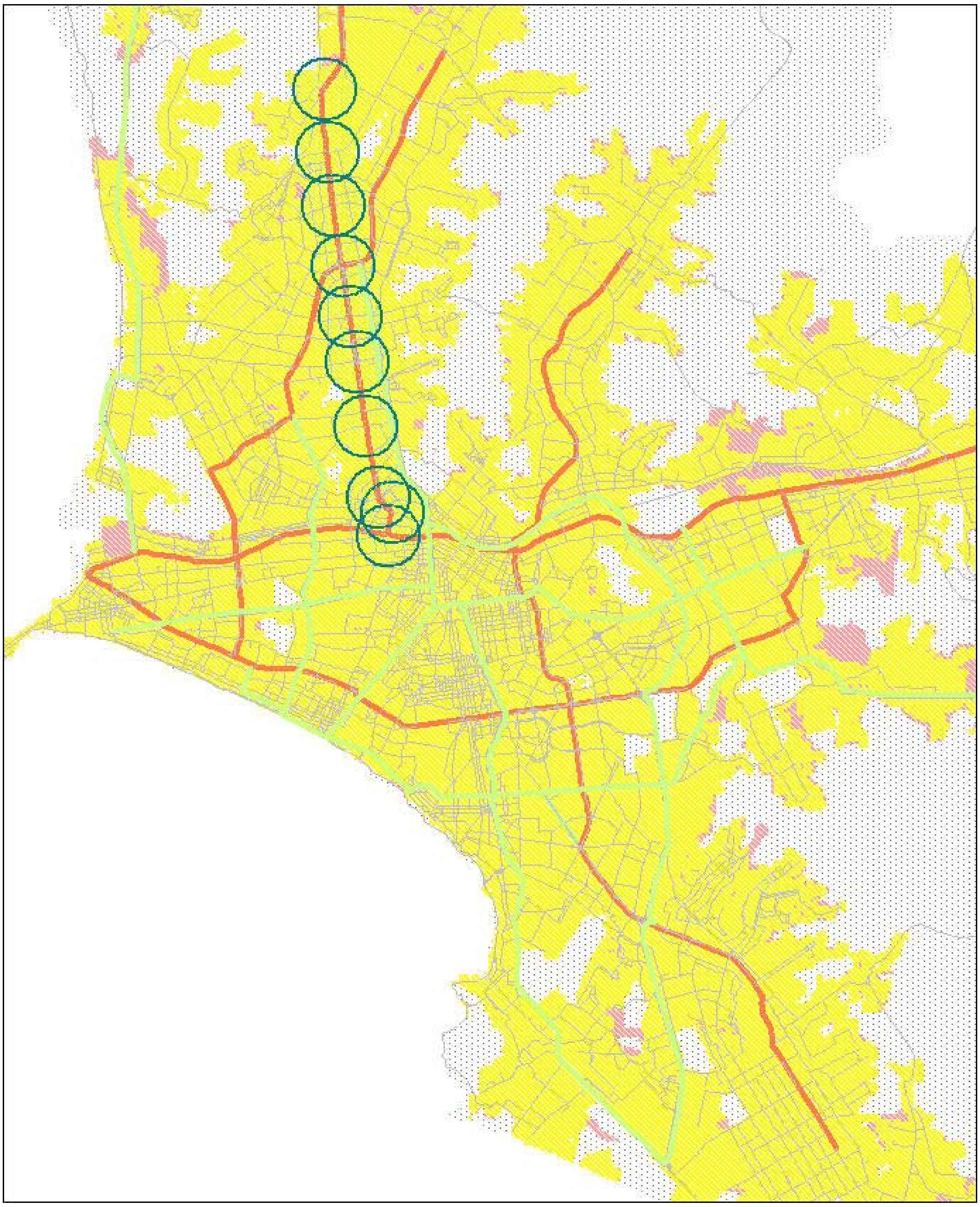


Figure 12.5-41 Stations on Line Nº 5