Chapter 5 Traffic Demand Forecast

One of the important objectives of traffic demand forecast in a transportation master plan study is to examine the concepts and policies in proposed plans by numerically indicators. It is, thus, to check whether plans provide sufficient capacity and structure performs functionally and effectively for the estimated demand, and to provide most favorable plans responding to the demand.

In general, the future transportation demand will be estimated by models. Modeling means the development of mathematical formulations that represent the travel patterns of persons living in a city, such as travel mode, travel speed, and traffic volume on a transport system and network. For this context, there are two major approaches. One approach is that the relation between demand and statistical information will be analyzed, and functional equations will be produced. The traditional four-step methodology is famous in this approach. The other one is an approach to focus travelers' behavior, in which representative models are 'Discrete' and 'Activity' model. In this Study, the former approach shall be taken.

This chapter summarizes basic considerations for the modeling, methodology and functions to be applied, a set of data for the forecast, and the result of the future traffic demand. Development of models shall be discussed in the first section of this chapter and the result of the estimation will be described in the second section.

5.1 Development of Models

5.1.1 General

(1) Model Development Procedure

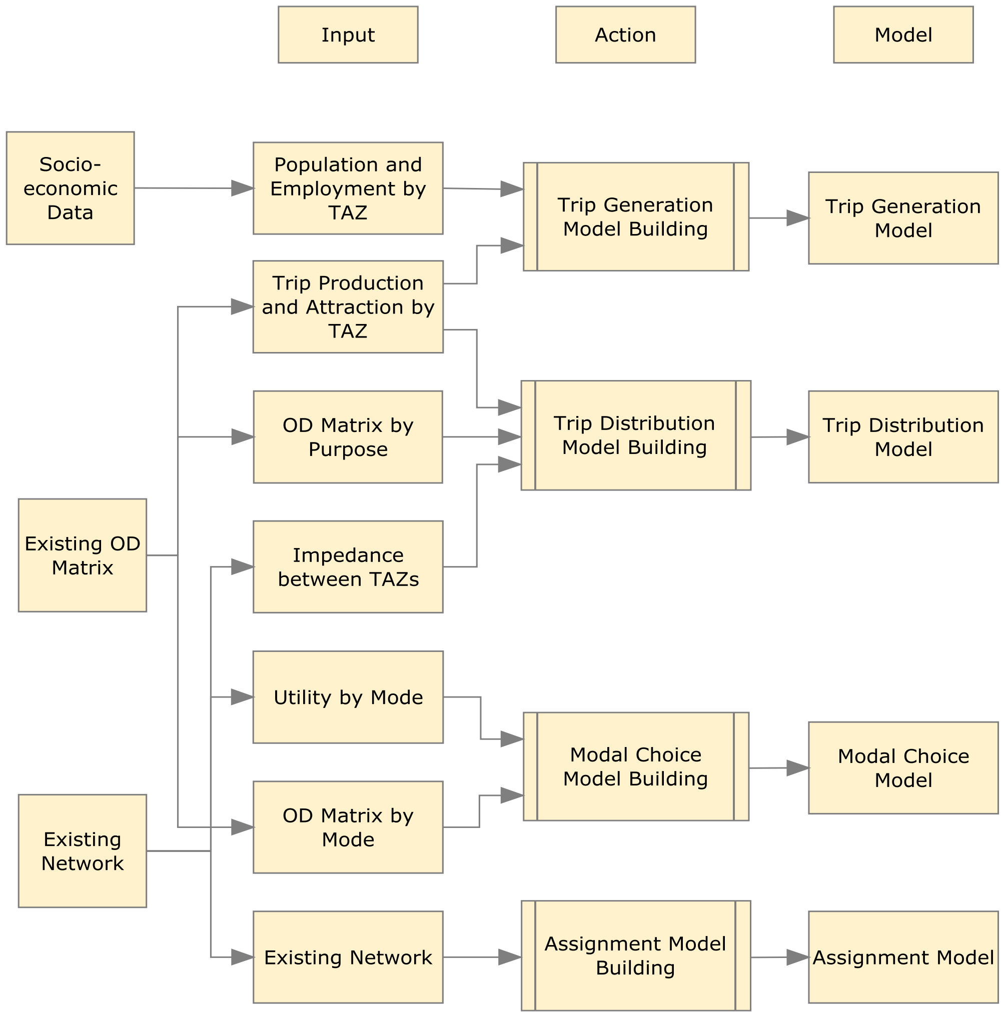
In many cases, the process for traffic demand forecast takes place as follows:

First, the current situation on the urban structure and travel demand in a study area shall be analyzed based on the results of transportation surveys. Models will be developed by examining the relationship between the travel demand pattern and exogenous variables such as socio-economic indicators in the analysis.

Next, the future travel demand will be estimated by entering the exogenous variables in the future into the estimated models. Examples of necessary exogenous variables are socio-economic data such as population and employment, and a transportation network plan that will be proposed in the study.

As mentioned above, the four-step methodology shall be applied in this Study. This methodology composed of four steps, namely: trip generation model, trip distribution model, modal share model, and traffic assignment model, and each model estimates the respective dimensions of travel demand sequentially. These four models can be grouped into two types: the first three models estimate an origin and destination matrix which represents travel demand between areas, and the last model calculates traffic volume on a transportation network.

The first step in the approach, "trip generation" model is designed to estimate the number of person trips leaving from, and/or arriving at in given zones, which is called traffic analysis zones (TAZ). The next stage of travel demand estimation in this approach is trip distribution. This step consists of distribution each of the trip production estimated in the first step into various destinations. The third stage in the traditional approach, modal share, is typically performed right after the trip distribution is completed. This step distributes the volume of origin and destination travel into various alternative modes. The last step is an "assignment" model. In this step, the modal trips obtained by the previous model is distributed on to the network, or more precisely, is assigned on links along the minimum cost routes between a given origin and destination. These steps are described in the following figure.



Source: Prepared by the JICA Study Team

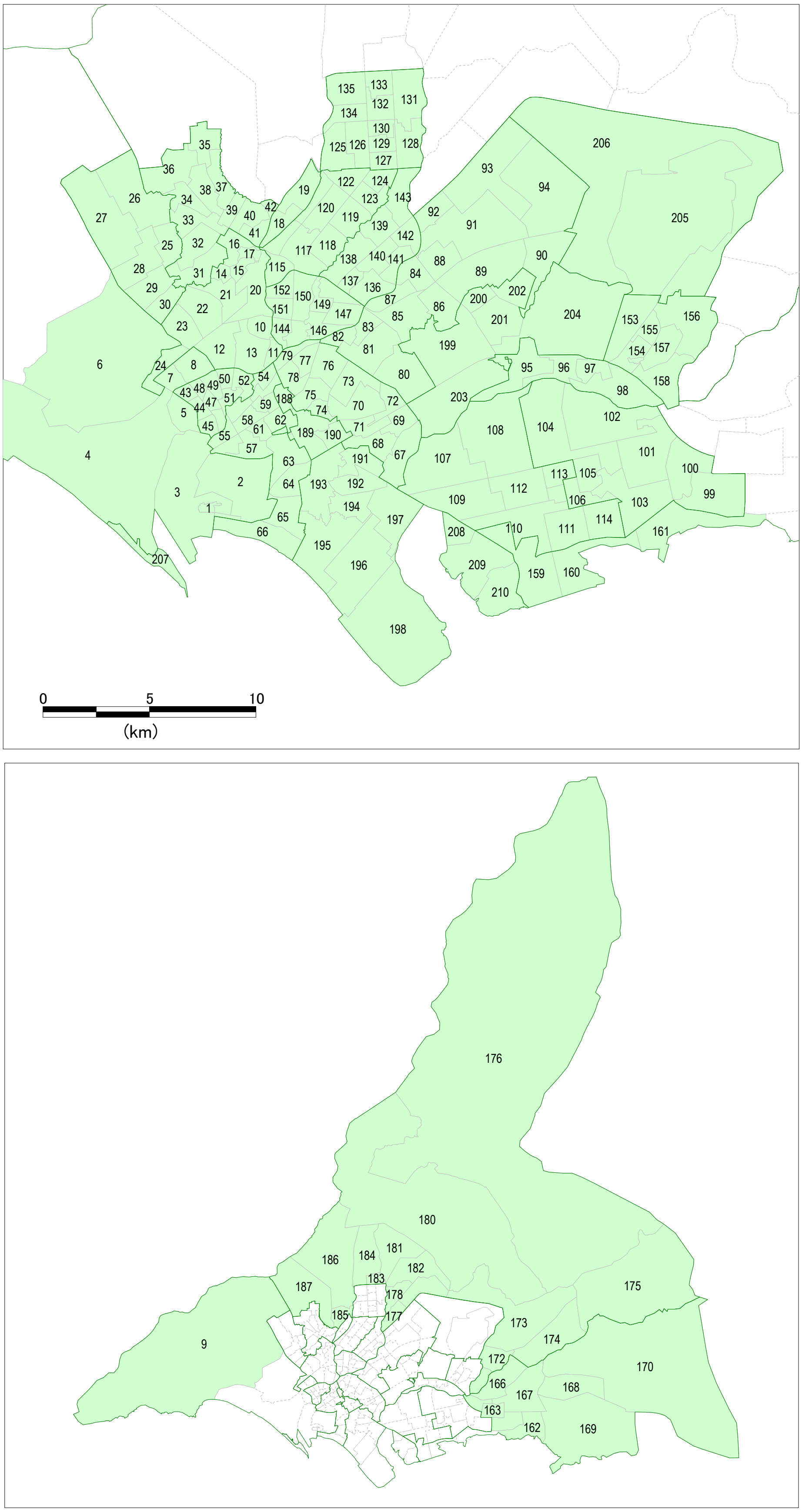
Figure 5-1-1 Model Development Approach

(2) Traffic Analysis Zone (TAZ)

Travel is an activity that takes place from one place to another so that spatial structure must be defined to express specifically where people start and finish their travel and how many people make their trips. Traffic analysis zones shall be established as specific regions in geographic unit. How the traffic analysis zones should be, such as size, shape, and other characteristics, must be determined with taking the following aspects into consideration.

- Existing administrative boundary and availability of resources in terms of data
- Homogeneity of landuse
- Level of detail required for the evaluation of proposed plans, and so on.

Actually the traffic analysis zone system applied in the Study is determined based on the existing UC boundary as shown in the following figure. The total number of zones is 210 for the Study area.



Source: Prepared by the JICA Study Team

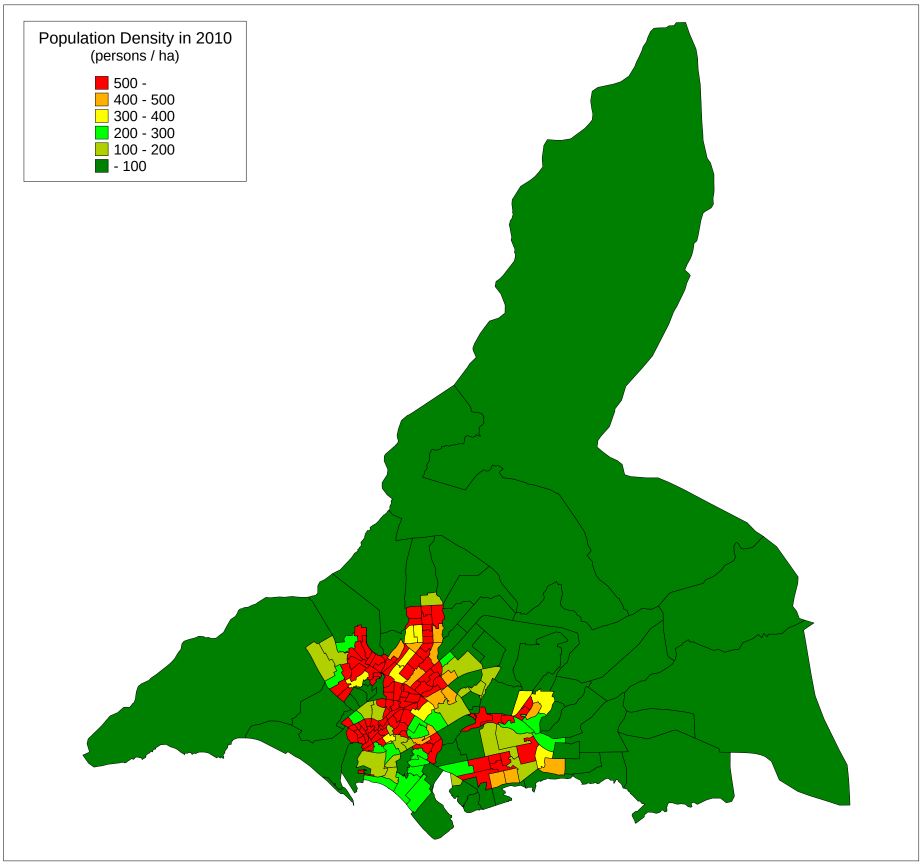
Figure 5-1-2 Traffic Analysis Zone

(3) Existing Socio-economic Indicators by TAZ

To build models for estimating the number of trips generated, it is necessary to analyze the relationship between the trip generation and exogenous variables, and to prepare the exogenous variables in terms of statistics by traffic analysis zone. In practice, the following indicators are prepared by TAZ.

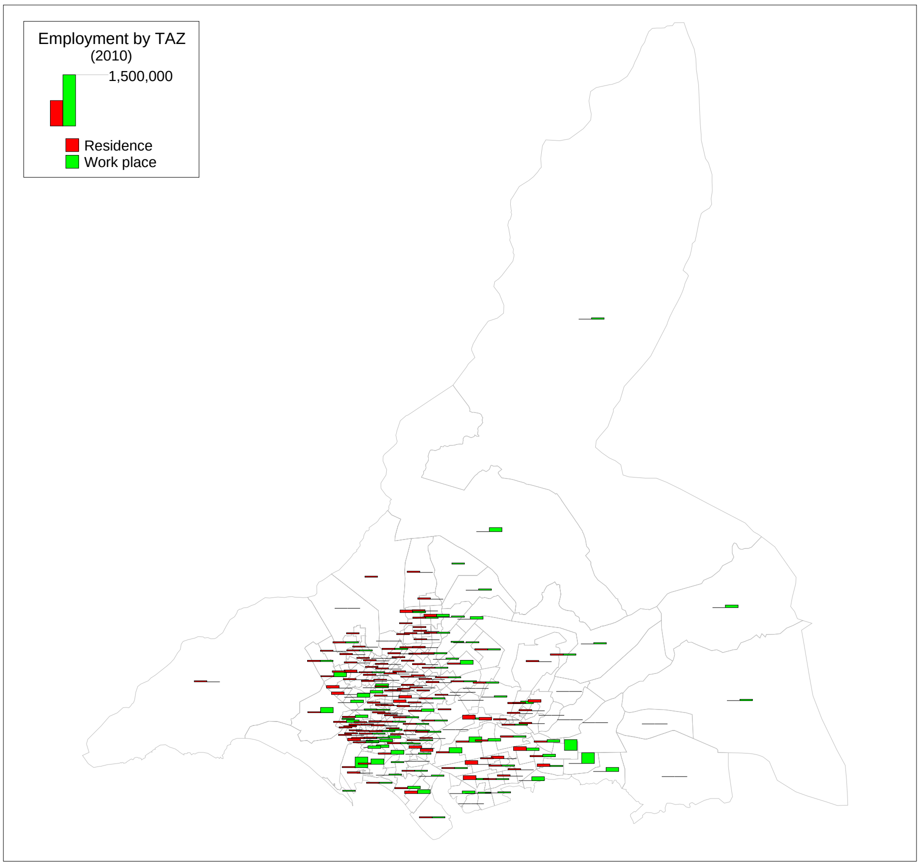
- Population
- Number of workers at resident place (zone)
- Number of employees at work place (zone)
- Number of students at resident place (zone)
- Number of students at school place (zone)

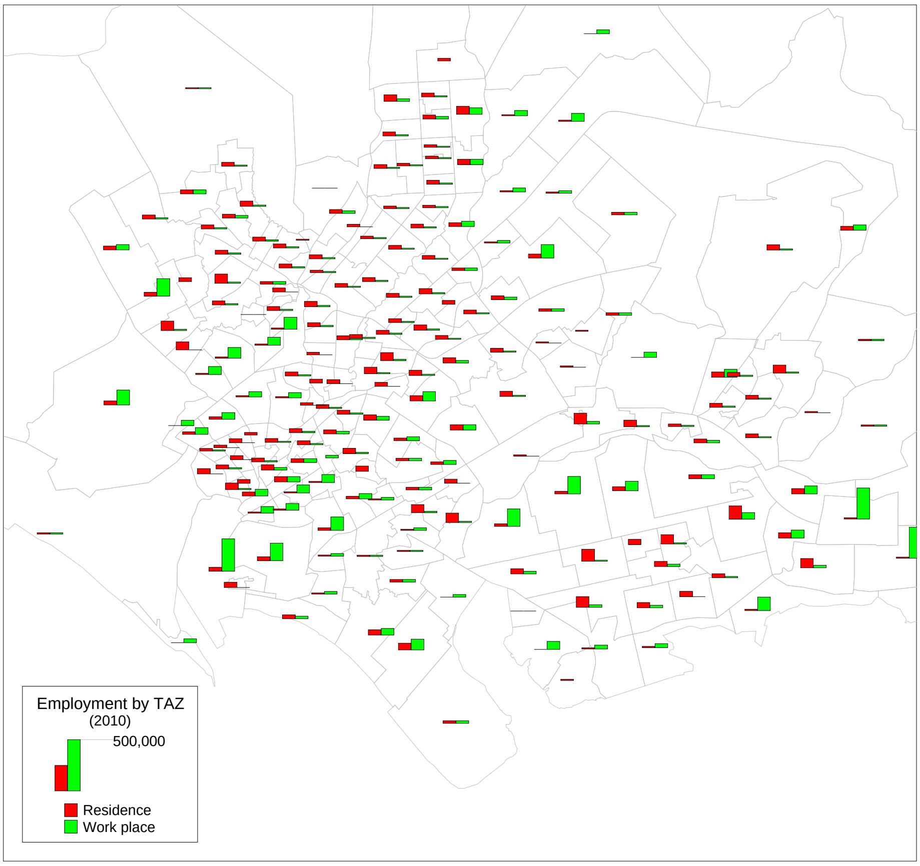
Figure 5-1-3 illustrates population density in 2010 by TAZ and Figure 5-1-4 shows the number of workers at resident place and employees at work place in each traffic analysis zone, which are shown as an example of the prepared indicators.



Source: Prepared by the JICA Study Team

Figure 5-1-3 Existing Population Density by TAZ





Source: Prepared by the JICA Study Team

Figure 5-1-4 Number of Workers at Resident and Working Place in 2010

5.1.2 Network Development

(1) Network Database Structure

Urban transportation system on which travel takes place generally consists of various modal networks, such as the road network for mobile vehicles and transit network for public transportation, for example, bus route service and railway. Both of the networks are composed of a set of nodes that represent intersections, junctions and terminals, and a set of links that connect nodes.

Each of the network links should be described by a number of physical characteristics representing the existing road condition at each section and these characteristics may influence the relationship between the volume of a link, ‘capacity’ and travel speed. The network database developed for the Study includes the characteristics listed in the following table.

Table 5-1-1 Structure of Road Network Database

Field Name	Data Type	Content
LinkName	Char(10)	ID of a link
Node_I	Char(10)	ID of the node at one end of the link
Node_J	Char(10)	ID of the node at the other end of the link
Length	Float	Link distance (km)
Vmax	Float	Free flow speed (km/h)
Qmax	Integer	Maximum capacity (pcu)
QVType	Integer	Code number to identify QV type
Fare	Float	Fare of each mode
Dir	Integer	Directional control for each mode
RoadType	Integer	Road type flag: 0=general, 1=toll road, 2=railway
Evaluation	Integer	No-evaluation flag: 1=excluding this link from the evaluation
RoadName	Char(50)	Name of a road
Class	Integer	Functional Class
Lane	Integer	Number of lanes
Stops	Integer	Number of bus stops in this link
Parking	Integer	Parking condition
Encroachment	Integer	Encroachment: yes or no
Operation	Integer	one way or two way
Median	Integer	yes or no

Source: Prepared by the JICA Study Team

(2) Capacity and Speed Relationship

When the fastest route between specific pair of zones is searched on a network, travel time on each link of the network must be calculated in advance. In general, travel speed depends on how much traffic passes at the same time. In other words, it is apparent that travel speed decreases according to the increase of traffic volume. The relationship between travel speed and traffic volume is often called ‘QV’ function.

A QV function for this Study was established with taking the following aspects into consideration:

- Free flow speed is the safe travel speed at which a vehicle would travel along a road section in the absence of other traffic.
- Capacity is expressed in terms of passenger car units (pcu).
- Link capacity can be expressed in terms of possible capacity and assignment capacity. Possible capacity, which can accommodate on a given condition of road section, such as the number of lanes, operation, median, and so on, was defined based on US Highway Capacity Manual.

- Assignment capacity represents the total number of daily traffic volume which is adjusted of the possible capacity by the consideration of various factors such as functional classification of a road, encroachment, peak characteristics and the presence of signals.

The proposed QV function applied in the demand forecast is shown in Table 5-1-2.

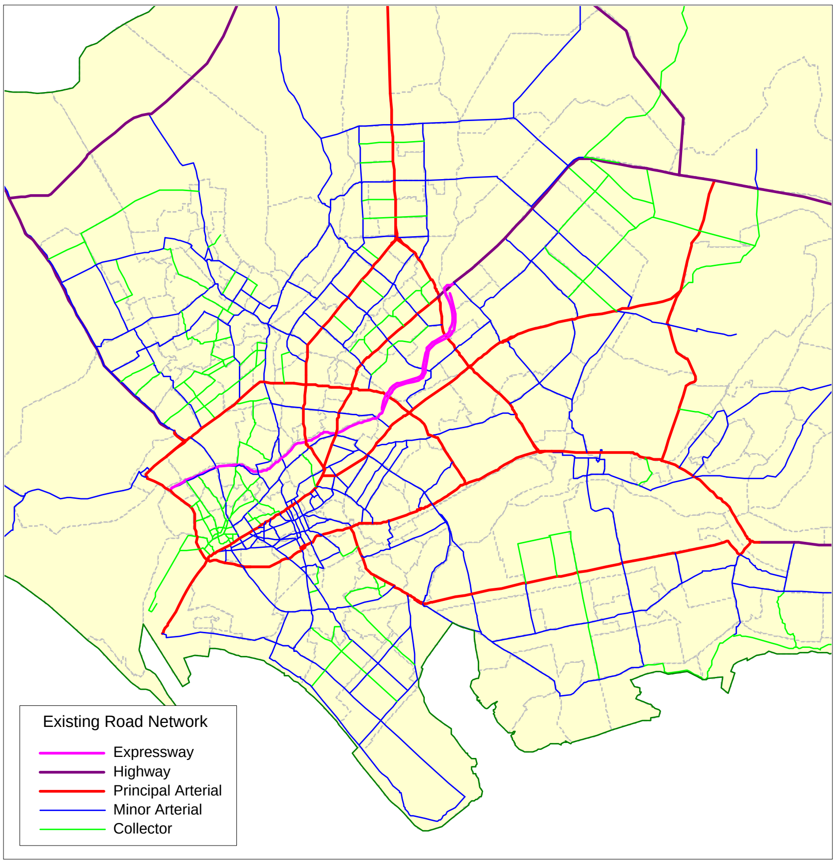
Table 5-1-2 QV Functioned by Type of Road

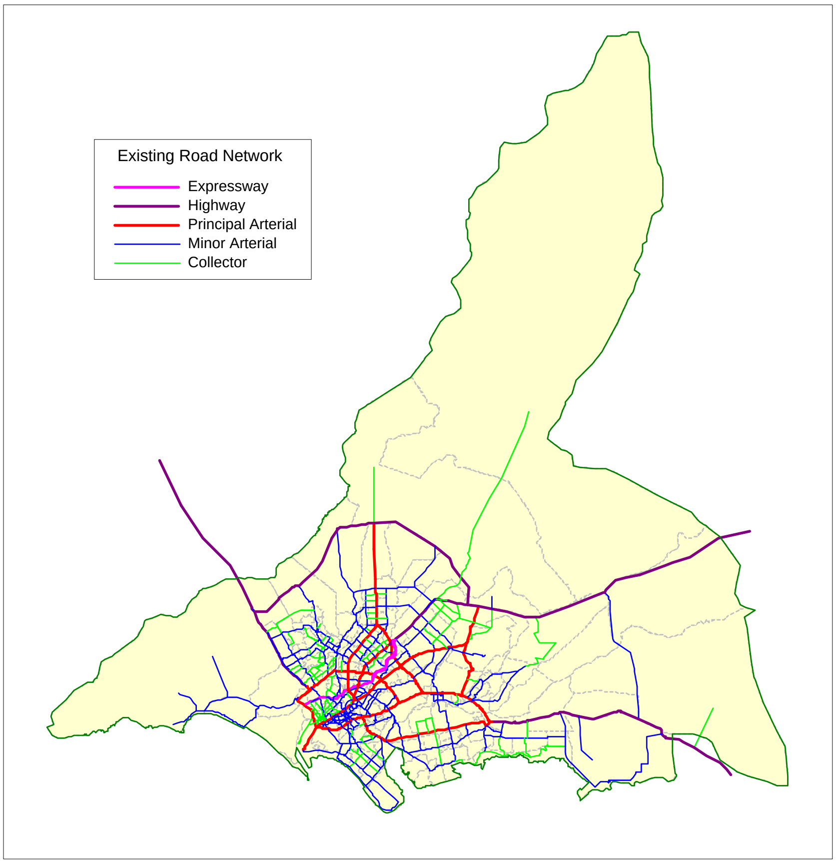
No.	Functional Classification	Lanes	Operation	CBD		Urban	
				Free-flow Speed (km/h)	Asgmt. Capacity (pcu/day)	Free-flow Speed (km/h)	Asgmt. Capacity (pcu/day)
1	Expressway	6	Two-way			100	138,000
		4	Two-way			100	92,000
		3	One-way			100	69,000
		2	One-way			100	46,000
2	Highway	8	Two-way			80	228,000
		6	Two-way			80	171,000
		4	Two-way			80	114,000
		2	Two-way			80	36,000
		2	One-way			80	57,000
3	Principal Arterial	10	Two-way	50	93,000	60	119,000
		8	Two-way	50	75,000	60	95,000
		6	Two-way	50	56,000	60	71,000
		5	Two-way	50	47,000	60	59,000
		4	Two-way	50	37,000	60	47,000
		3	One-way	50	28,000	60	36,000
		2	Two-way	50	12,000	60	16,000
		2	One-way	50	19,000	60	24,000
4	Minor Arterial	8	Two-way	40	49,000	50	64,000
		6	Two-way	40	37,000	50	48,000
		4	Two-way	40	24,000	50	32,000
		3	One-way	40	18,000	50	24,000
		2	Two-way	40	8,000	50	11,000
		2	One-way	40	12,000	50	16,000
5	Collector Road	6	Two-way	30	23,000	40	33,000
		4	Two-way	30	16,000	40	22,000
		3	One-way	30	12,000	40	16,000
		2	Two-way	30	6,000	40	9,000
		2	One-way	30	8,000	40	11,000

Source: Prepared by the JICA Study Team

(3) Base Year Network

The base year network database was prepared by selecting major roads: expressway, arterial road, and collector road in the whole Karachi city. For the selected network links, physical characteristics were surveyed by making a field investigation and the recorded information was stored on a database with GIS software. The information of each link is used for the calculation of assignment capacity for the simulation. The established base year network is shown in the following figure.





Source: Prepared by the JICA Study Team

Figure 5-1-5 Existing Road Network for Model Development

5.1.3 Model Description

(1) Trip Generation Model

The first step of the development models procedure estimates the total number of trips generated in the Study area per day for the future. There are three typical models commonly used as follows:

- Trip rate model
- Growth rate model
- Functional model

In this Study, trip rate model was applied.

Formula: $G^k = P \times r^k$

Where, G^k : the number of person trips by trip purpose

P : the number of population aged 5 years and more

r^k : trip rate by trip purpose

Table 5-1-3 Trip Rate by Trip Purpose

Trip Purpose	Trip Rate (trips / person)
To Work	0.31
To School	0.21
Business	0.02
Private	0.10
To Home	0.63
Total	1.27

Source: Prepared by the JICA Study Team

(2) Trip Production and Attraction Model

Trip production and attraction models are to estimate the number of trips originating from and ending in each zone, while the trip generation model estimates the total number of trips in the Study area. A multiple regression analysis was applied for finding the relationship between existing trip production and attraction, and the socio-economic indicators discussed in the previous section, and the analysis resulted in the following models.

Formula: $P_i = a^0 + a^1 \cdot x_i^1 + a^2 \cdot x_i^2 + \dots$

$A_j = a^0 + a^1 \cdot x_j^1 + a^2 \cdot x_j^2 + \dots$

Where, P_i : The number of trip production from zone i

A_j : The number of trip attraction at zone i

$x_i^1, x_i^2, \dots$: Socio-economic indicators of zone i

$a^0, a^1, a^2, \dots$: Parameters (regression coefficient)

Table 5-1-4 Trip Production and Attraction Model

Model	Purpose	Population	Workers at resident place	Employees at work place	Students at resident place	Students at school place	Constant	Correlation Coefficient
Production	To Work		0.8133				2,574.4	0.907
	To School	0.0919			0.6065		1,559.2	0.864
	Business			0.0144			433.3	0.691
	Private	0.1115					1,542.3	0.684
	To Home	0.1691		0.0400		2.0038	5,263.5	0.860
Attraction	To Work	0.0188		1.2077			1,404.5	0.825
	To School					1.3441	910.0	0.927
	Business	0.0089		0.0043			820.9	0.545
	Private	0.1009		0.0105			2,995.6	0.510
	To Home	0.6061					4,916.8	0.874

Source: Prepared by the JICA Study Team

(3) Trip Distribution Model

A trip distribution model is to estimate the number of distributed trips by the combination of origin and destination (OD) zones, i.e., OD matrices. This is typically performed right after trip production and attraction are calculated.

The trip distribution model composes of two models: intra-zonal and inter-zonal model. Each model estimates different elements of an OD matrix, i.e., intra-zonal model estimates the number of trips leaving and ending inside the same zone and inter-zonal model estimates the number o f trips traveling between different zones.

For the intra-zonal model, the following formula was obtained.

Formula: $T_{ii} = K \cdot P_i^{\alpha} \cdot A_i^{\beta} \cdot \left(\sqrt{R}\right)^{\gamma}$

Where, T_{ii} : The number of intra-zonal trips of zone i

P_i, A_i : Trip production and attraction of zone i

R : Area of zone i (square km)

K, α, β, γ : Parameters

Table 5-1-5 Intra-zonal Distribution Model

Purpose	K	α	β	γ
To Work	0.0120	1.0788	0.1975	0.1216
To School	0.0168	0.8317	0.5018	0.0037
Business	1.8891	0.4858	0.3518	0.1098
Private	1.4401	0.6826	0.2239	0.1529
To Home	0.0084	0.2936	1.0379	0.0146

Source: Prepared by the JICA Study Team

A typical traditional approach to build an inter-zonal trip distribution model is to use synthetic models. One of the most commonly used models is the gravity model, which is practically applied of law of physics (Newton's gravitational). This aims to estimate travel demand based on the relationship between trip production, trip attraction, and impedance function between zones such as a travel distance. This analysis resulted in the following formulas as a trip distribution model.

Formula: $T_{ij} = K \cdot P_i^{\alpha} \cdot A_j^{\beta} \cdot d_{ij}^{\gamma}$

Where, T_{ij} : The number of inter-zonal trips between zone i and j

P_i, A_j : Trip production of zone i and trip attraction of zone j

d_{ij} : Travel distance between zone i and j (km)

K, α, β, γ : Parameters

Table 5-1-6 Inter-zonal Distribution Model

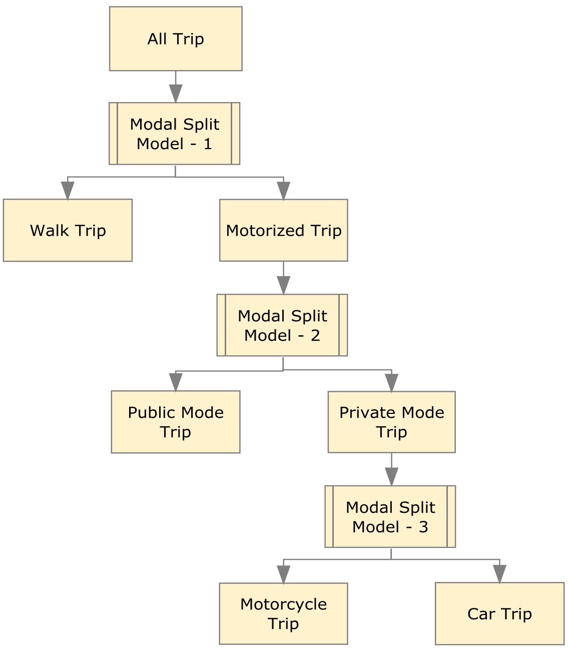
Purpose	K	α	β	γ
To Work	1.0774E-03	0.7400	0.6065	-0.6870
To School	1.2513E+01	0.2659	0.2679	-1.1262
Business	1.4862E+00	0.6078	0.6078	-0.4141
Private	1.0029E+01	0.4203	0.4203	-0.9163
To Home	9.2047E-05	0.7439	0.7439	-0.9429

Source: Prepared by the JICA Study Team

The output of a distribution model is a set of elements that show the travel flow between each pair of zones. However, the row totals of distribution elements do not match with trip productions and the column totals of distribution elements do not match with trip attractions. Therefore, an iteration shall be carried out until satisfied that the row totals match trip productions and the column totals match trip attractions.

(4) Modal Share Model

After each of the origin and destination volumes is obtained by applying the trip distribution model, the volumes are distributed into trip volumes of several modes. Structure of modal choice, transport modes to be selected, and formula estimating the probability of selection are important factors for building this model. In this study, those factors are specified as follows:



Source: Prepared by the JICA Study Team

Figure 5-1-6 Modal Split Structure

Modal Split Model - 1

Formula: $$R_{ij}^{Walk} = \frac{1}{e^{a \cdot d_{ij} + K}}$$

Where, R_{ij}^{Walk} : Ratio of walk trips to all trip traveling between zone i and j

d_{ij} : Travel distance between zone i and j (km)

a, K : Parameters

Table 5-1-7 Parameters for Modal Split Model - 1

Purpose	Distance (a)	Constant (K)	Correlation Coefficient
To Work	0.3475	0.1570	0.980
To School	0.2533	0.0279	0.974
Business	0.5032	0.3526	0.976
Private	0.3879	0.0789	0.983
To Home	0.3611	-0.0170	0.990

Source: Prepared by the JICA Study Team

Modal Split Model - 2

Formula: $$R_{ij}^{Public} = \frac{1}{1 + e^{a \cdot D_{ij} + b \cdot \left(\frac{t_{ijt}^{public}}{t_{ij}^{car}} \right) + c \cdot NCO_i + d \cdot NCO_j + K}}$$

Where, R_{ij}^{Public} : Ratio of public trips to all motorized trips traveling between zone i and j

D_{ij} : Travel distance (km) between zone i and j

NCO_i, NCO_j : No-owning-vehicle households ratio in origin zone i and destination zone j

$t_{ij}^{public}, t_{ij}^{car}$: Travel time between zone i and j by public and private mode

K, a, b, c, d : Parameters

Table 5-1-8 Parameters for Modal Split Model - 2

Purpose	Travel Distance (a)	Travel Time Ratio (b)	Vehicle Ownership at Origin (c)	Vehicle Ownership at Destination (d)	Constant (K)
To Work	-0.0287	0.4985	-2.5279	0.0000	0.1566
To School	-0.0378	0.0391	-0.9672	-0.6087	1.1563
Business	-0.0760	0.0000	-2.7307	-1.3550	3.7996
Private	-0.0201	0.0223	-2.3792	-1.0221	2.9589
To Home	-0.0364	0.0741	0.0000	-2.4539	1.9358

Source: Prepared by the JICA Study Team

Modal Split Model - 3

Formula: $$R_{ij}^{Car} = \frac{1}{1 + e^{aD_{ij} + b \cdot \left(\frac{t_{ijt}^{car}}{t_{ij}^{motorcycle}} \right) + c \cdot CO_i + d \cdot CO_j + K}}$$

Where, R_{ij}^{Car} : Ratio of car trips traveling between zone i and j

D_{ij} : Travel distance (km) between zone i and j

CO_i, CO_j : Ratio of car-owning households in origin zone i and destination zone j

$t_{ij}^{car}, t_{ij}^{motorcycle}$: Travel time between zone i and j by car and motorbike

K, a, b, c : Parameters

Table 5-1-9 Parameters for Modal Split Model - 3

Purpose	Travel Distance (a)	Travel Time Ratio (b)	Vehicle Ownership at Origin (c)	Vehicle Ownership at Destination (d)	Constant (K)
To Work	-0.0163	1.3364	-2.8791	-0.7526	-0.5339
To School	0.0000	3.8136	-1.3954	-0.8999	-3.3471
Business	-0.0579	2.9963	-2.2844	-0.2477	-2.0934
Private	-0.0627	1.6842	-2.1300	-1.4774	-0.8695
To Home	0.0000	0.1320	-0.6583	-3.1126	0.2498

Source: Prepared by the JICA Study Team

(5) Assignment Model

JICA STRADA, which was developed by JICA, is used for traffic assignment simulation. This system provides two major types of highway assignment model, namely, incremental assignment and user equilibrium assignment. For this Study, the incremental assignment is employed.

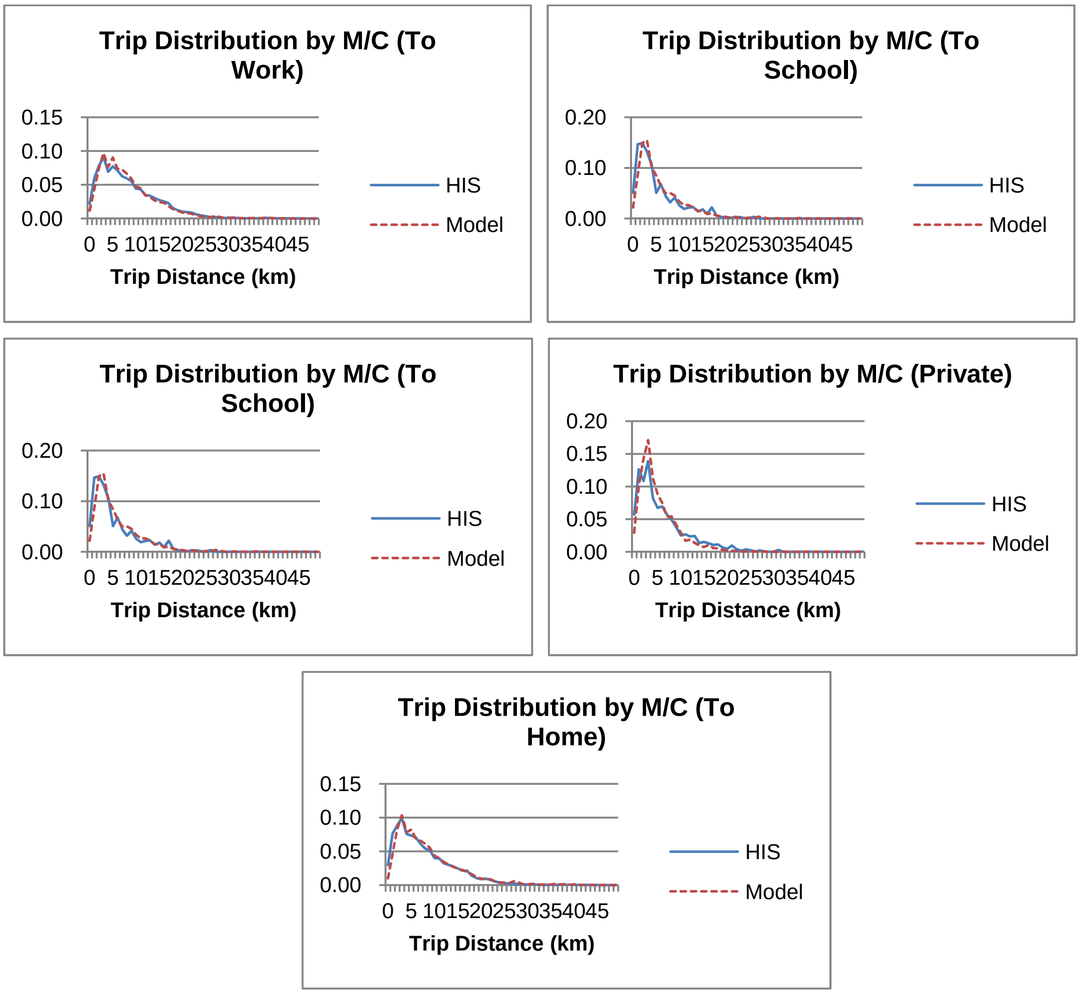
The incremental assignment divides the input OD matrix data into several increments and assigns each increment to the shortest route where the generalized cost is the least. Once the increments are assigned, link cost of each link is re-calculated, and the shortest route is found again for the next increments. This calculation is repeated until the number of designated times.

5.1.4 Calibration of Models

The models have been developed, and a set of network database has established. The last task of the development procedure is calibration. It is necessary to examine how accurate the developed models represent the existing transport situation by comparing the output from the models and the existing transport characteristic surveyed.

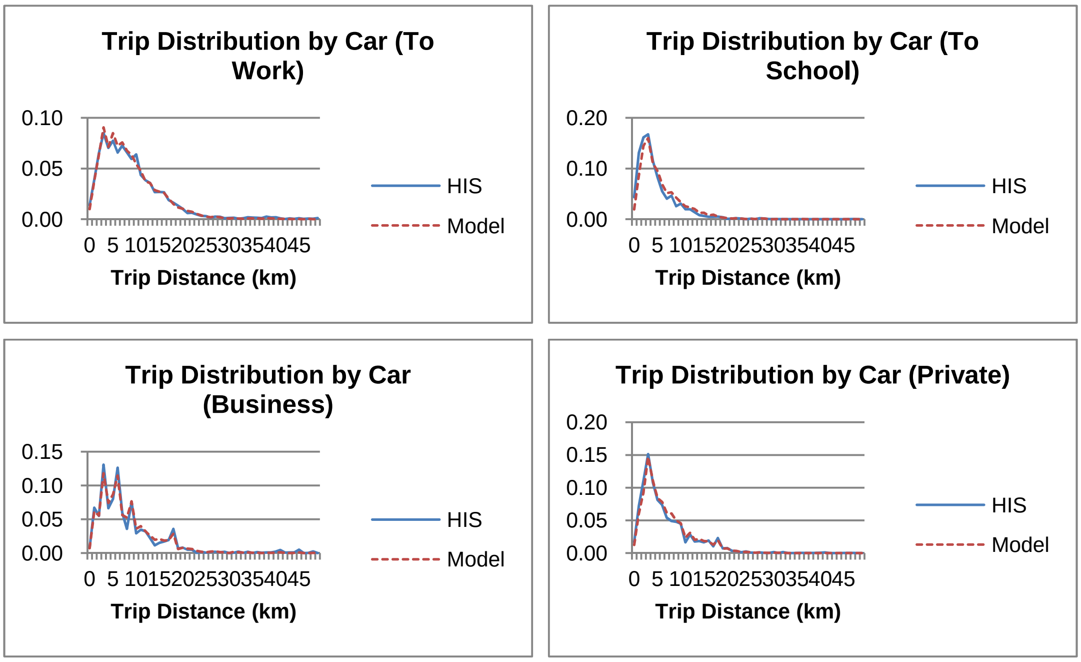
In this section, two different ways of calibration are discussed. The first is to compare trip distribution by each mode estimated with the models and that of calculated based on HIS survey result. This comparison can check how accurate the models represent existing travel pattern by mode and distance. The second way compares the traffic demand that can be calculated by traffic assignment model and observed traffic volume. This calibration work can show how much the network and travel demand represent appropriately.

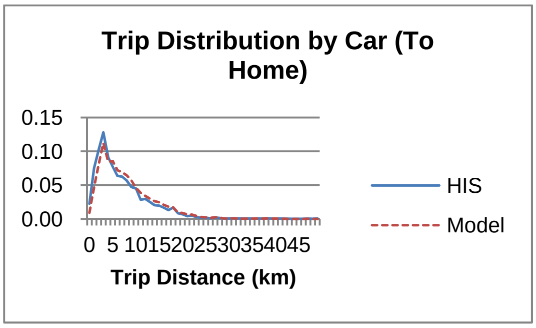
The result of the first comparison is shown in the following figures.



Source: Prepared by the JICA Study Team

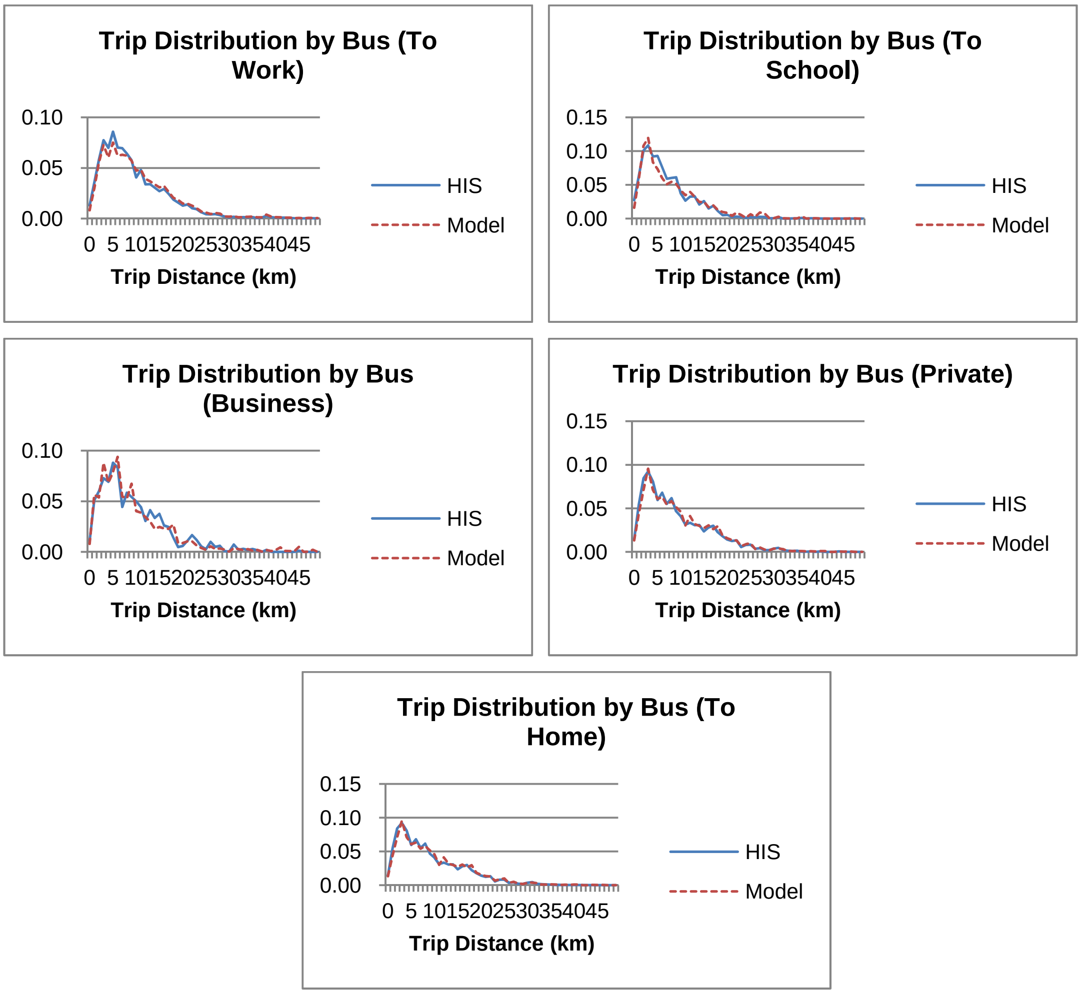
Figure 5-1-7 Comparison of Travel Distribution by Motorcycle





Source: Prepared by the JICA Study Team

Figure 5-1-8 Comparison of Travel Distribution by Car

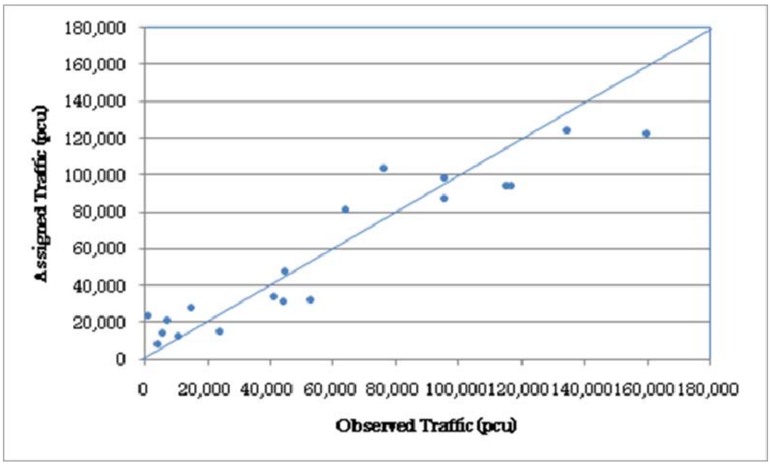


Source: Prepared by the JICA Study Team

Figure 5-1-9 Comparison of Travel Distribution by Bus

For the second comparison, link volumes that can be estimated as an assignment result on the base year road network are compared with the traffic volumes that were observed by the transport surveys conducted by JICA Study Team.

Figure 5-1-10 show the result of the comparison. In the graph, the horizontal line indicates observed traffic volumes in terms of pcu (passenger car unit) and the vertical line indicates link volume of traffic assignment. Nearer a result is plotted to the straight line, which is an equation of y = x, more accurate the models represent. The correlation coefficient is calculated at 0.84, and this figure indicates that the models are tolerable.



Source: Prepared by the JICA Study Team

Figure 5-1-10 Calibration Result

5.2 Future Transport Demand Forecast

5.2.1 Future Zonal Attribute

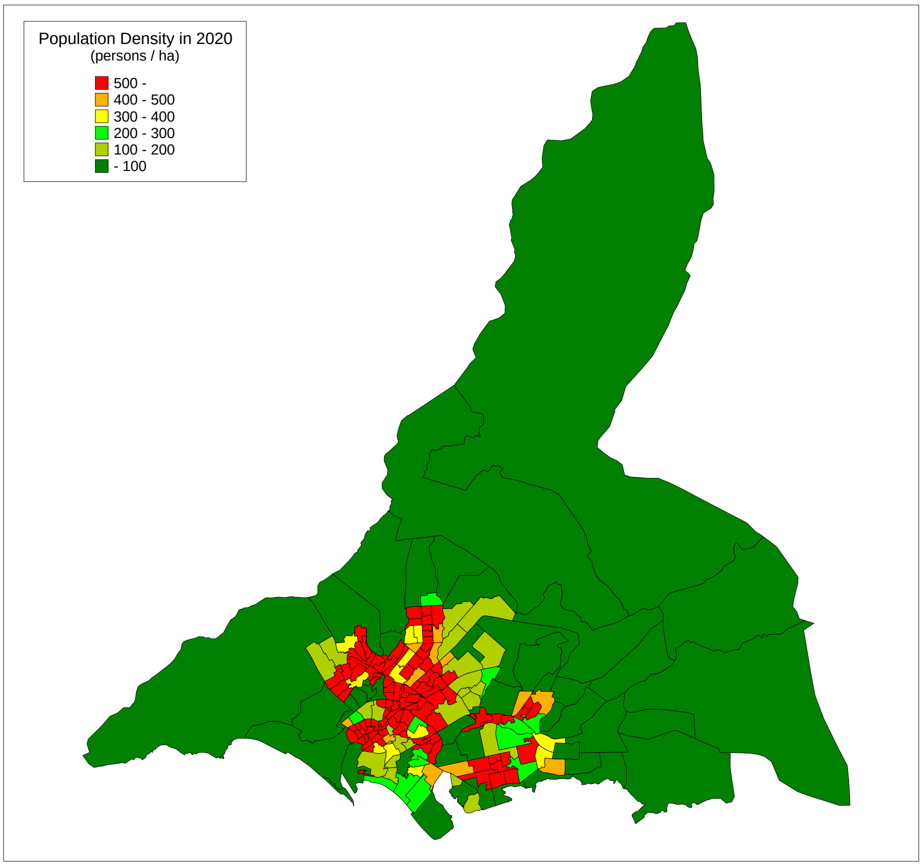
Based on the existing socio-economic indicators, the future value of the indicators was prepared by traffic analysis zone for the future forecast of transport demand in the year of 2020 and 2030. This is established based on the scenario of urban development discussed in the former chapter. The following table summarizes the projection of population and employment which is the number of workers at work place, by city and cantonment. These figures are assumed by traffic analysis zone, and they are used for future demand forecast later.

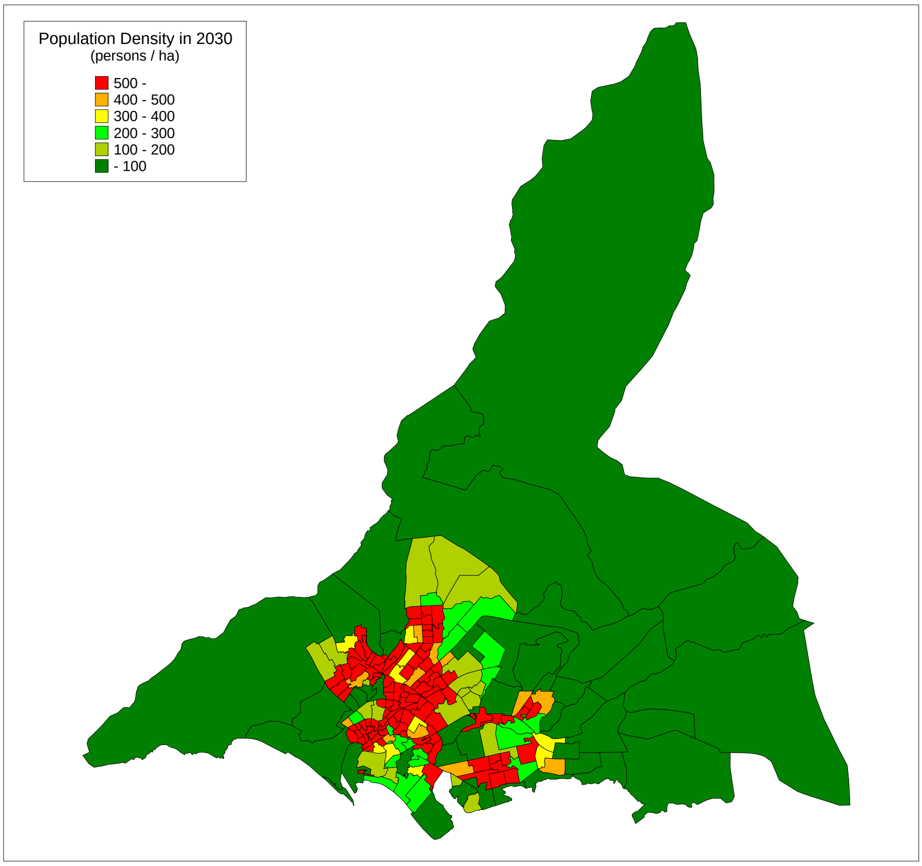
Table 5-2-1 Socio-economic Indicators for Future Demand Forecast

No.	City/Cantonment	Population (1,000)			Employment (1,000)		
		2010	2020	2030	2010	2020	2030
1	Keamari	761.7	1,913.8	2,290.0	800.2	1,304.3	1,708.2
2	S.I.T.E	853.7	894.5	894.5	620.7	565.9	560.9
3	Baldia	864.4	1,110.1	1,110.1	256.4	285.5	308.7
4	Orangi	1,337.7	1,428.9	1,522.5	182.0	186.6	195.3
5	Lyari	938.6	969.3	969.3	81.2	84.9	89.5
6	Saddar	1,104.3	1,122.7	1,233.0	702.8	861.8	989.4
7	Jamshed	1,397.3	1,559.9	1,713.2	262.2	401.1	508.7
8	Gulshan-E-Iqbal	1,458.3	2,373.4	2,684.4	537.6	686.4	802.9
9	Shah Faisal	601.9	611.9	646.9	73.4	80.9	86.5
10	Landhi	1,353.4	1,822.3	1,822.3	348.8	388.6	430.5
11	Korangi	1,285.5	1,825.6	1,825.6	446.1	390.8	379.7
12	North Nazimabad	917.1	979.5	1,043.6	118.3	129.3	138.8
13	New Karachi	1,226.2	1,246.6	1,328.3	279.7	291.9	307.8
14	Gulberg	838.1	895.2	953.8	144.5	143.3	147.9
15	Liaquatabad	1,002.0	1,034.9	1,034.9	96.5	163.3	215.0
16	Malir	780.7	907.1	936.9	149.3	165.9	177.9
17	Bin Qasim	517.8	2,031.7	2,697.3	1,098.1	2,591.1	3,293.4
18	Gadap	538.2	3,077.7	5,059.2	556.7	1,577.4	2,029.7
19	Karachi Cantonment	88.4	90.2	96.1	96.6	165.1	220.9
20	Clifton Cantonment	559.0	770.6	821.1	304.9	350.9	386.1
21	Faisal Cantonment	247.5	352.1	362.6	67.1	219.7	335.4
22	Malir Cantt Civil	205.8	400.3	414.4	74.2	69.0	68.9
23	Manora Cantonment	10.0	10.0	10.0	40.3	32.5	30.2
24	Korangi Cantonment	47.5	121.8	129.8	80.6	193.8	276.8
Total		18,935.1	27,550.2	31,600.0	7,418.0	11,330.0	13,689.0

Source: Prepared by the JICA Study Team

The upper chart in Figure 5-2-1 illustrates the population density by traffic analysis zone in 2020 and the lower chart shows those in 2030.





Source: Prepared by the JICA Study Team

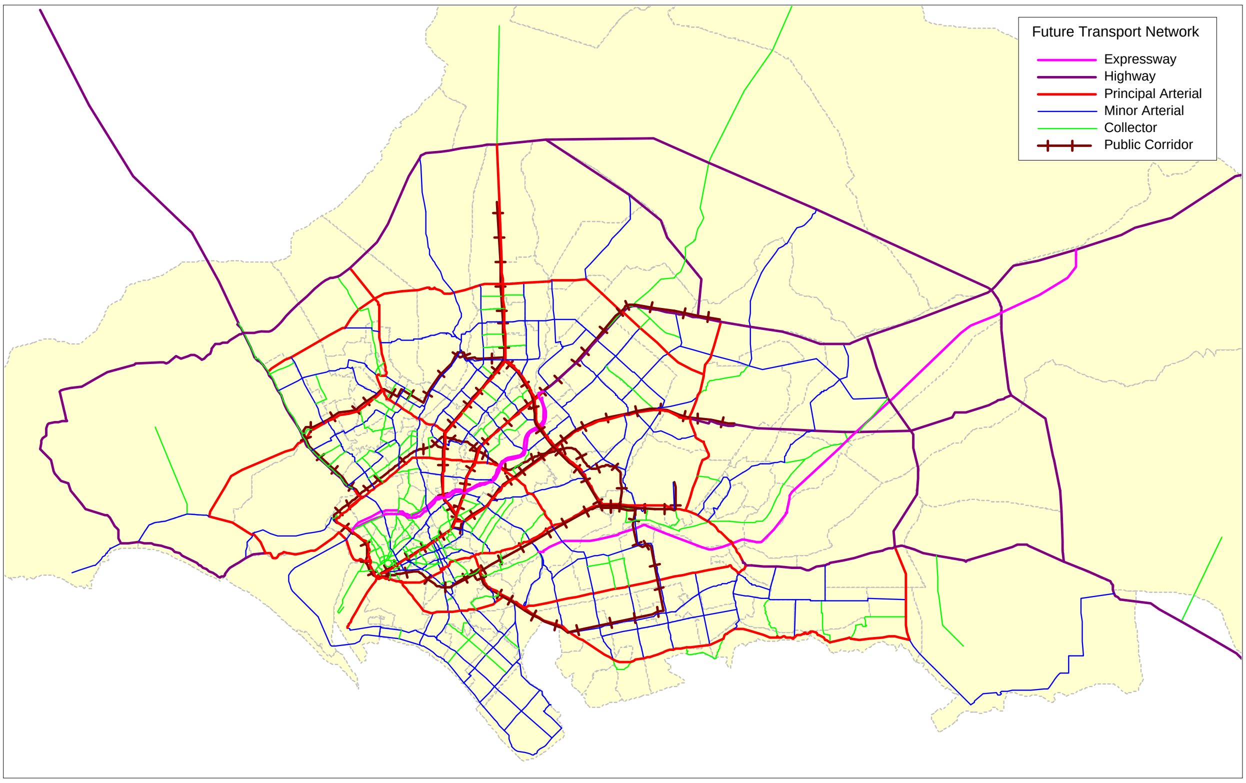
Figure 5-2-1 Population Density by Traffic Analysis Zone

5.2.2 Future Transport Network

The future network used for forecasting the future demand consists of two kinds of network data set: namely, highway network, and transit network. The highway network is used to estimate traffic demand on the road while the transit network is used to estimate the number of passengers on each public transport corridor.

The full network that all proposed plan is included, is developed by adding the future projects that are planned to be constructed by 2030, on the highway network calibrated on the existing transport situation. The principal new construction/improvement projects involved in the full network for the simulation are as follows:

- Lyari expressway and its extension
- Malir expressway
- Northern bypass westwards extension
- Northern bypass eastern extension along Jinnah Avenue
- Six public transport corridors proposed by the JST



Source: Prepared by the JICA Study Team

Figure 5-2-2 Full Network for Demand Forecast

5.2.3 Demand Forecast

(1) Trip Generation

The first step of the demand forecast is the estimation of trip generation. This can be performed with inputting the population aged over five years and above into the trip generation model, which is trip rate by travel purpose. The result is shown in the following table.

The number of trips generated can be calculated as 29 million in 2020 and 33 million in 2030, which is the sum of trips by travel mode. These values indicate 1.5 times increase in 2020 and 1.7 times in 2030 of that in 2010 as shown in the lowest row of the table.

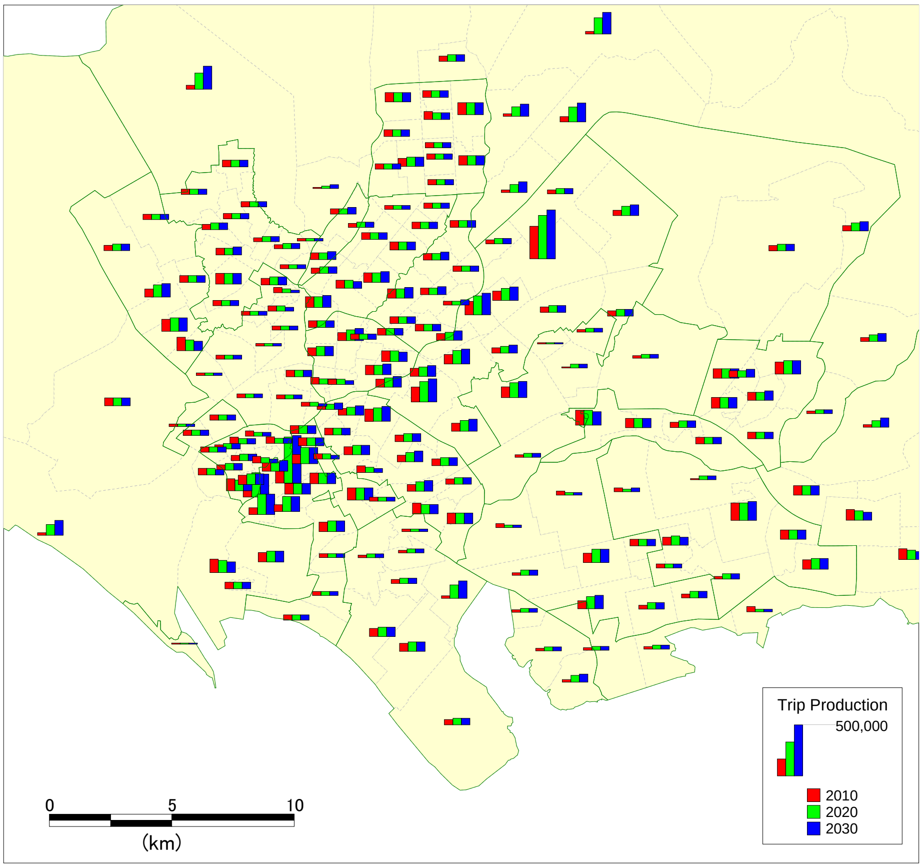
Table 5-2-2 Estimated Trip Generation

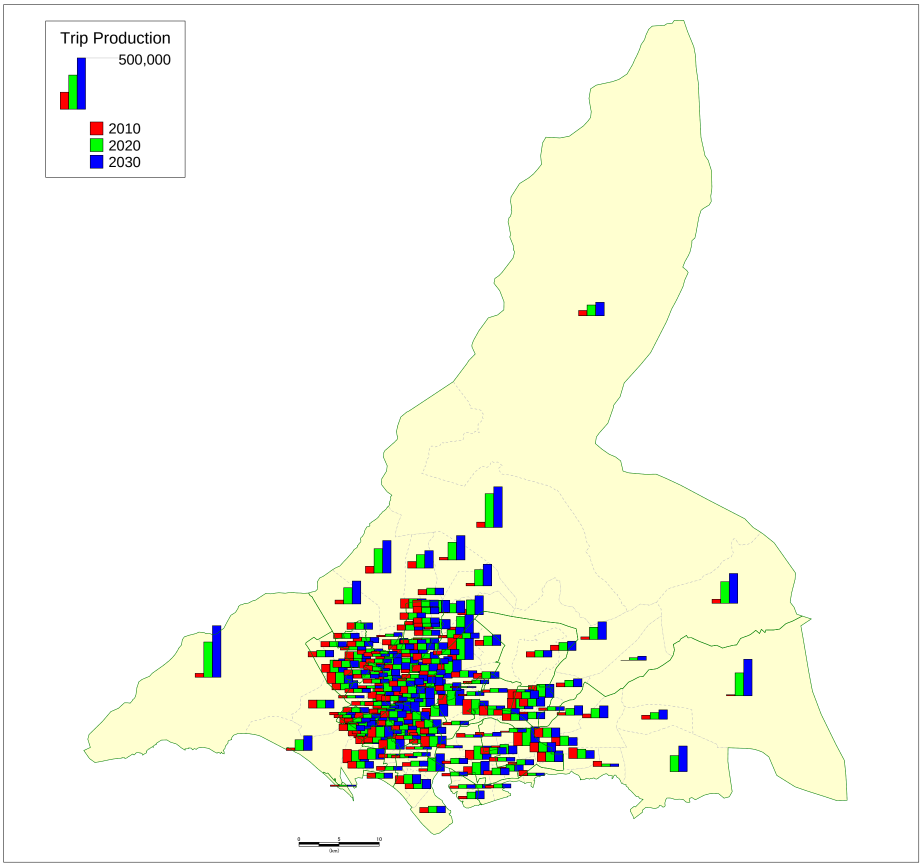
Trip Purpose	Trip Rate	No. of Trips (1,000)		
		2010	2020	2030
To work	0.31	4,894	7,121	8,167
To school	0.21	3,232	4,702	5,393
Business	0.02	281	409	469
Private	0.10	1,613	2,348	2,693
To home	0.63	9,924	14,439	16,561
Total	1.27	19,944	29,018	33,283
Increase		1.00	1.45	1.67

Source: Prepared by the JICA Study Team

Next, the trip production and attraction of each traffic analysis zone are estimated by using the trip production and attraction models, and the above total number of trips is distributed into each traffic analysis zone in proportion with the model value for the trip production and attraction.

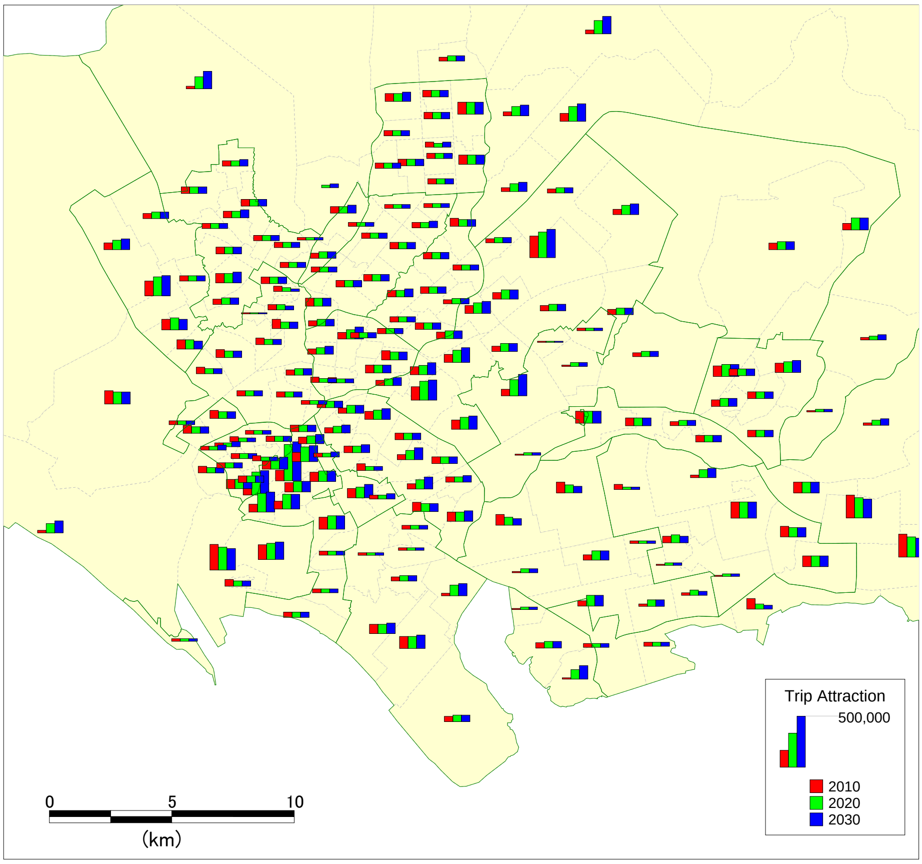
The following figures, Figure 5-2-3 and Figure 5-2-4illustrate the change of trip production and attraction estimated by traffic analysis zone.

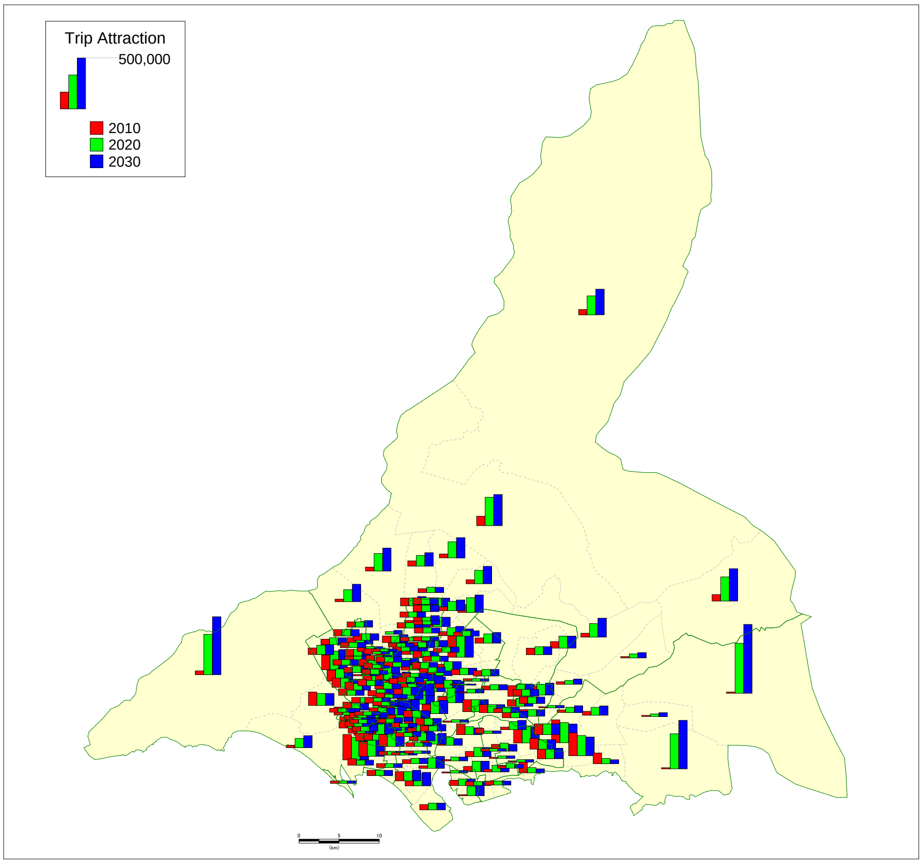




Source: Prepared by the JICA Study Team

Figure 5-2-3 Increase of Trip Production by Traffic Analysis Zone





Source: Prepared by the JICA Study Team

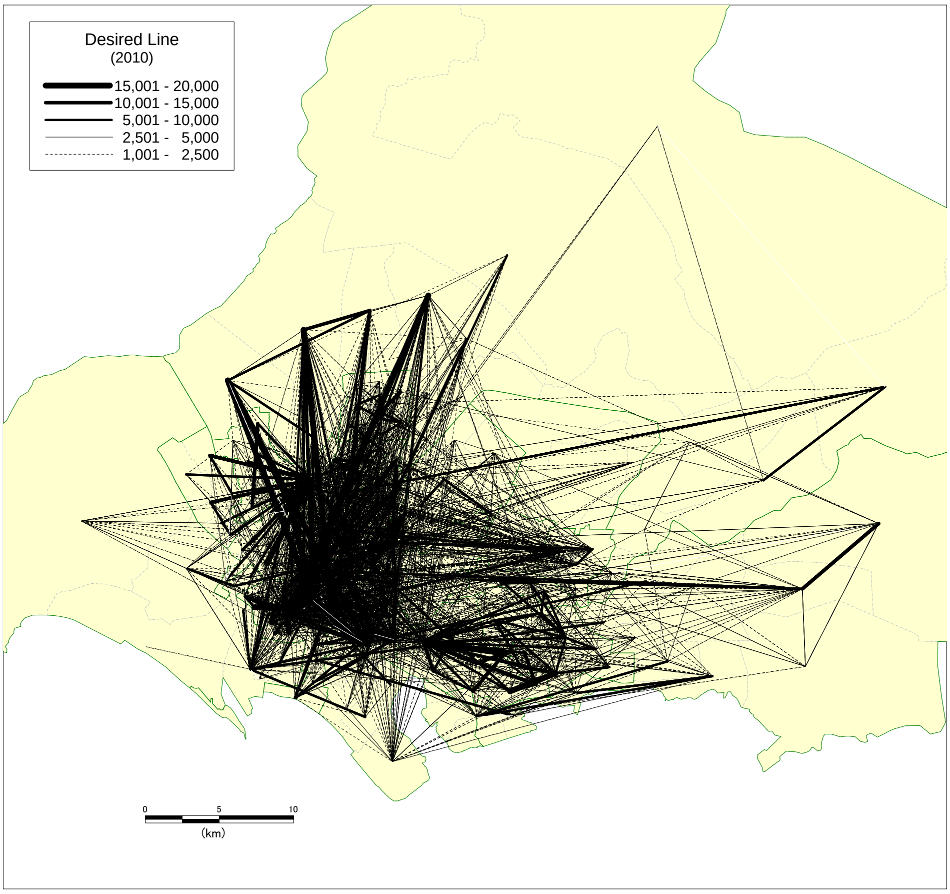
Figure 5-2-4 Increase of Trip Attraction by Traffic Analysis Zone

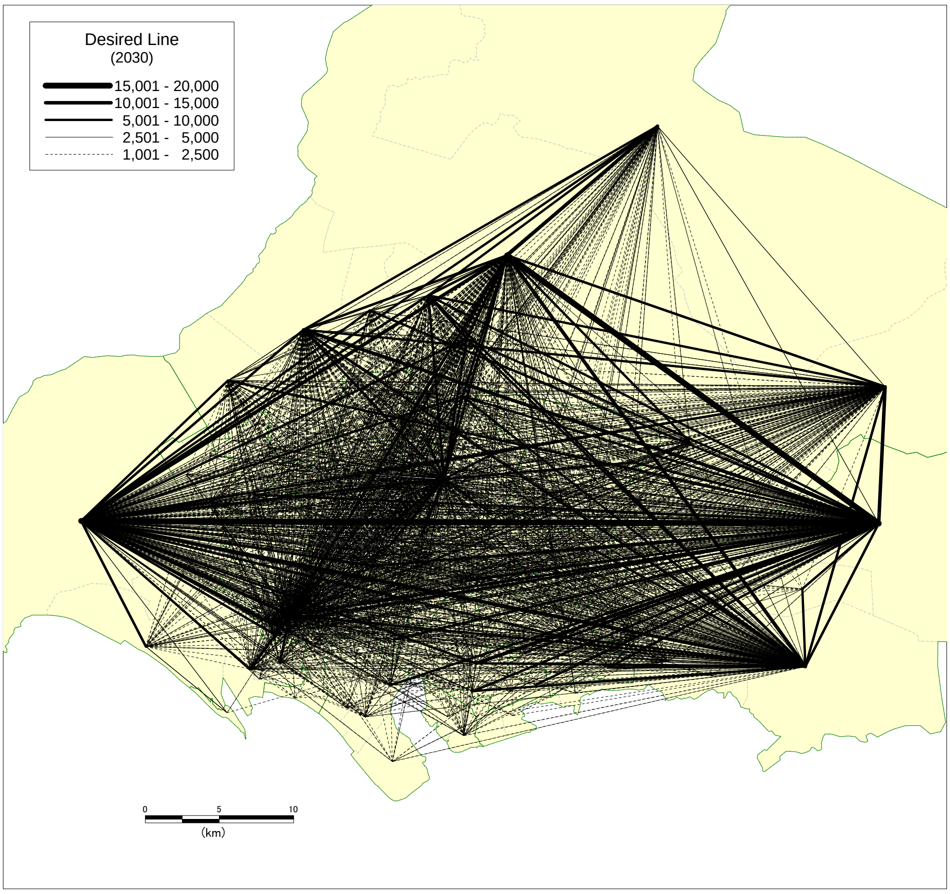
(2) Future Trip Distribution

Based on the trip distribution model, person trip origin and destination (OD) matrix are built by trip purpose. This matrix represents the estimates where travelers start a trip and to where they are going.

The comparison of the OD matrix of both the existing and future, in the year 2030, is exhibited in Figure 5-2-5. These drawings are known as “Desired Line” or “Desire Line”; the width of its lines precisely represents the travel demand between the origin and destination zones of their trips.

From this figure, it can be seen that the travel demand becomes larger, and their destination spreads in all direction, specially northern and eastern suburban areas in the Study area, while the existing travel demand is likely to have a strong flow between CBD and northern part of Karachi city.





Source: Prepared by the JICA Study Team

Figure 5-2-5 Existing and Future Desired Line

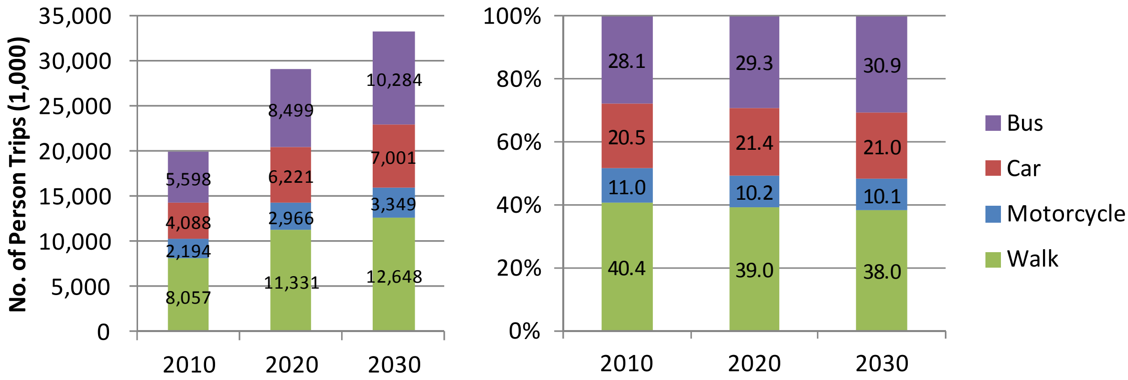
(3) Future Modal Share

The next step is to distribute the trips in the estimated OD matrix into each mode: walking, motorbike, car and public transport, by applying the three modal split models. The modal split models require several parameters. One of the Parameters is travel time by mode. The ratio of travel time of bus to car varies modal share. Table 5-2-3 summarizes the result of modal split model calculation, and Figure 5-2-6 shows the change of modal share. This is calculated by using travel time by mode based on the network that public transport is included.

Table 5-2-3 Number of Trips by Mode

Mode	2010		2020		2030	
	(1,000)	(%)	(1,000)	(%)	(1,000)	(%)
Walk	8,057	40.4	11,331	39.0	12,648	38.0
Motorcycle	2,194	11.0	2,966	10.2	3,349	10.1
Car	4,088	20.5	6,221	21.4	7,001	21.0
Bus	5,598	28.1	8,499	29.3	10,284	30.9
Total	19,937	100.0	29,017	100.0	33,283	100.0

Note (1): This is the modal share of Full Network Case (see P5-28)
Note (2): "Bus" includes other types of public transport systems
Source: Prepared by the JICA Study Team

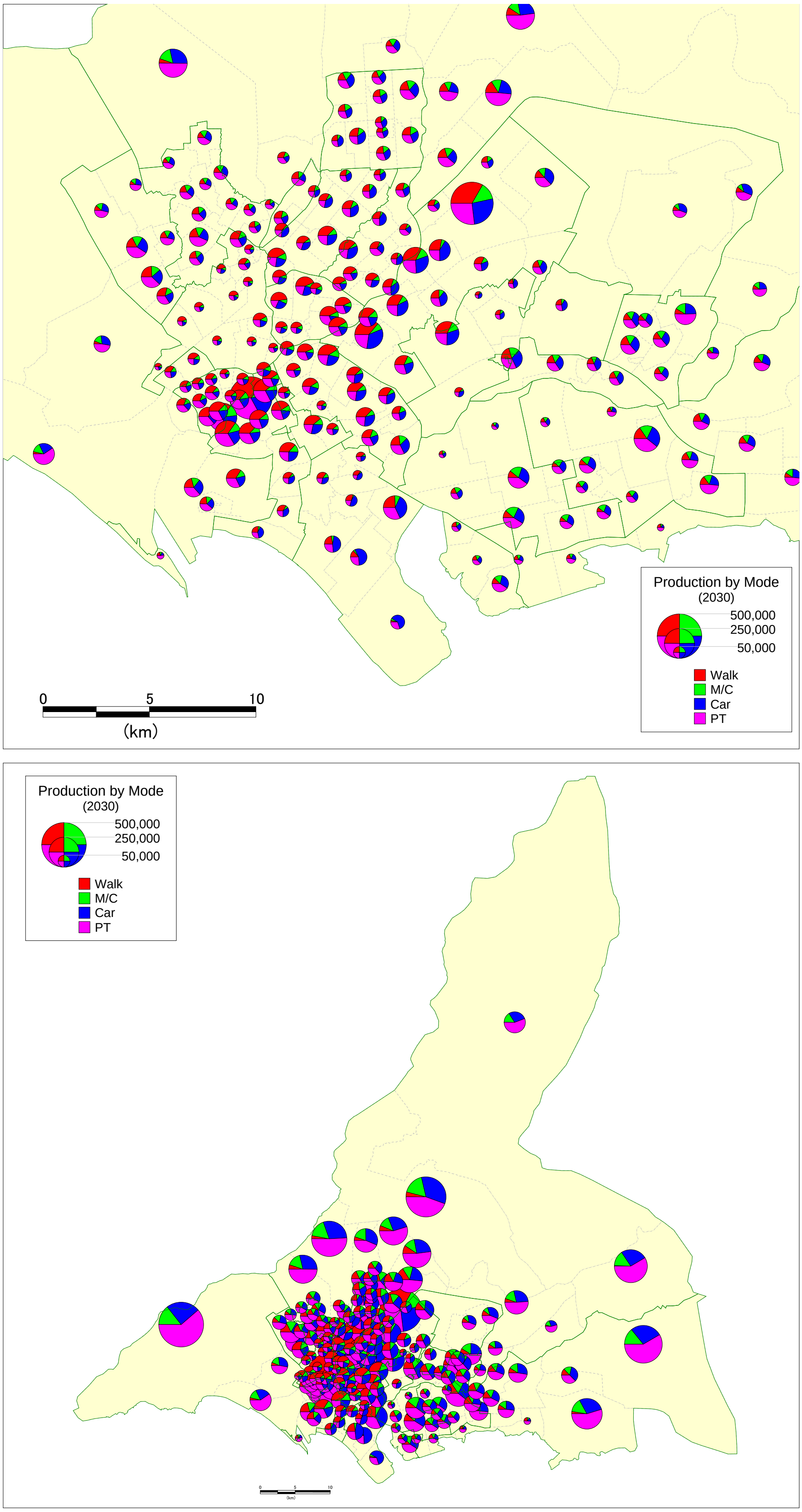


Source: Prepared by the JICA Study Team

Figure 5-2-6 Change of Modal Share

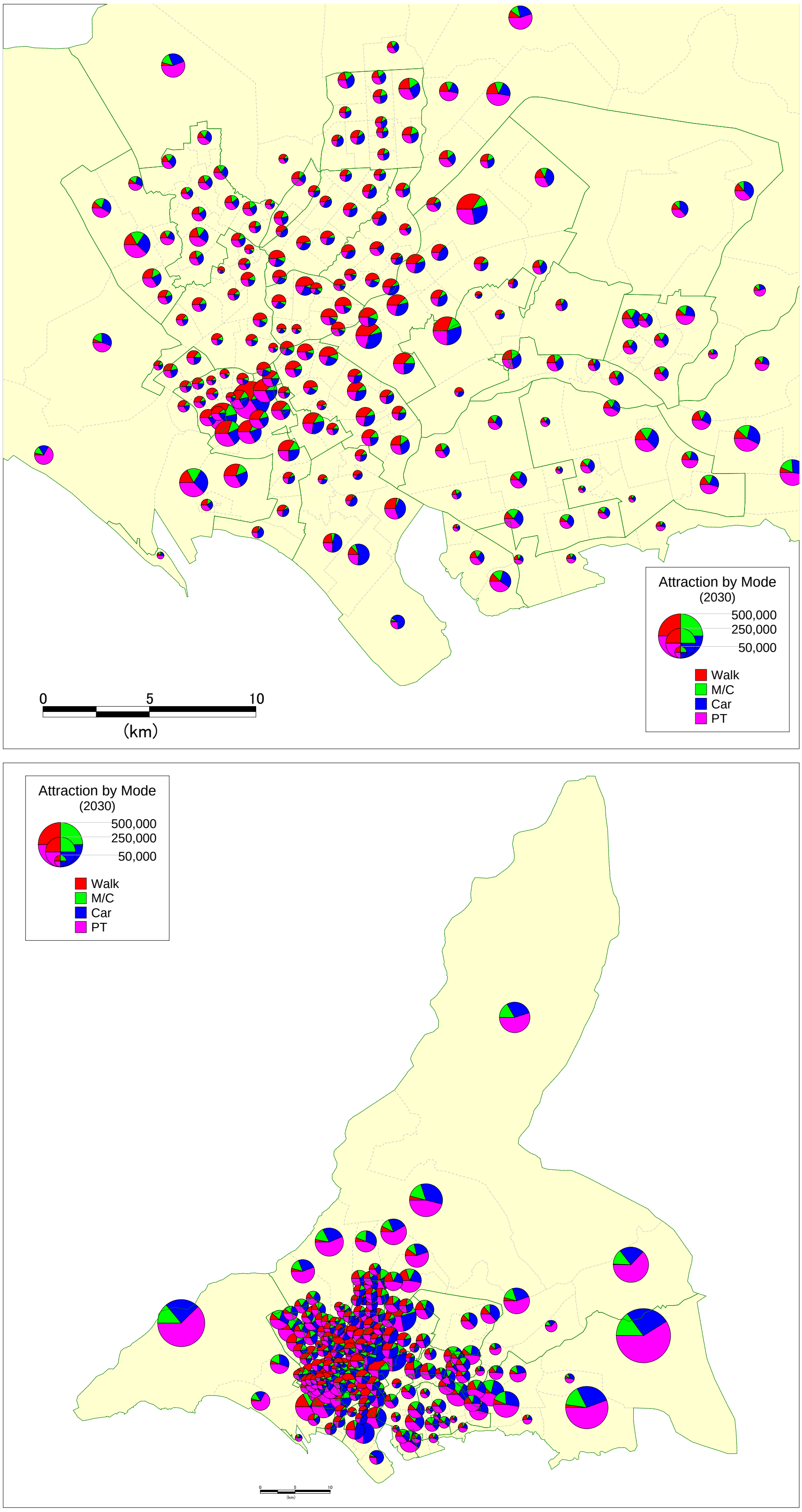
In the future, average travel length will be longer according to the spread of urban area. Therefore, the share of walk trips appears to slightly decrease and the share of motorized trips to increase. The number of motorized trip, which is the sum of trips by motorbike, car and bus, seems to be 20 million person trips. The increase ratio from the year 2010 to 2030 indicates 1.7 times, which is higher that the increase of population.

The number of trip production by mode and traffic analysis zone in 2030 is illustrated in Figure 5-2-7, and that of trip attraction is in Figure 5-2-8.



Source: Prepared by the JICA Study Team

Figure 5-2-7 Trip Production by Mode and TAZ in 2030



Source: Prepared by the JICA Study Team

Figure 5-2-8 Trip Attraction by Mode and TAZ in 2030

(4) Result of Traffic Assignment

The objective of traffic assignment is not only to predict the traffic demand on each network link or road section but also to assess the performance of network alternatives by using the indicators that are principal output calculated in assignment methodology.

As discussed in the former section, the modal split models divide the total trips into several mode trips. When motorized trips are distributed into private mode trips, and public mode trips such as BRT and MRT, the travel time by each mode is an important factor. If the network includes mass transit lines, travel speed by public mode is faster than that in the highway-only network, and modal share of public transport in case of mass transit included network is necessarily higher. In other words, modal shift from private mode to public mode takes a place and the impact of the introduction of mass transit network can be measured.

The following table shows the result of above-mentioned exercise. If mass transit is introduced into the network, the public mode trips increase by 1.7 million to 10.3 million, while the share of public mode changes from 41.6% to 49.8%. Modal shift from car user indicates about 1 million trips. This may be composed of taxi and Suzuki users, not of car owners.

Table 5-2-4 Difference of Modal Share between Networks in 2030

Motorized Mode	Modal Share when travel speeds are calculated on Highway-only Network		Modal share when travel speeds are calculated on Mass Transit included Network		Difference (1,000)
	No. of Trips (1,000)	(%)	No. of Trips (1,000)	(%)	
Motorcycle	3,908	18.9	3,349	16.2	-558
Car	8,146	39.5	7,001	33.9	-1,144
Bus	8,582	41.6	10,284	49.8	1,703
Total	20,635	100.0	20,635	100.0	

Source: Prepared by the JICA Study Team

In order to evaluate network performance, these two matrices are assigned on network. The following cases are established to measure the impact by comparing the result of each case.

Do Nothing Case: assigns the future OD matrix calculated on highway-only network onto the existing highway network.

Highway Developed Case: assigns the future OD matrix calculated on highway-only network onto the highway developed network that includes future highway projects but no mass transit developed.

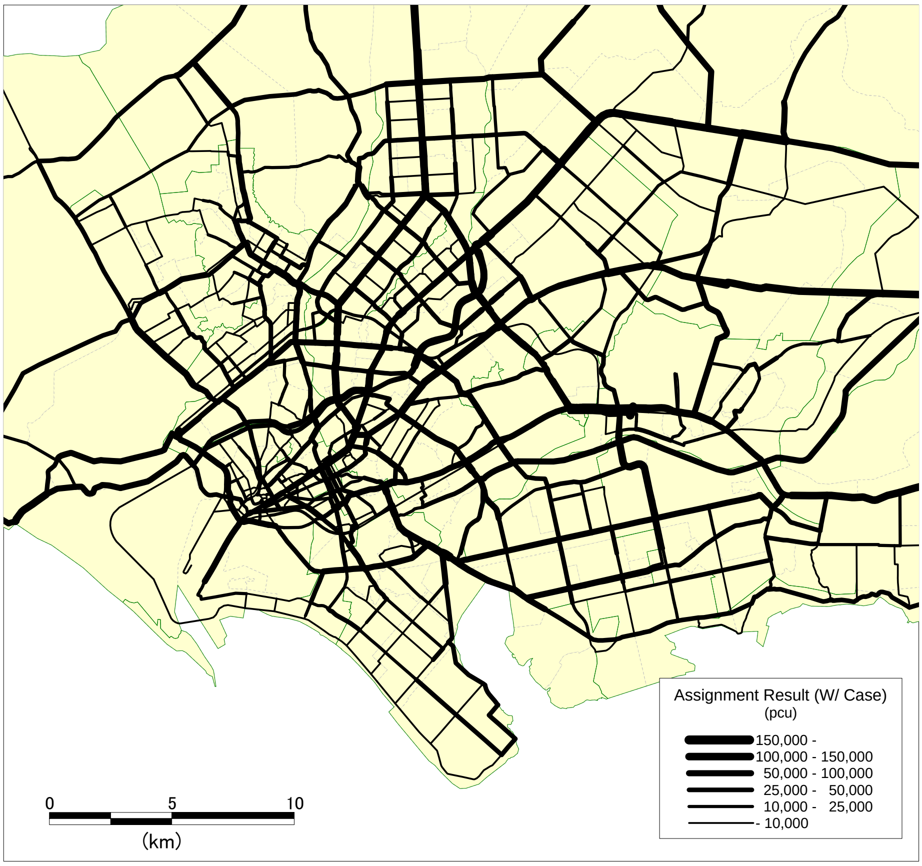
Full Network Case: assigns the future OD matrix calculated on mass transit-included network on the full network that includes future highway projects and mass transit.

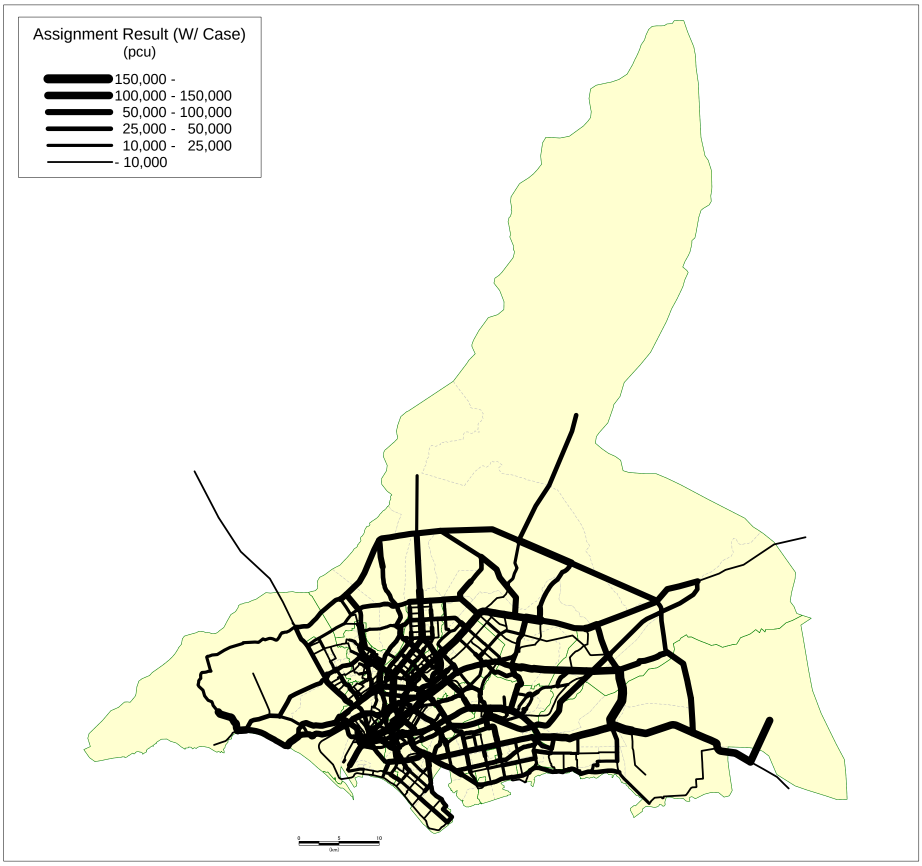
Table 5.2-5 shows the performance indicators as the result of assignment procedure. The indicators of travel distance and travel time for “Full Network” case are calculated without including the performance on transit network. In the case of “Do Nothing”, average congestion will be 2.15 which doesn’t realize in the actual situation. If only the proposed highway plan is introduced in 2030, congestion ratio decreases at 1.23. The average volume capacity ratio in the case of full network, which consists of the highway network plan and transit network plan indicates at 1.03.

Table 5-2-5 Evaluation of Network Performance

Case	Year	Total Travel Distance (1,000 pcu*km)	Total Travel Time (1,000 pcu*h)	Total Capacity Distance (1,000 pcu*km)	Average Volume Capacity Ratio	Average Travel Speed (km/h)
Do Nothing	2030	89,575.2	5,061.4	41,759.5	2.15	17.7
Highway Developed	2030	90,630.7	2,277.6	73,981.7	1.23	39.8
Full Network	2030	75,859.9	1,725.7	73,981.7	1.03	44.0

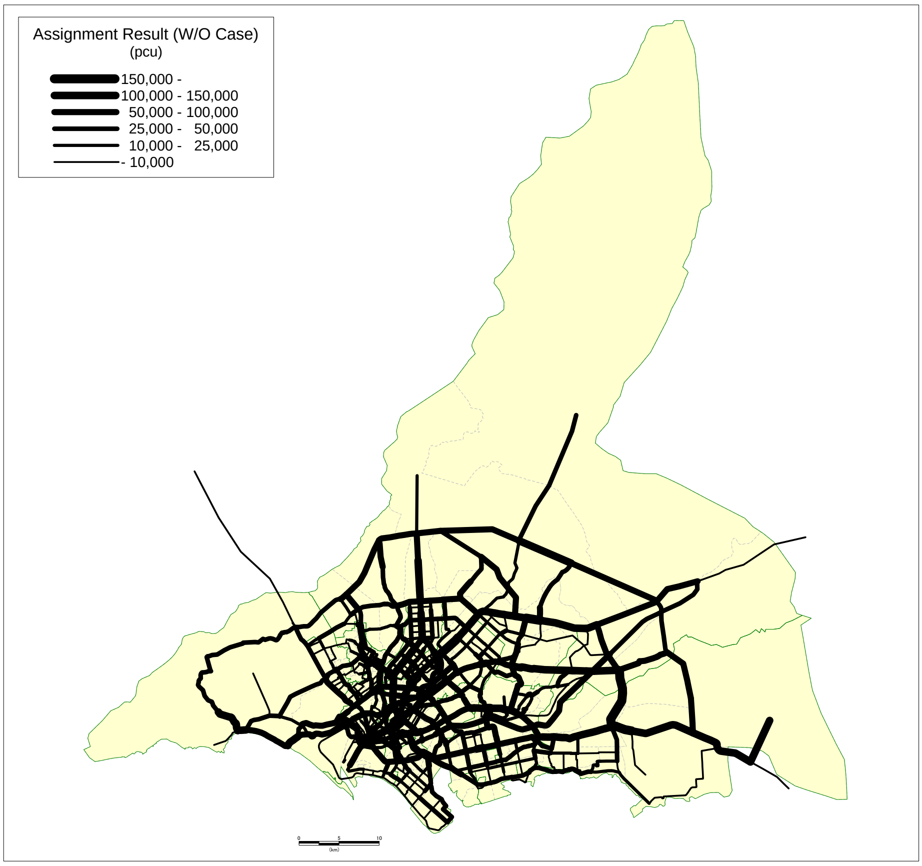
Source: Prepared by the JICA Study Team





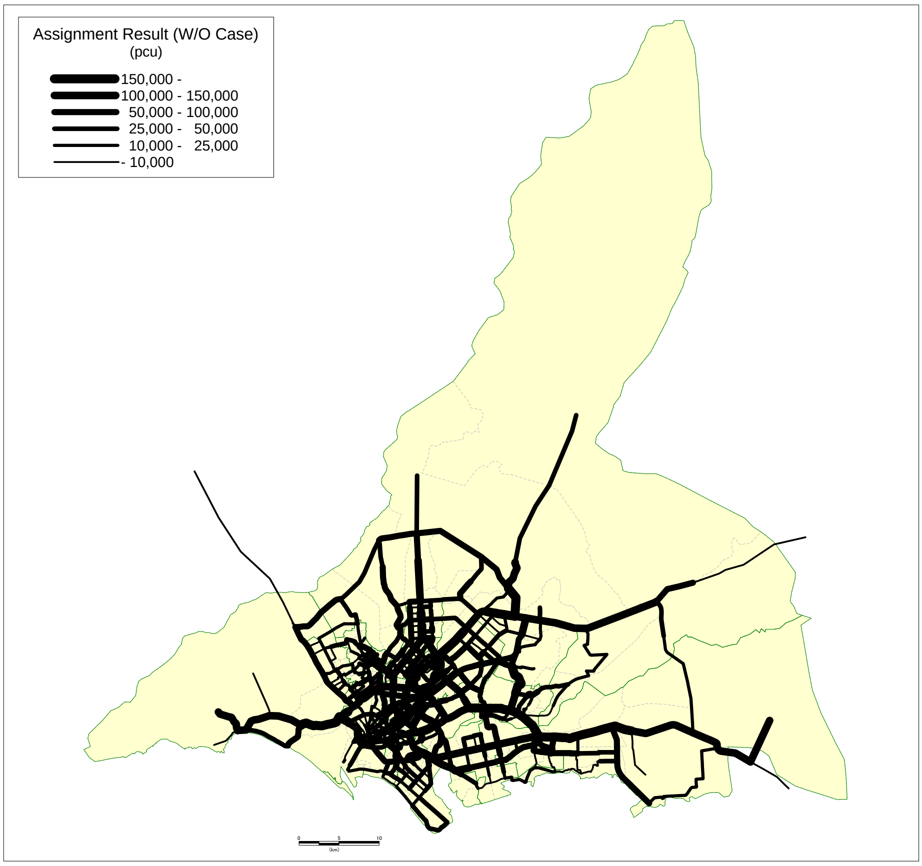
Source: Prepared by the JICA Study Team

Figure 5-2-9 Traffic Volume Assigned for Full Network Case (2030)



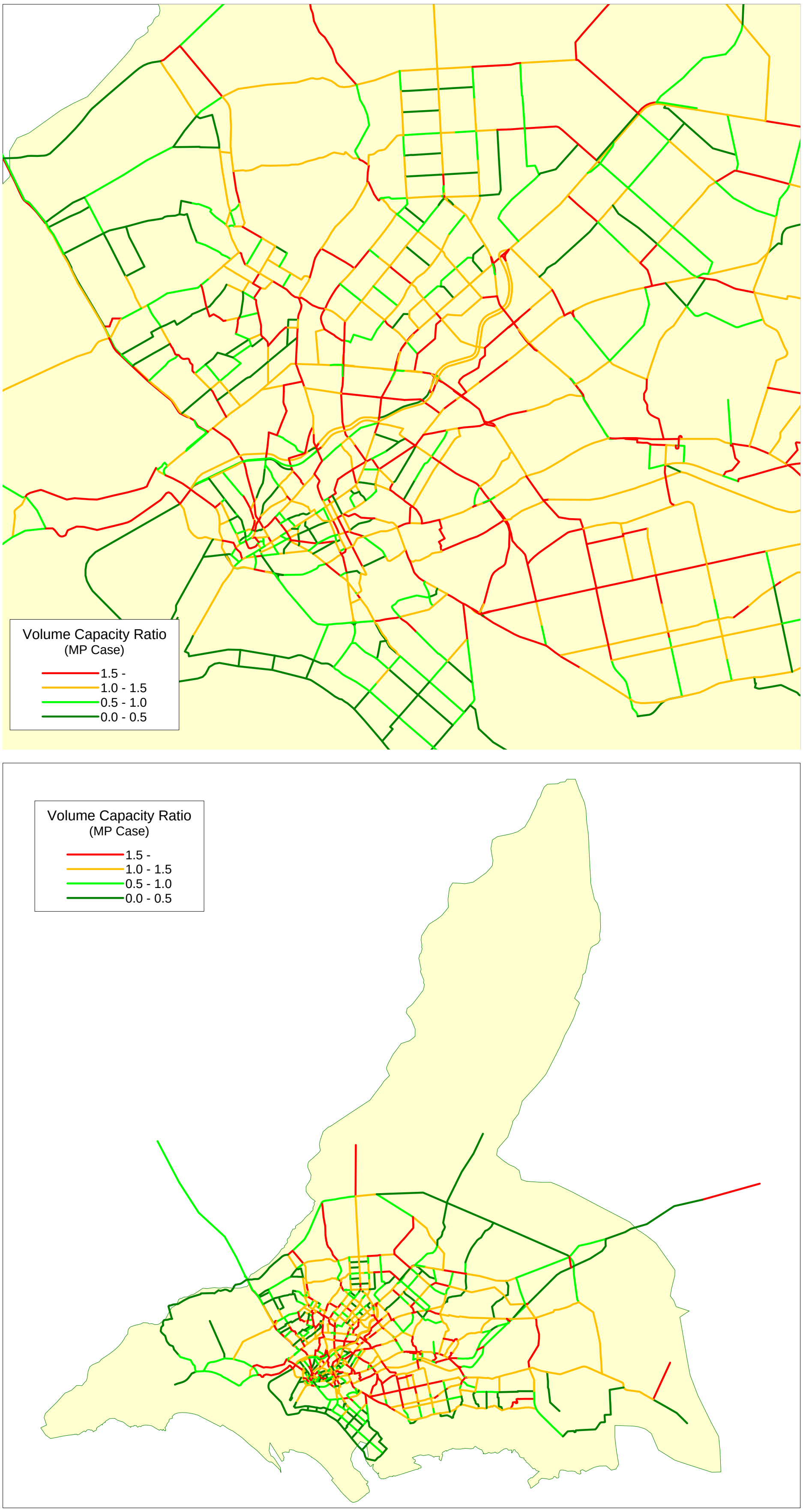
Source: Prepared by the JICA Study Team

Figure 5-2-10 Traffic Volume Assigned for Highway Developed Case (2030)



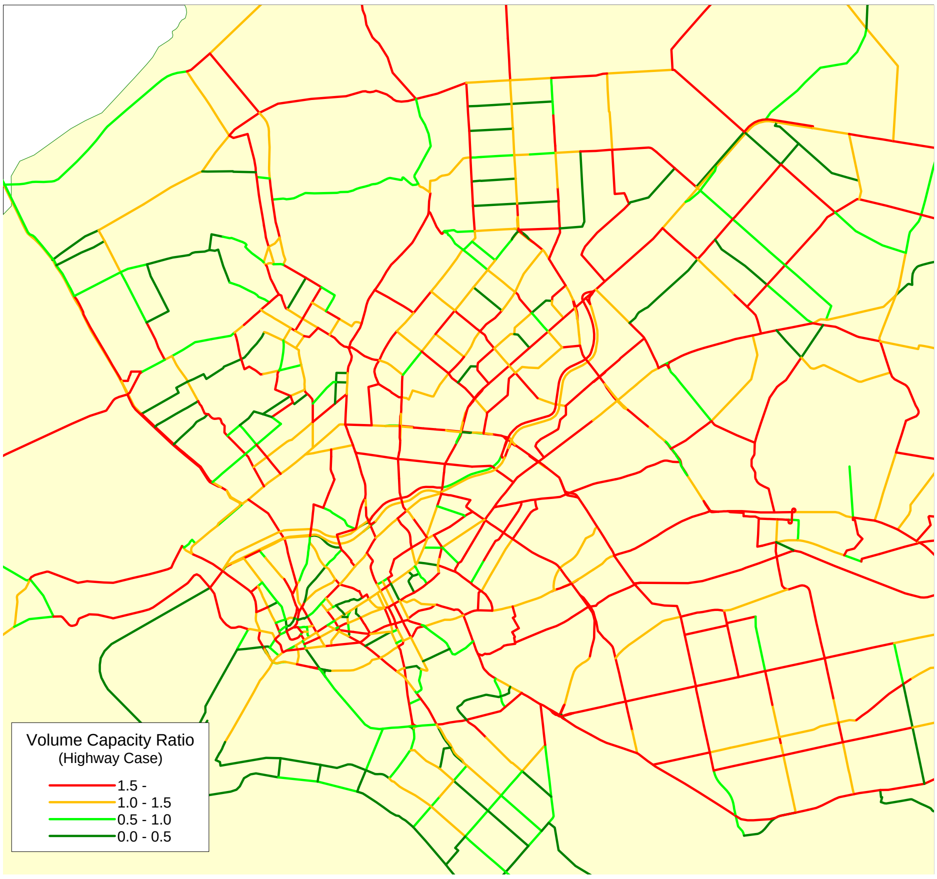
Source: Prepared by the JICA Study Team

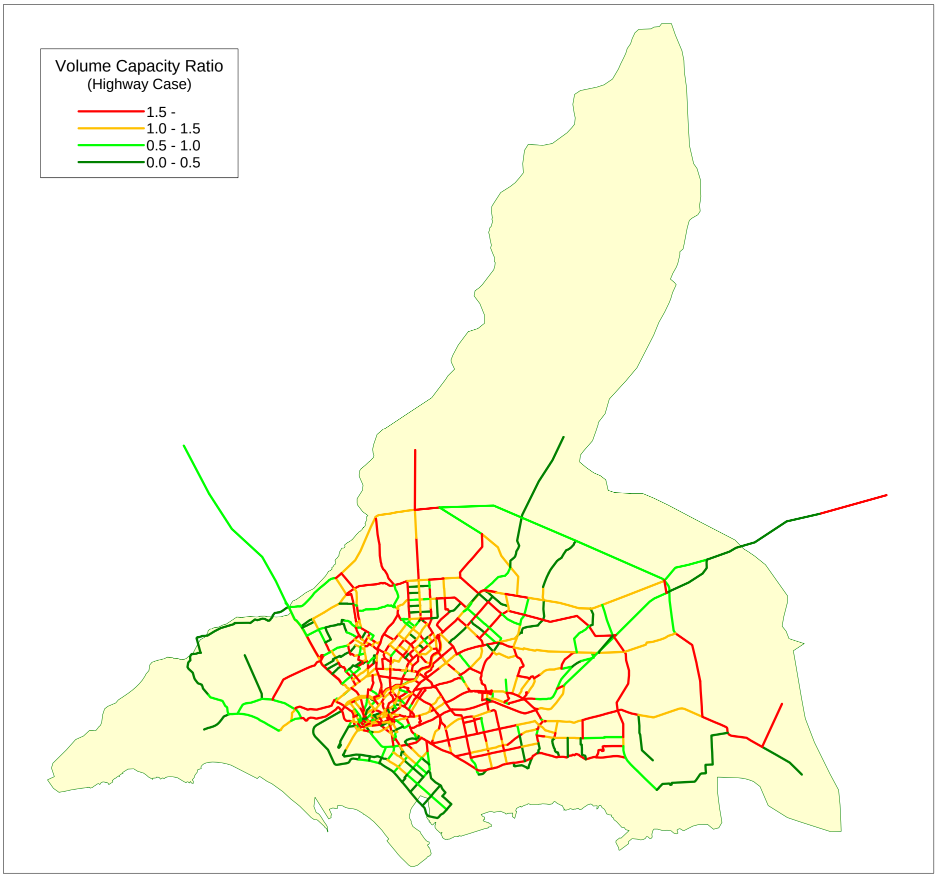
Figure 5-2-11 Traffic Volume Assigned for Do Nothing Case (2030)



Source: Prepared by the JICA Study Team

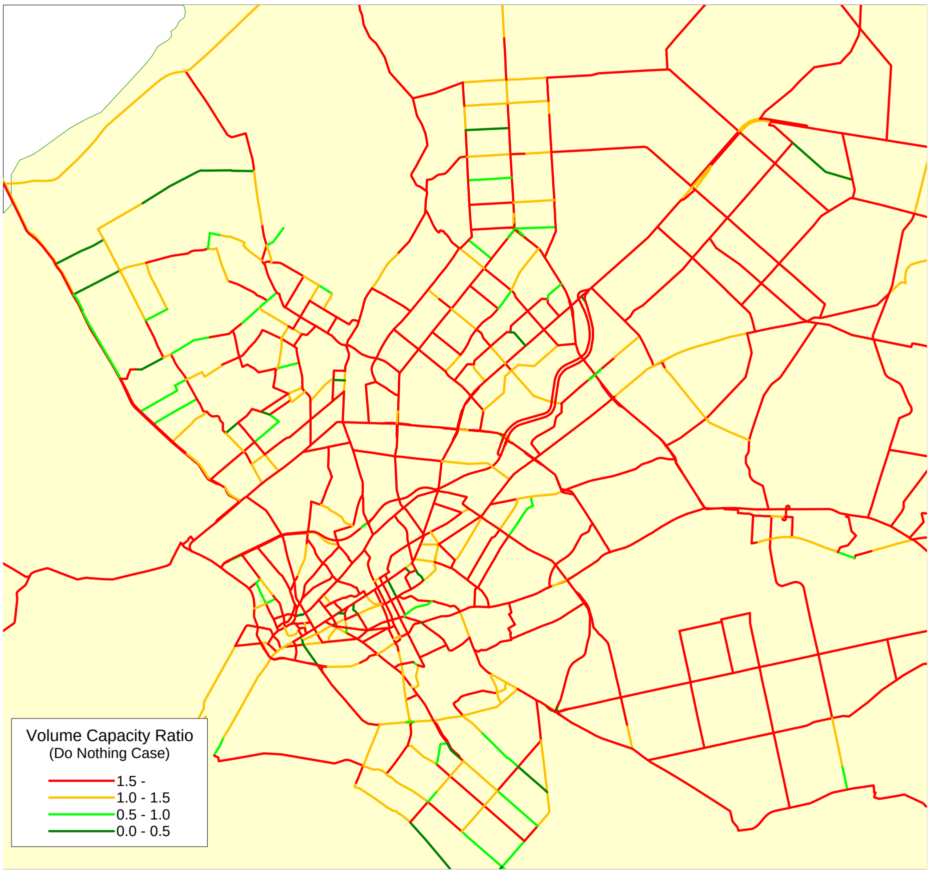
Figure 5-2-12 Volume Capacity Ratio of Full Network Case (2030)

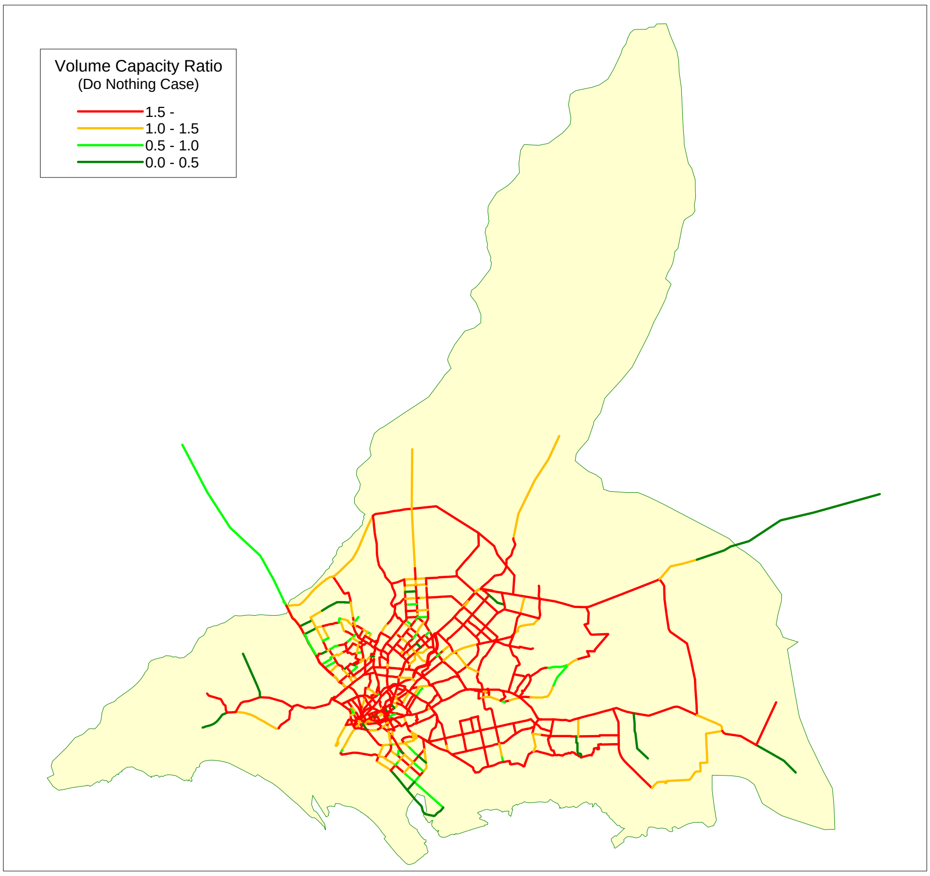




Source: Prepared by the JICA Study Team

Figure 5-2-13 Volume Capacity Ratio of Highway Developed Case (2030)





Source: Prepared by the JICA Study Team

Figure 5-2-14 Volume Capacity Ratio of Do Nothing Case (2030)