No.

Dar es Salaam City Council

The United Republic of Tanzania

Dar es Salaam

Transport Policy and System Development

Master Plan

Technical Report 7

Transport Modeling & Demand Forecast

June 2008

JAPAN INTERNATIONAL COOPERATION AGENCY

PACIFIC CONSULTANTS INTERNATIONAL

CONSTRUCTION PROJECT CONSULTANTS

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Chapter 1 Strategic Transport Model for Dar es Salaam

One of the important objectives of the strategic transport modelling is to examine proposed concepts and principles of urban land use planning such as "Urban Growth Boundary" (refer Technical Report 1) and transportation system proposals in a numerical manner. For this master plan development, the demand forecast shall be prepared for the two strategic planning horizons: the year 2015 and 2030. Based on the year 2015 demand forecast with consideration of the associated project costs, a set of short-term (urgent) projects will be prepared. Finally, a comprehensive year 2030 transport system shall be developed through testing with the year 2030 traffic demand.

1.1 Existing Transport Network

1.1.1 Existing Road Network

Figure 1.1.1 shows number of lanes for traffic simulation of existing road network in the study area. Existing road network in Dar es Salaam consists of several 4-lane arterial roads and 2-lane roads. The total length of the existing road network is about 783km.

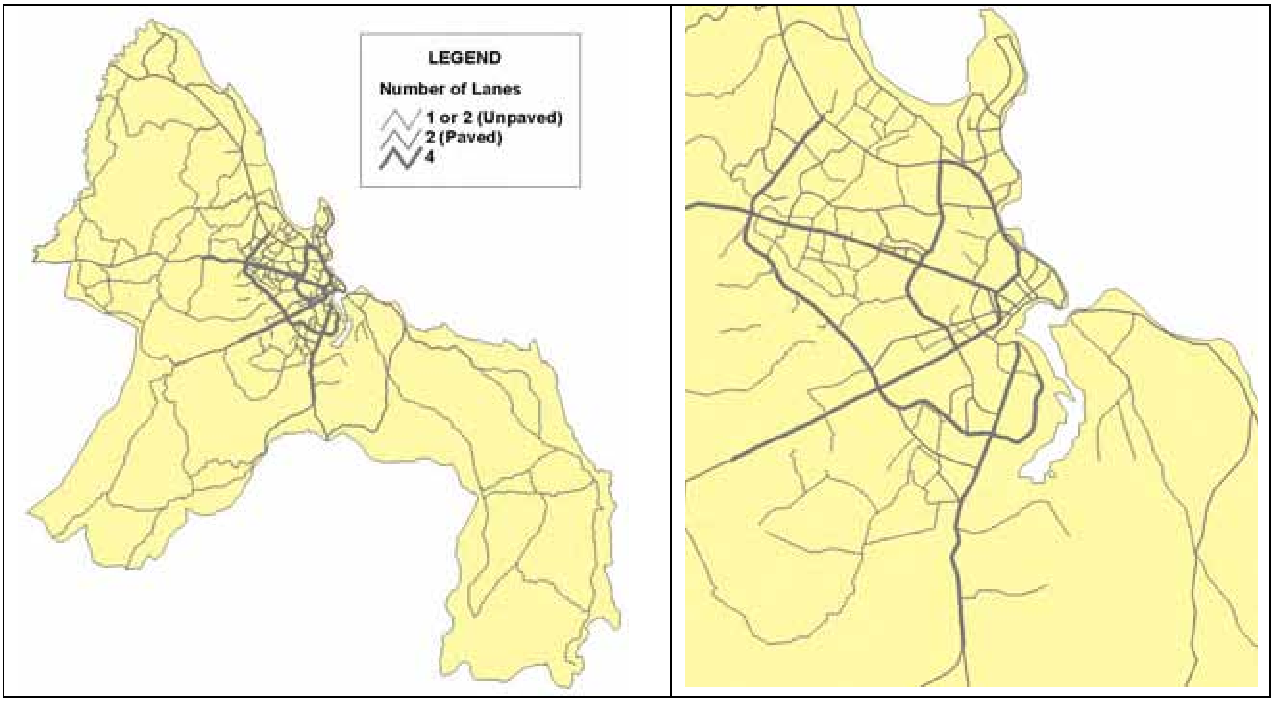


Figure 1.1.1 Existing Road Network for Traffic Simulation

1.1.2 Existing Bus Service

For the transit assignment purpose in the base-year model (2007), the existing bus (Dala dala) services including route and headway are defined as about 382 computerized lines based on the LOGIT survey in 2006.

Figure 1.1.2 shows the existing bus routes and the number of buses operated in a day. The service of existing dala dala concentrates within a radius of 10km from CBD of Dar es Salaam.

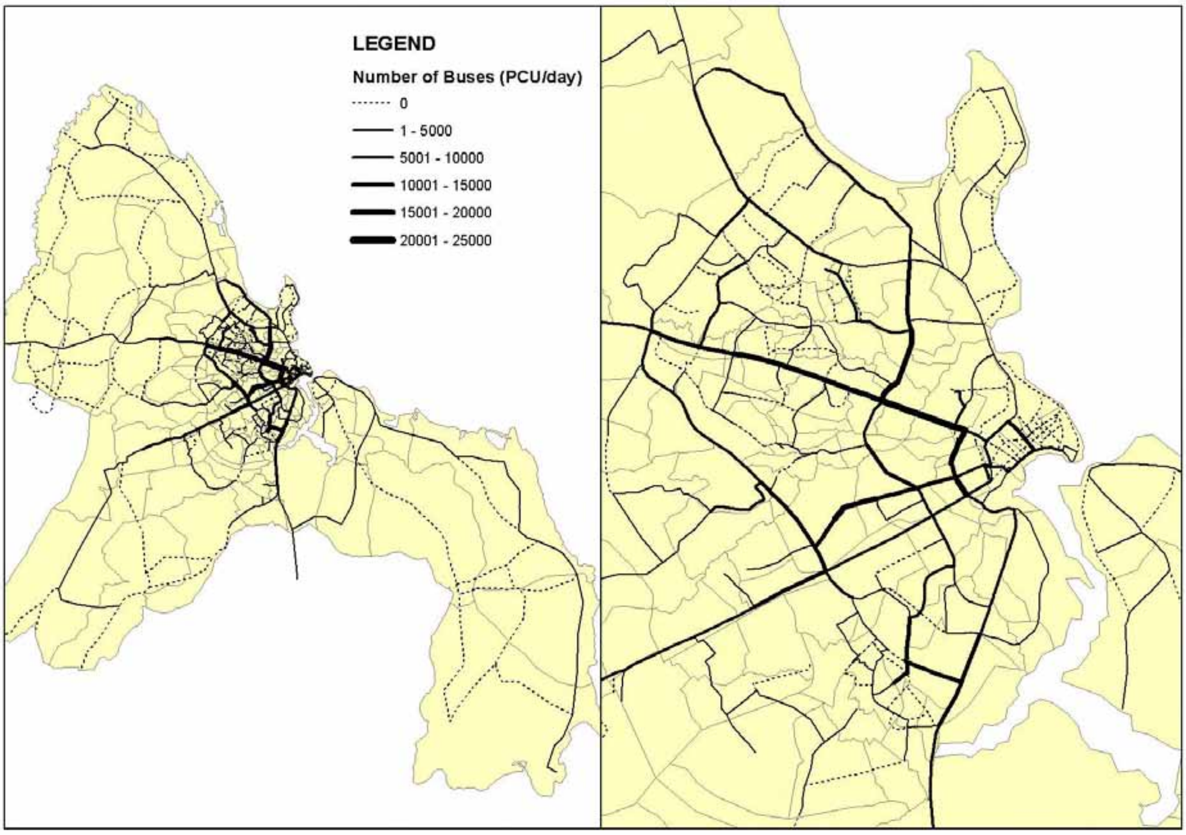


Figure 1.1.2 Estimated Existing Dala dala Operation

1.2 Traffic Analysis Zone System

1.2.1 Zone System and Attributes

A Traffic Analysis Zone (TAZ) system is defined as geographical units of traffic analysis and modeling based on sub-wards in the urban area and wards in the suburban area as shown in Figure 1.2.1. The number of TAZ is 170 zones including six external zones.

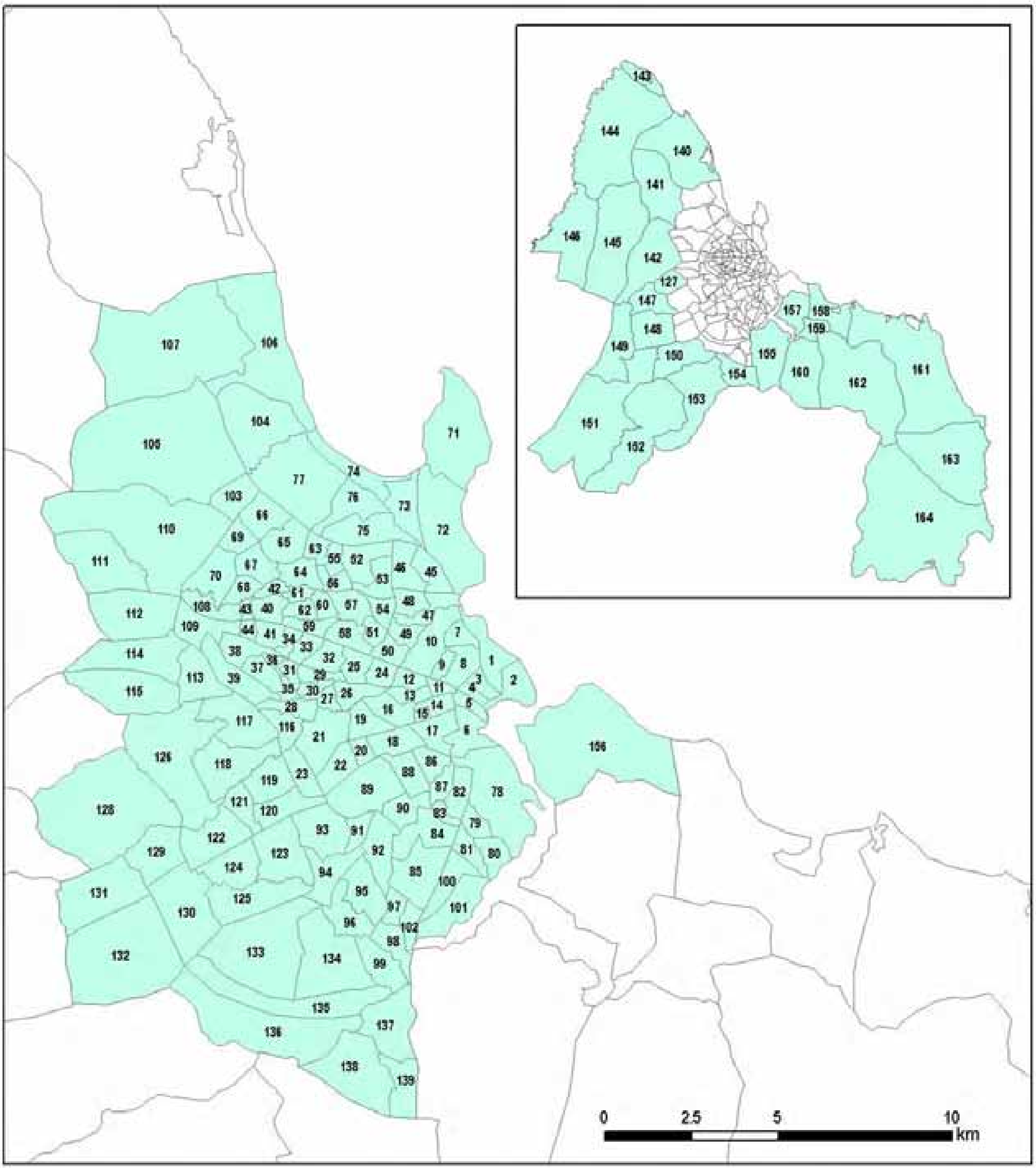


Figure 1.2.1 Traffic Analysis Zone System in Dar es Salaam

Figure 1.2.2 shows population density (left) and ratios of employees at working place over workers at residence in 2007 by TAZ. The high population density areas (TAZ) are found around Manzese ward along Morogoro Rd. and Azimio ward along Kilwa Rd. High employees-over-workers ratios are observed in CBD and surrounding areas, especially Kalia Koo and Kivukoni wards.

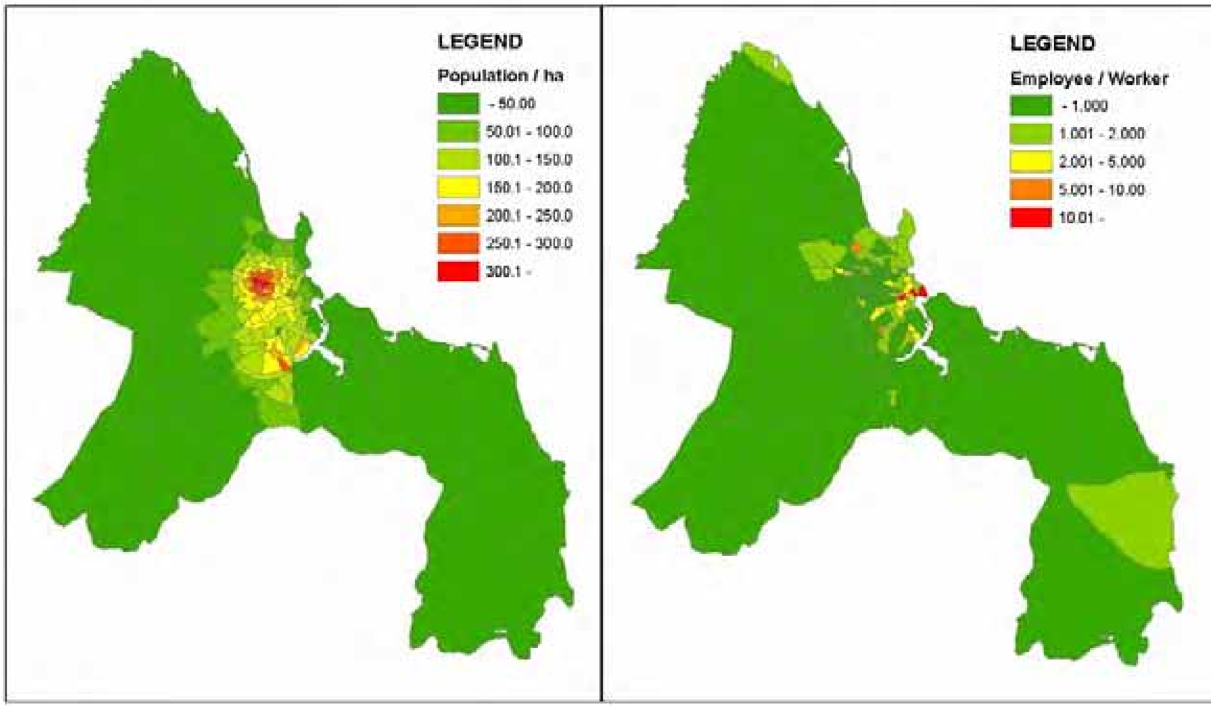


Figure 1.2.2 Population Density (Left) and Employees over Workers Ratio at Residence (Right)p

1.3 Transport Model and Parameters

1.3.1 Model Development Framework

A conventional four-step transport modeling technique is employed as shown in Figure 1.3.1, showing the framework of model building for this study.

As the first step of transport modeling, a model for forecasting the future car ownership is developed because there are significant differences between car owners and non-car owners in their travel behavior in Dar es Salaam. It is very necessary to develop modal choice models for these two groups separately. Major determinant factors to explain the future car ownership level should be economic indicators such as GDP and GDP per capita or household income.

The trip generation modeling is the first step in the four-step procedure, which are developed as function of land use and demographic variables, and gives total trip generations by TAZ.

The second step is to develop trip distribution models by trip purpose, that is, to estimate inter and intra zonal trips as function of inter-zonal impedances.

The third step is modal split. The modal split models are prepared for car owners and non-car owners separately.

The final step is traffic assignment; incremental traffic assignment technique is employed for this master plan.

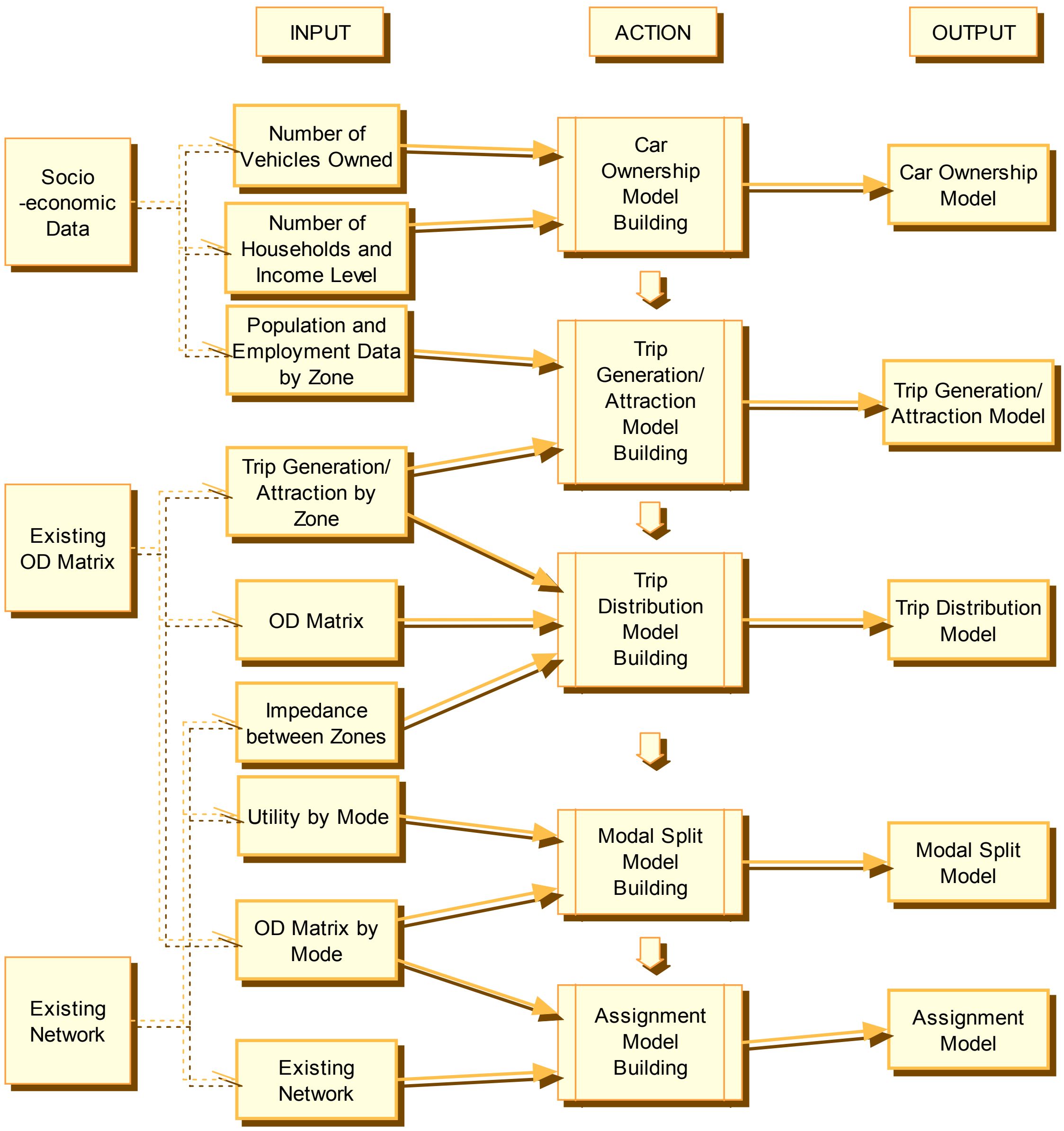


Figure 1.3.1 Transport Model Development Framework

1.3.2 Car Ownership Model

As discussed in the previous section, the future travel demand is separately forecasted for persons in the car owning household and the non-car owning household.

First a relationship between car ownership ratio and the household income levels was examined at TAZ level of detail based on HIS. A statistically significant model was developed as shown below.

$$R_{car} = \frac{0.5935}{1 + 8792 \times e^{-1.6373x}} \qquad (r^2: 0.997)$$

R_{car} : Car owning household ratio at TAZ

x : Average household income (1,000Tsh. in 2007 prices)

Figure 1.3.2 shows the relationship between household income and car owing, and Figure 1.3.3 shows the modeled car ownership household ratio by average monthly income.

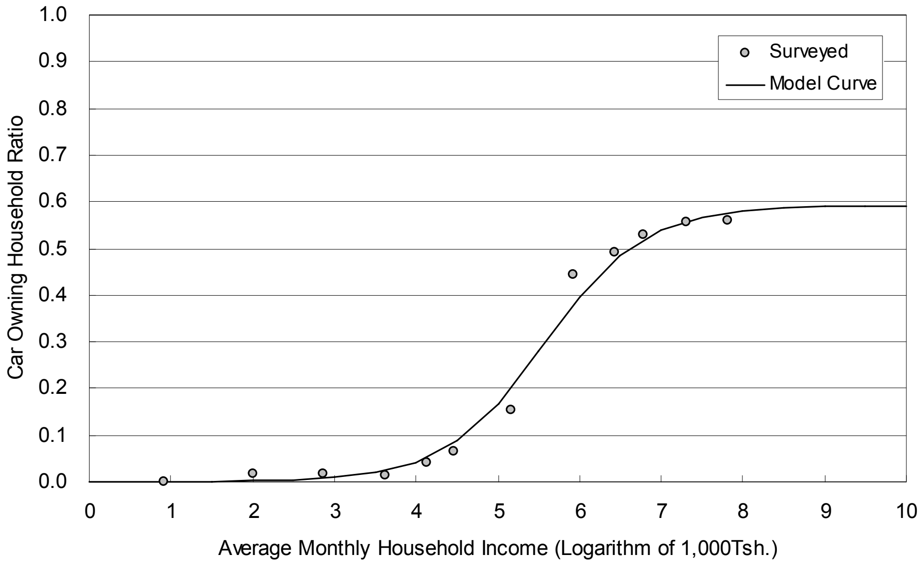


Figure 1.3.2 Relation between Income and Car Owning

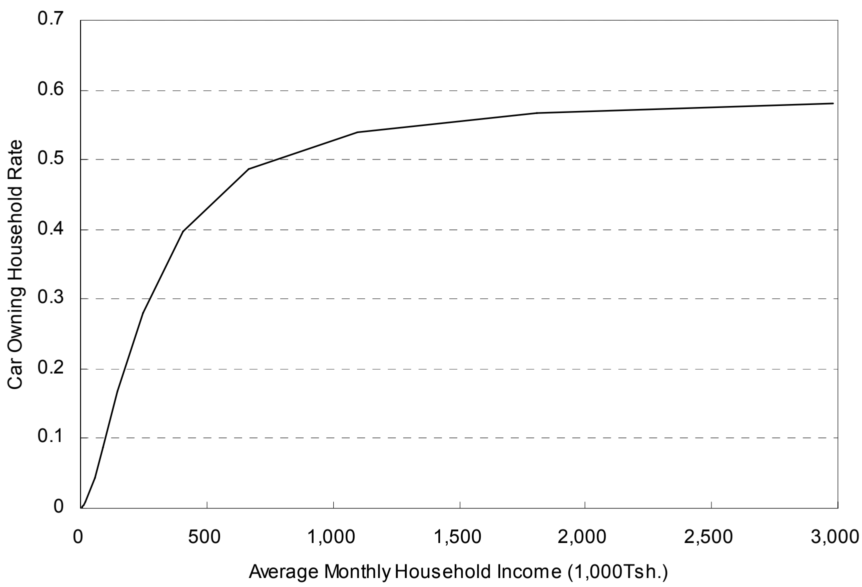


Figure 1.3.3 Car Ownership and Average Household Income

1.3.3 Trip Generation Model

Trip generation models consist of two models: namely, trip production model at origin zone and trip attraction model at destination zone. The parameters for trip generation models are estimated by the regression modeling technique by using zonal attributes such as population and the number of employees.

Table 1.3.1 and 1.3.2 show estimated model parameters by trip purpose namely non-home based to home (NHBH), home-base to work place (HBW), home-base school (HBS), home-base other purpose (HBO) and non-home base other purpose (NHBO).

Table 1.3.1 Trip Production (Left) and Attraction (Right) Model for Car Own Household

Model	Number of Sample	Variable	Results of Analysis			Model	Number of Sample	Variable	Results of Analysis		
			Coefficient	t Value	r^2				Coefficient	t Value	r^2
NHBH	164	ET3	0.212	10.594		NHBH	164	SCt	1.762	12.341	
		Dummy	20,224	16.172				WCt	1.084	9.980	
					0.886						0.960
HBW	164	WC2	1.851	6.444		HBW	119	ET3	0.203	8.707	
		WC3	1.076	23.019				Dummy	2,650	4.264	
					0.913						0.570
HBS	101	SCt	1.006	22.280		HBS	96	TT2	0.365	12.408	
								TT3	0.367	4.249	
					0.832						0.694
HBO	100	PC	0.181	18.822		HBO	100	ET3	0.079	9.507	
								Dummy	2,835	5.566	
					0.782						0.812
NHBO	103	ET3	0.035	8.349		NHBO	42	ET3	0.034	5.756	
								Dummy	639.27	1.864	
					0.613						0.768

Variables

Dummy only TAZ =2,3,14 (eastern area of CBD and K/Koo) are "1".
ET3 Number of tertiary emloyees by work place
PC Population of car own household
SCt Total number of student by resident (Car Own Household)
TT2 Number of secondaly students at school
TT3 Number of university / institute students at school
WC2 Number of secondary industrial workers at resident (Car Own Household)
WC3 Number of tertiary industrial workers at resident (Car Own Household)
WCt Number of workers at resident (Car Own Household)

Table 1.3.2 Trip Production (Left) and Attraction (Right) Model for No Car Own Household

Model	Number of Sample	Variable	Results of Analysis			Model	Number of Sample	Variable	Results of Analysis		
			Coefficient	t Value	r^2				Coefficient	t Value	r^2
NHBH	164	ET3	2.162	44.389		NHBH	164	SNt	0.959	6.148	
								WNt	1.089	9.470	
					0.924						0.968
HBW	164	WN2	1.093	4.996		HBW	164	ET3	1.039	42.037	
		WN3	0.667	19.721							
					0.958						0.916
HBS	164	SNt	0.982	41.475		HBS	164	TT1	0.886	24.726	
								TT2	1.005	14.014	
					0.913			TT3	0.479	2.764	0.926
HBO	154	PN	0.158	34.629		HBO	167	ET3	0.628	13.451	
								Dummy	9,710.626	3.333	
					0.887						0.759
NHBO	103	ET3	0.084	18.884		NHBO	101	ET3	0.082	12.808	
		Dummy	595.356	2.170				Dummy	734.643	1.884	
					0.898						0.813

Variables

Dummy only TAZ =2,3,14 (eastern area of CBD and K/Koo) are "1".
ET3 Number of tertiary emloyees by work place
PN Population of no car own household
SNt Total number of students by resident (No Car Own Household)
TT1 Number of primary students at school
TT2 Number of secondaly student at school
TT3 Number of university / institute students at school
WN2 Number of secondary industrial workers at resident (No Car Own Household)
WN3 Number of tertiary industrial workers at resident (No Car Own Household)
WNt Number of workers at resident (No Car Own Household)

1.3.4 Trip Distribution Model

Trip distribution models are estimated based on the following gravity model involving travel distance between origin and destination as zone impedance.

$$T_{ij} = K \cdot P_i^{\alpha} \cdot A_j^{\beta} \cdot D_{ij}^{\gamma} \cdot \delta^{x}$$

where, T_{ij} : Trip

P_i : Trip production in zone i.

A_j : Trip attraction in zone j.

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

$K, \alpha, \beta, \gamma, \delta$: Parameter shown in the following table

x : = 1 if production zone or attraction zone is the central area (TAZ 2, 3 and 14)

= 0 if not

Table 1.3.3 Trip Distribution Models (left: Car Own Household, right: No car Own)

Model	Number of Samples	Variable	Results of Analysis		
			Coefficient	t Value	r^2
NHBH	400	K	31.198	8.569	
		α	0.166	4.449	
		β	0.249	8.171	
		γ	-0.556	-9.668	
		δ	1.264	2.045	0.446
HBW	230	K	15.801	7.395	
		α	0.284	8.494	
		β	0.227	10.374	
		γ	-0.510	-7.076	
					0.559
HBS	138	K	114.262	8.233	
		α	0.168	3.125	
		β	0.116	2.087	
		γ	-0.515	-6.439	
					0.299
HBO	84	K	23.970	5.104	
		α	0.296	5.417	
		β	0.164	2.615	
		γ	-0.481	-4.022	
		δ	1.227	1.036	0.639
NHBO	86	K	5.015	1.852	
		α	0.404	5.470	
		β	0.327	4.438	
		γ	-0.316	-2.245	0.672

Model	Number of Samples	Variable	Results of Analysis		
			Coefficient	t Value	r^2
NHBH	1,949	K	24.774	12.346	
		α	0.202	10.986	
		β	0.223	11.505	
		γ	-0.770	-35.861	
		δ	1.582	8.418	0.521
HBW	1,034	K	25.580	10.941	
		α	0.211	9.039	
		β	0.206	8.980	
		γ	-0.686	-21.704	
		δ	1.352	4.439	0.539
HBS	516	K	274.496	15.706	
		α	0.102	3.387	
		β	0.096	3.222	
		γ	-0.734	-20.181	
					0.446
HBO	816	K	23.810	13.025	
		α	0.218	9.372	
		β	0.168	9.637	
		γ	-0.542	-17.100	
		δ	1.312	4.314	0.575
NHBO	133	K	28.426	7.428	
		α	0.176	5.341	
		β	0.186	5.519	
		γ	-0.339	-4.274	0.497

1.3.5 Modal Split Model

For car own household, two modal split models are built. Model-1 split into non-motorized trip and motorized trip, and Model-2 split motorized trip into private car and public transport namely dala dala. Figure 1.3.4 shows the model structure for car own household.

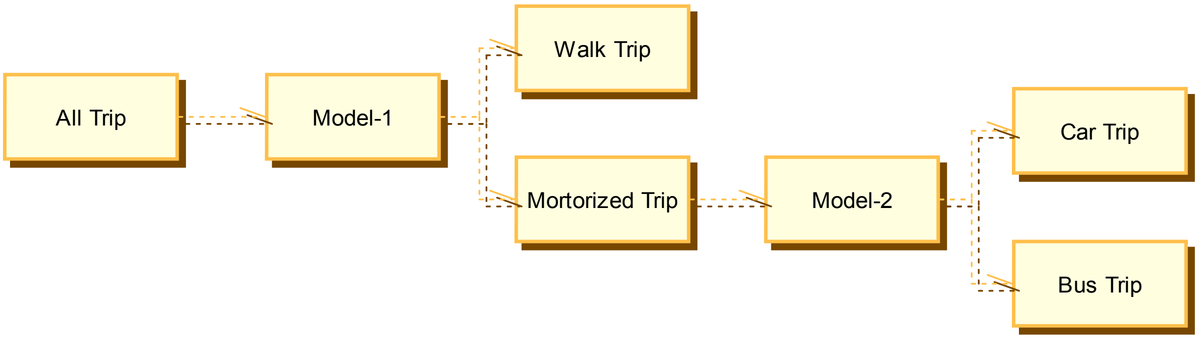


Figure 1.3.4 Modal Split Model Structure for Car Own Household

On the other side, for no car own household, Model-3 split into non-motorized trip and motorized namely dala dala as shown in Figure 1.3.5.

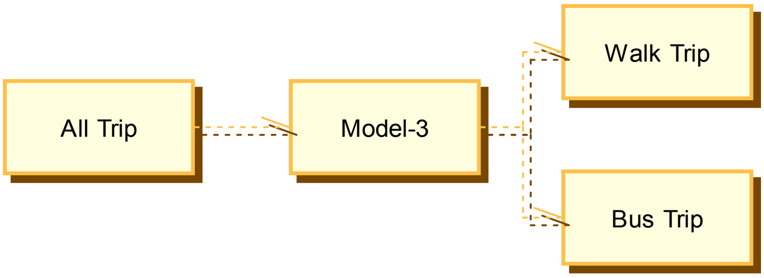


Figure 1.3.5 Modal Split Model Structure for No Car Own Household

Model-1 and Model-3 shows the probability of non-motorized mode and it is regards as share of non-motorized trip. These models were built by logistic regression as shown in following formula and Table 1.3.4 and 1.3.5.

$$y = \frac{a}{1 + b \cdot e^{(-c \cdot x)}}$$

where, y : Share of non-motorized trip

a, b, c : Parameter shown in Table 1.3.4 and 1.3.5

x : Zonal Impedance (Distance in km)

Table 1.3.4 Modal Split Model 1 Parameters (Car own household)

	A	b	c	r^2
NHBH	0.785	0.121	-1.327	0.967
HBW	0.599	0.069	-2.188	0.916
HBS	0.756	0.014	-1.696	0.593
HBO	1.189	0.658	-0.905	0.869
NHBO	-	-	-	-

Table 1.3.5 Modal Split Model-3 Parameters (No car own Household)

	A	b	c	r^2
NHBH	1.132	0.251	-0.744	0.701
HBW	0.871	0.098	-1.139	0.501
HBS	6.529	5.509	-0.264	0.875
HBO	0.891	0.077	-1.306	0.967
NHBO	-	-	-	-

Model-2 is applied to divide private car use and public transport use of car own household. This model was built by logistic regression as shown in following formula and Table 1.3.6 and 1.3.7.

$$y = \frac{1}{1 + e^{-\alpha \cdot (TimeC - TimeB) - \beta \cdot CostC + \gamma \cdot CostB + \delta}}$$

where, y : Share of private car use

$\alpha, \beta, \gamma, \delta$: Parameter shown in Table 1.3.6 and 1.3.7

$TimeC$: Entire travel time of private car

$TimeB$: Entire travel time of bus

$CostC$: Estimated travel cost of private car based on the travel distance

$CostB$: Bus fare in Tsh

Table 1.3.6 Modal Split Model-2 Parameters

Model	variables	Coefficient	t-value	ρ^2	Hit Ratio 1 (%)	Hit Ratio 2 (%)
NHBH	α	-0.0011	-0.260			
	β	-0.0001	-0.781			
	γ	-0.0027	-6.543			
	δ	-0.2801		0.189	75.28	62.86
HBW	α	-0.0351	-3.575			
	β	-0.0003	-1.622			
	γ	-0.0030	-4.492			
	δ	-0.0772		0.414	86.8	75.9
HBS	α	-0.0101	-0.336			
	β	-0.0005	-0.940			
	γ	-0.0012	-1.158			
	δ	-0.5204		-0.023	65.7	51.7
OTHERS (HBO, NHBO)	α	0.0082	1.190			
	β	-0.0003	-1.280			
	γ	-0.0031	-3.870			
	δ	-0.4819		0.085	69.23	57.07

1.3.6 Assignment Model

For the traffic assignment on road network, traditional incremental assignment module in JICA STRADA is adopted. The incremental assignment divides O-D traffic demand data into appropriate increments and assigns each increment to the minimum route wherein the generalized cost in the least.

Figure 1.3.6 shows the results of traffic assignment and volume capacity ratio in 2007. Assigned traffic volume in O-D matrices are estimated and calibrated by HIS and screen line traffic count survey . Heavy traffic volumes are observed at Ali Hassan Mwinyi Rd., Morogoro Rd. and Nyerere Rd. however, considerable traffic congestion are observed at Bagamoyo Rd., Uhuru St. and Morogoro Rd. in suburbs. Figure 1.3.7 shows the daily total traffic volume in pcu of results of traffic assignment and actual traffic count at screen line. The assigned traffic volume is slightly overestimated than actual results.

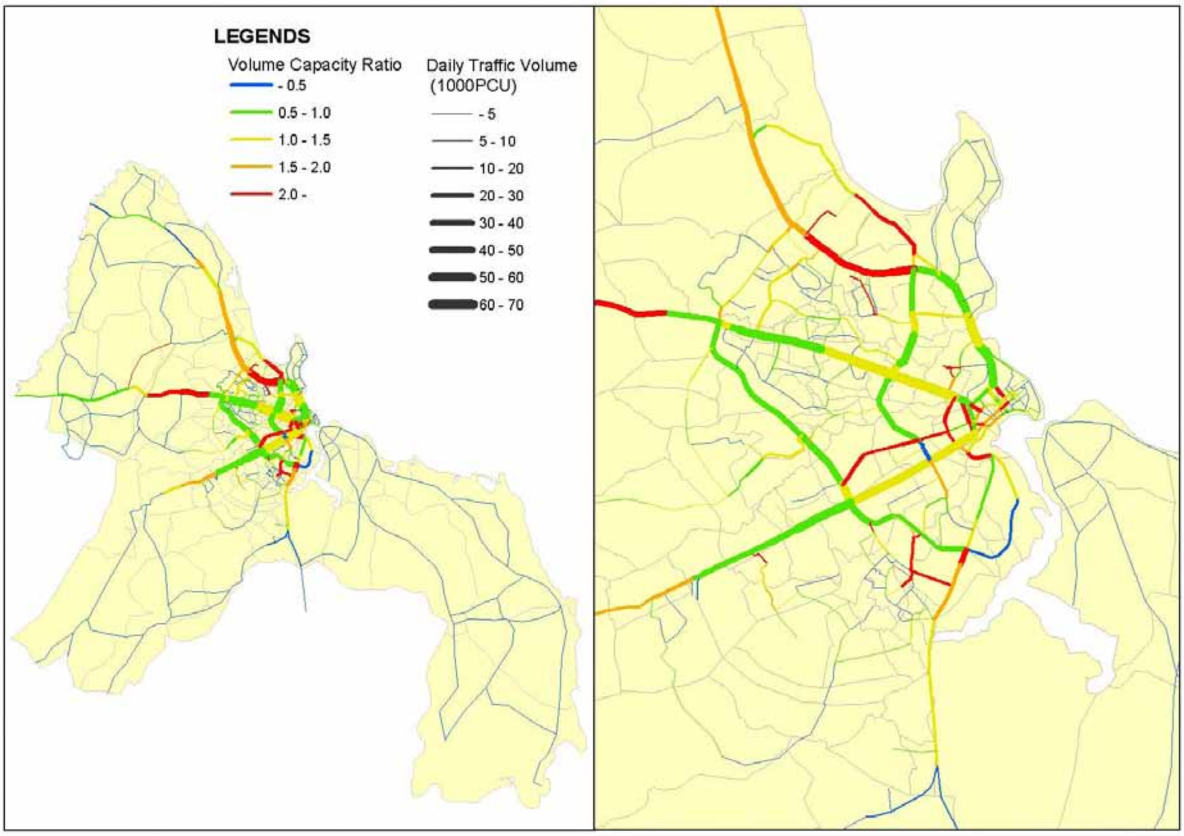
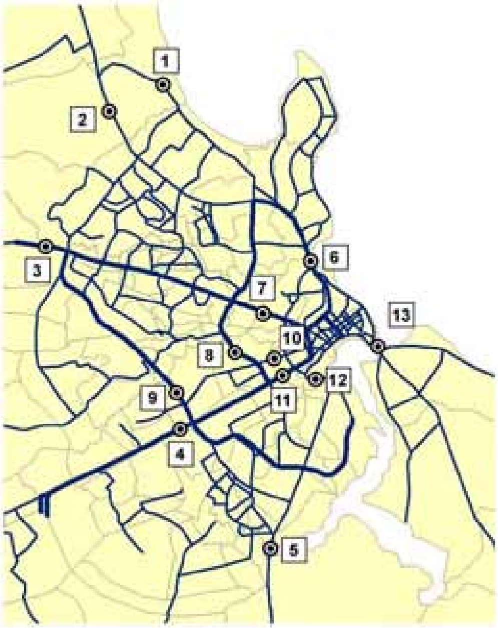


Figure 1.3.6 Assigned Traffic Volume in 2007



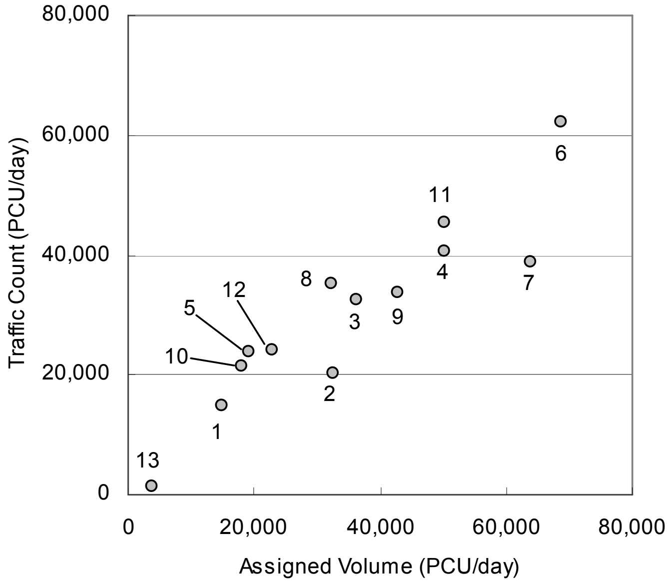


Figure 1.3.7 Comparison between Traffic Count and Traffic Assignment at Screen Line

1.4 Future Transport Network and Scenario

1.4.1 Future Zonal Attributes

For the appropriate and sustainable growth of Dal es Salaam, distribution of residence and civic function should be considered. For that purpose, a concept of Urban Growth Boundary (UGB) and Compact Corridor Development are proposed in this study and future zonal attributes involving these concepts are defined as with UBG case. On the other hand, future trend case based on the 2007 zonal attributes is defined for the comparison with UGB case. Figure 1.4.1 to 1.4.3 show defined future population density and the ratio of number of employees at working place to number of workers at residence.

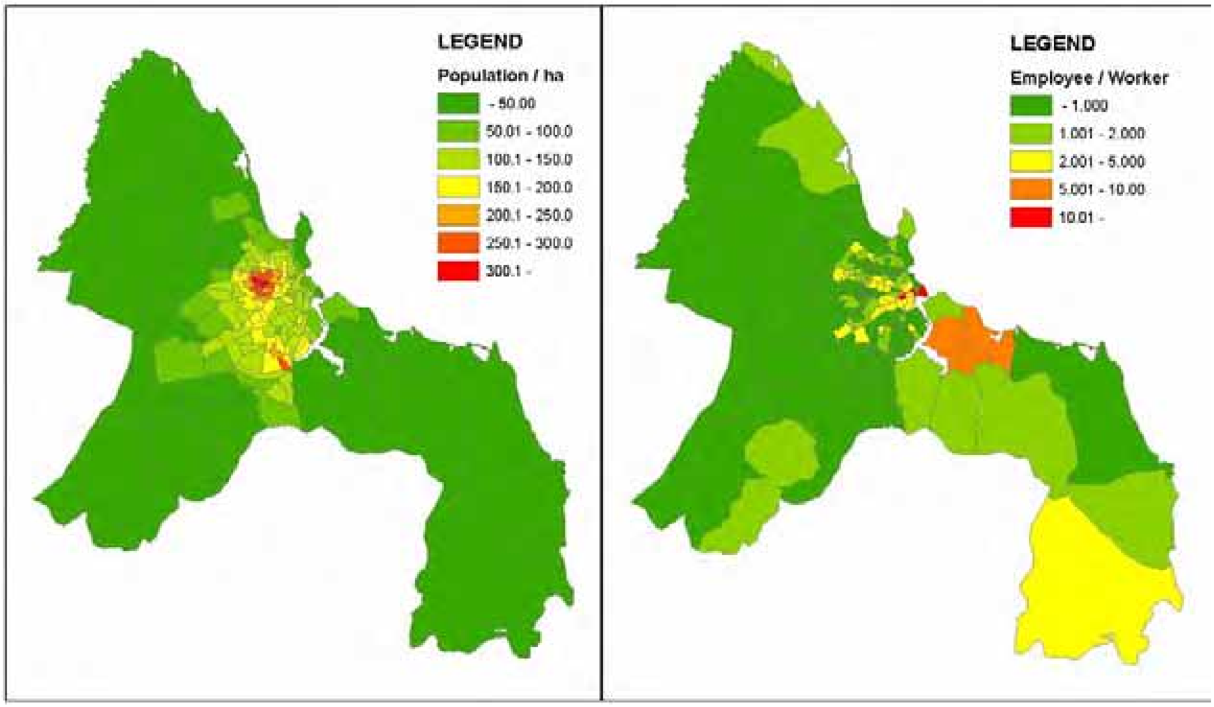


Figure 1.4.1 Population Density (Left) and Ratio of Employees at Working Place to Worker at Residence (Right) in 2015

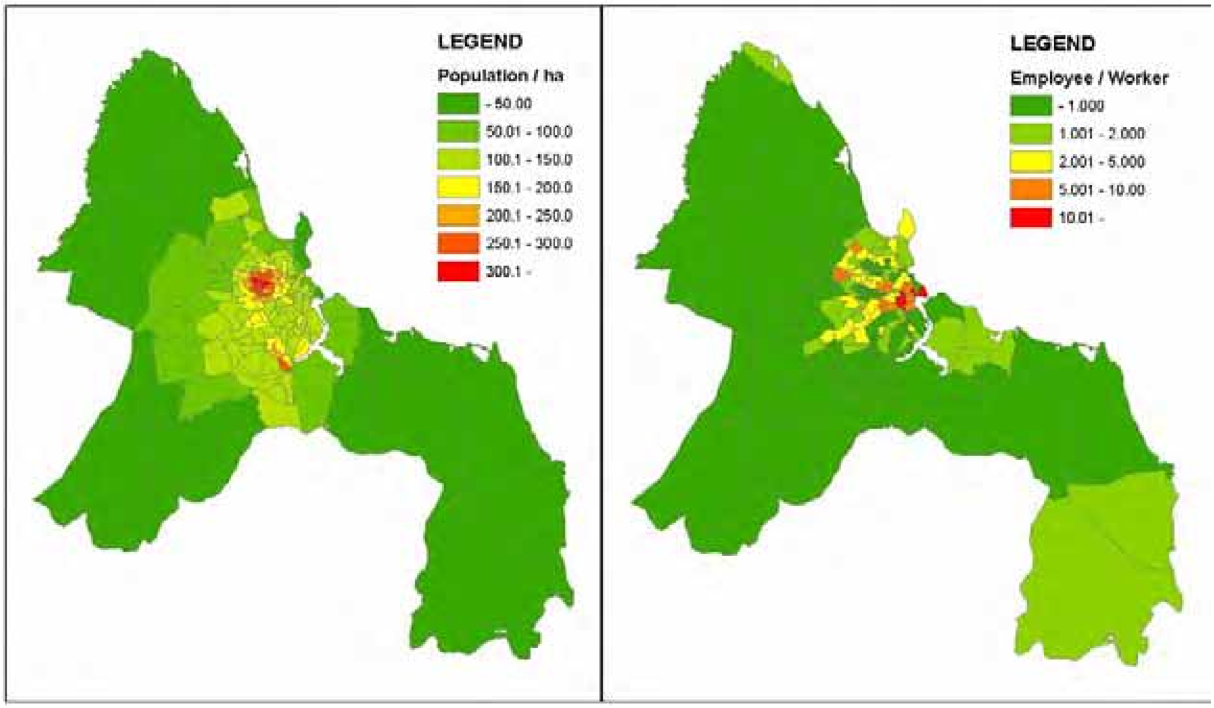


Figure 1.4.2 Population Density (Left) and Ratio of Employees at Working Place to Worker at Residence (Right) in 2030 Trend Case

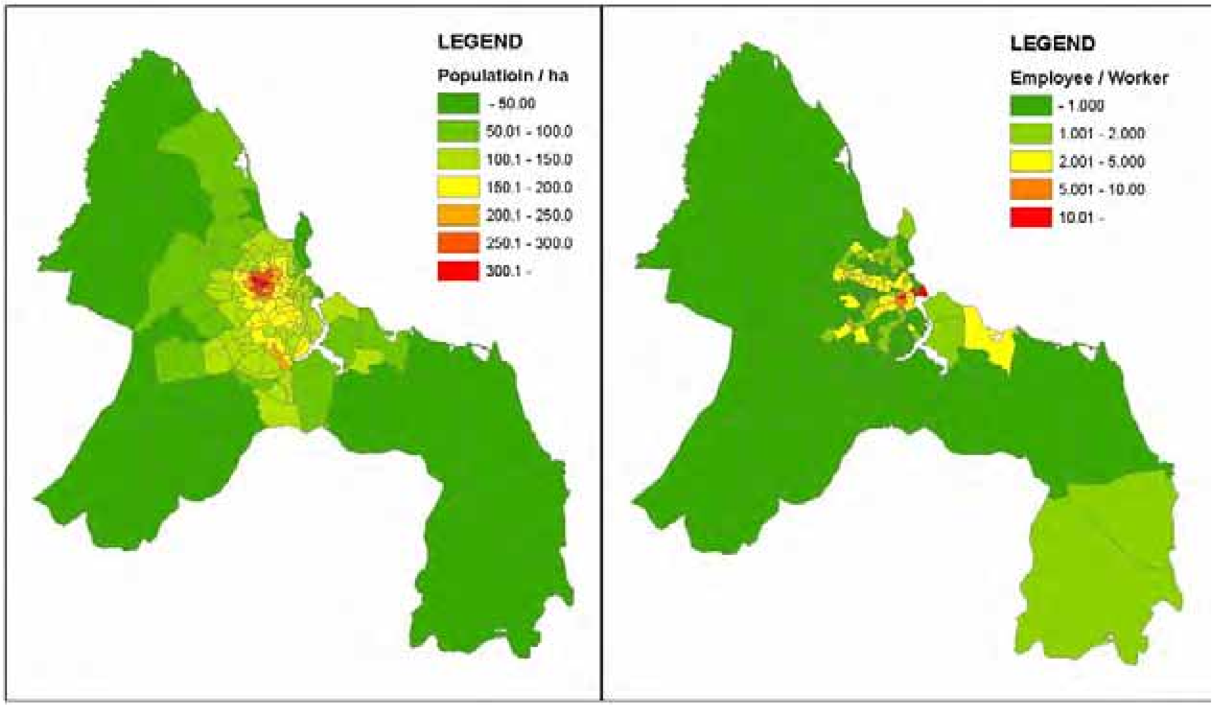


Figure 1.4.3 Population Density (Left) and Ratio of Employees at Working Place to Worker at Residence (Right) in 2030 with UGB

1.4.2 Future Road Network

Figure 1.4.4 shows future road network in 2030 full network case including BRT lanes proposed by the study team. The total length of expansion of existing road is about 240 km and additional new road including expressway is about 346 km.

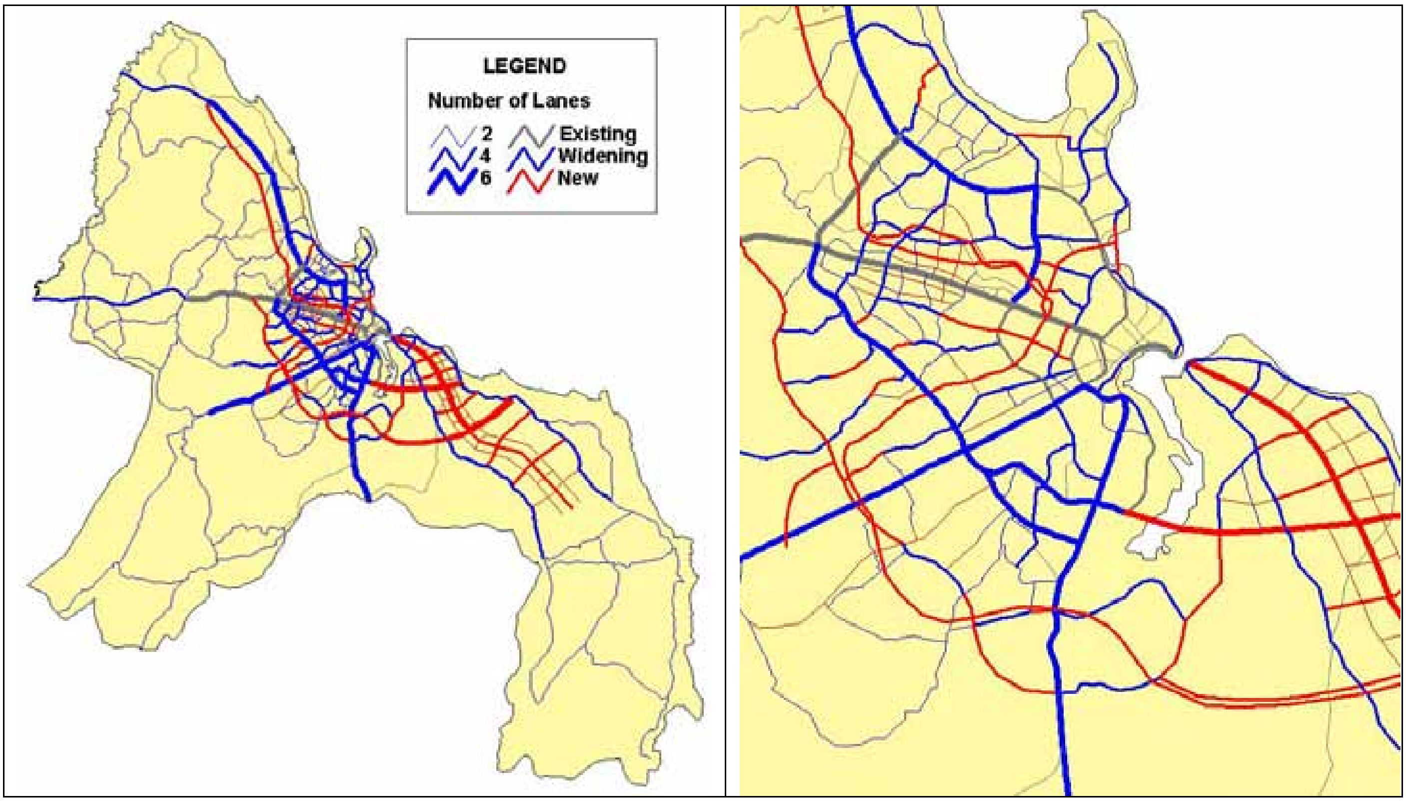


Figure 1.4.4 Proposed Future Road Network in Dar es Salaam (2030 Full Network)

Based on the 2030 full network, road network for 2015 is built by reducing several links and expressway. Figure 1.4.5 shows proposed road network in 2015.

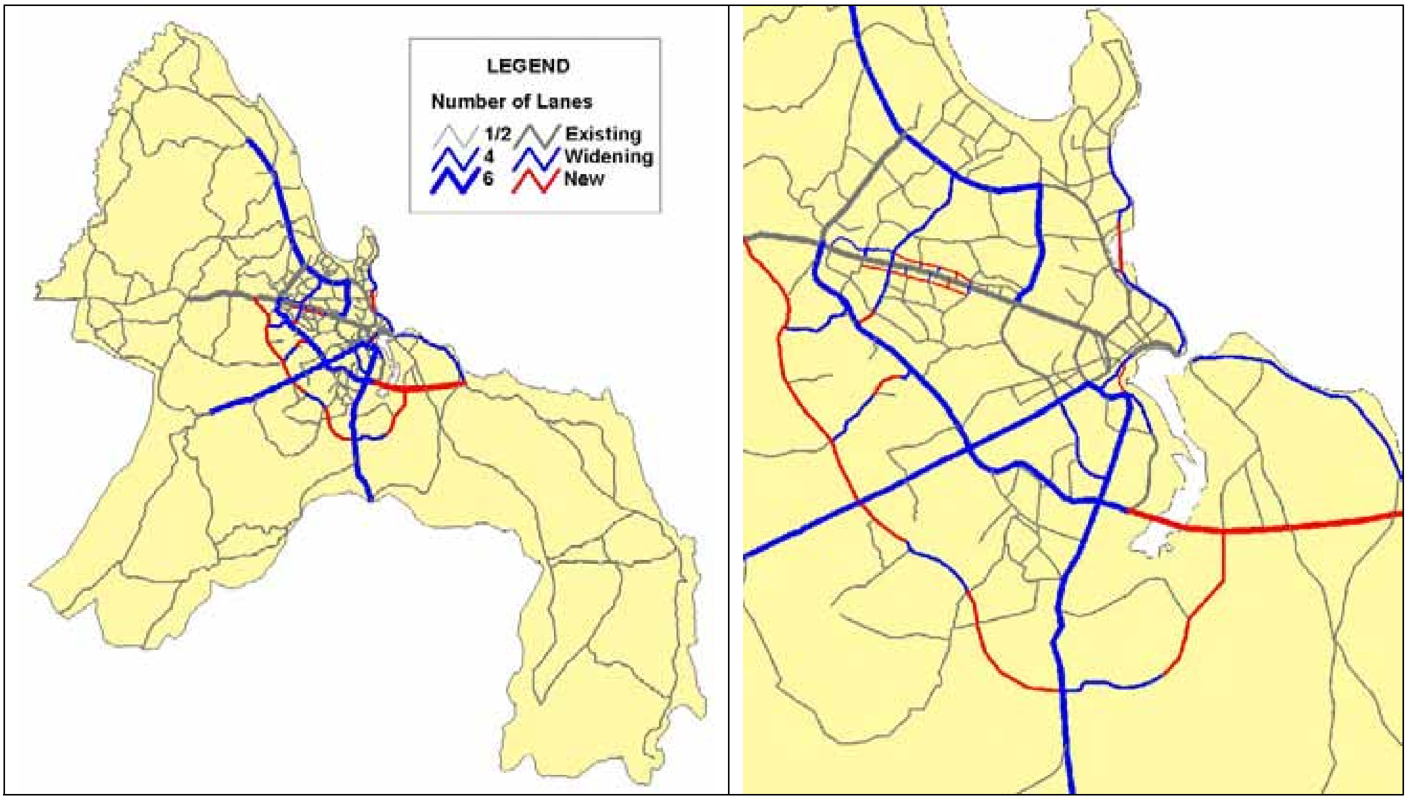


Figure 1.4.5 Proposed Future Road Network in Dar es Salaam (2015)

1.4.3 Future Public Transport Service

Future public transport service is proposed by study team as mentioned in Technical Report 2 which includes 17 BRT lines and 18 secondary buses as shown in Figure 1.4.6. Proposed public transport network is planned to complete and start its service from 2015.

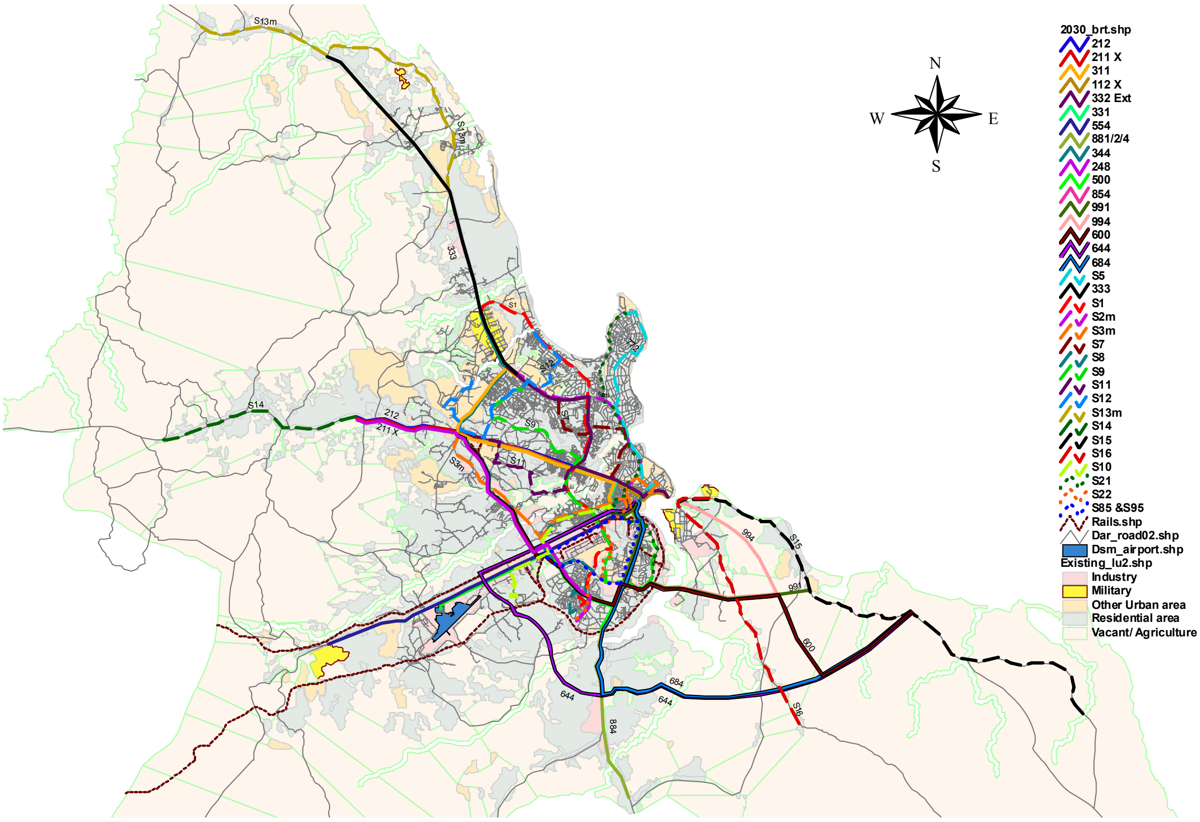


Figure 1.4.6 Future Bus Service in 2030

1.4.4 Demand Forecast Scenario

Table 1.4.1 shows simulation cases for future demand forecast.

Table 1.4.1 Simulation Cases

Year	Demand	Road Network	Transit Network	Notes
2007	HIS based 2007 demand	Existing Road Network	Existing Transit Network	2007 Existing Case
2015	2015 with UGB demand	Existing Road Network	Existing Transit Network	2015 Without Case
	2015 with UGB demand	2015 Road Network	2015 Transit Network	2015 Base Case
2030	2030 without UGB	Existing Road Network	Existing Transit Network	2030 Without Case
	2030 with UGB demand	2030 Full Network	2030 Transit Network	2030 Base Case
	2030 with UGB demand	2030 Without Expressway	2030 Transit Network	2030 Without Expressway

1.5 Demand Forecast

1.5.1 Future Trip Generation

Based on the results of household interview survey, gross trip rates by purpose and car ownership are estimated as shown in Table 1.5.1. The trip rate of car ownership household member is larger than no car own household member.

Table 1.5.1 Gross Trip Rate

Existing (2007)		Population ('000)	Trip Generation ('000)					
			NHBH	HBW	HBS	HBO	NHBO	Total
HIS	Car Own Household	324	250	115	85	45	19	514
	No Car Own Household	2,706	1,551	596	615	365	50	3,176
	Total	3,030	1,800	711	701	410	69	3,690
Gross Trip Rate	Car Own Household		0.77	0.36	0.26	0.14	0.06	1.59
	No Car Own Household		0.57	0.22	0.23	0.14	0.02	1.17
	Total		0.59	0.24	0.23	0.14	0.02	1.22

Future trip generation is calculated by estimated future population and gross trip rate by car ownership and trip purpose respectively as shown in Table 1.5.2. Based on the future trip generation as a control total, trip production and attraction by TAZ are estimated by trip generation model and adjusted by frater method. Figure 1.5.1 shows the estimated future trip production of all purposes and Figure 1.5.2 shows the estimated trip production and attraction of home to work place by TAZ. A tendency on future trip generation is alleviation of concentration of trip generation by population dispersion.

Table 1.5.2 Estimated Future Trip Generation

Future Control Total		Population ('000)	Trip Generation ('000)					
			NHBH	HBW	HBS	HBO	NHBO	Total
2015	Car Own Household	634	488	226	167	87	37	1,005
	No Car Own Household	3,366	1,929	741	764	454	61	3,949
	Total	4,000	2,417	966	931	542	98	4,954
2030 with UGB	Car Own Household	1,918	1,477	683	504	265	113	3,042
	No Car Own Household	3,882	2,224	854	881	524	70	4,554
	Total	5,800	3,701	1,537	1,386	789	183	7,595
2030 without UGB	Car Own Household	1,927	1,483	686	507	266	114	3,056
	No Car Own Household	3,873	2,219	852	879	523	70	4,543
	Total	5,800	3,703	1,538	1,386	789	183	7,599

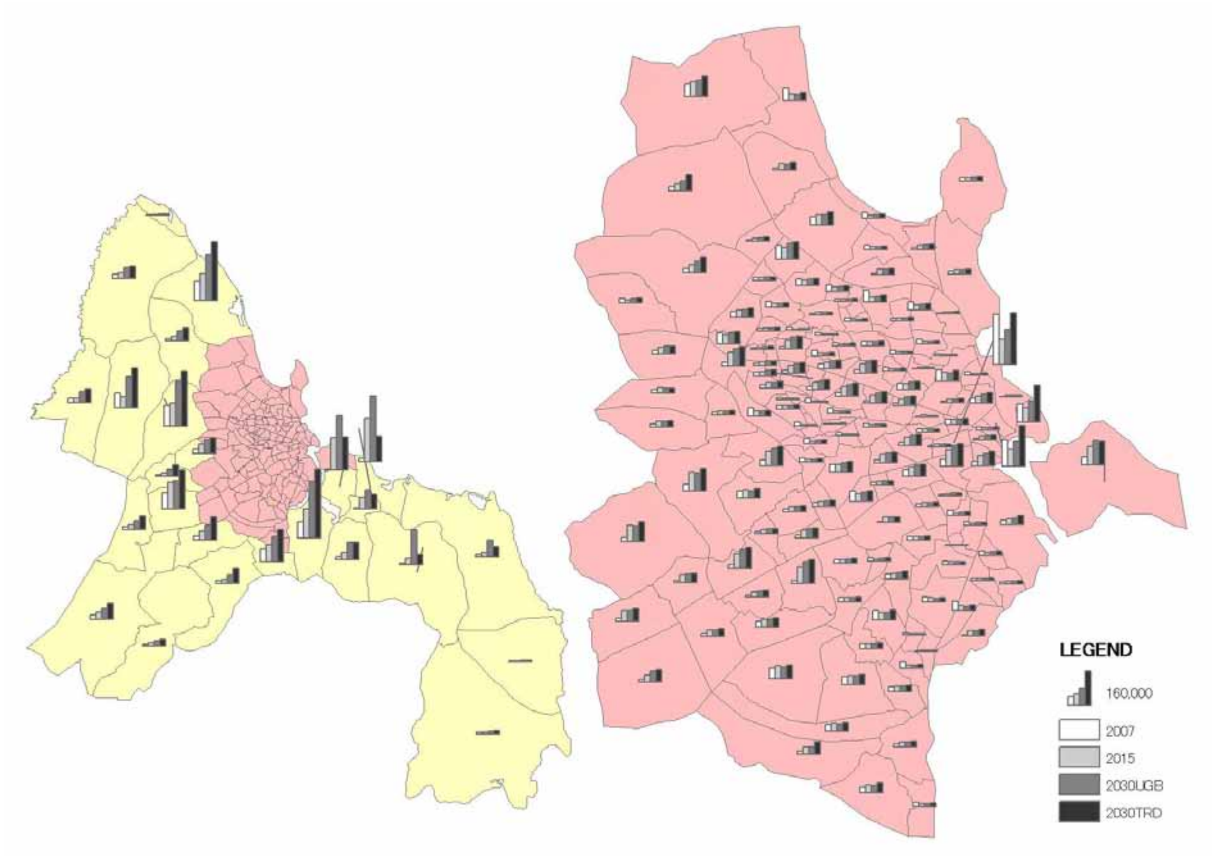


Figure 1.5.1 Trip Production by TAZ (All purposes)

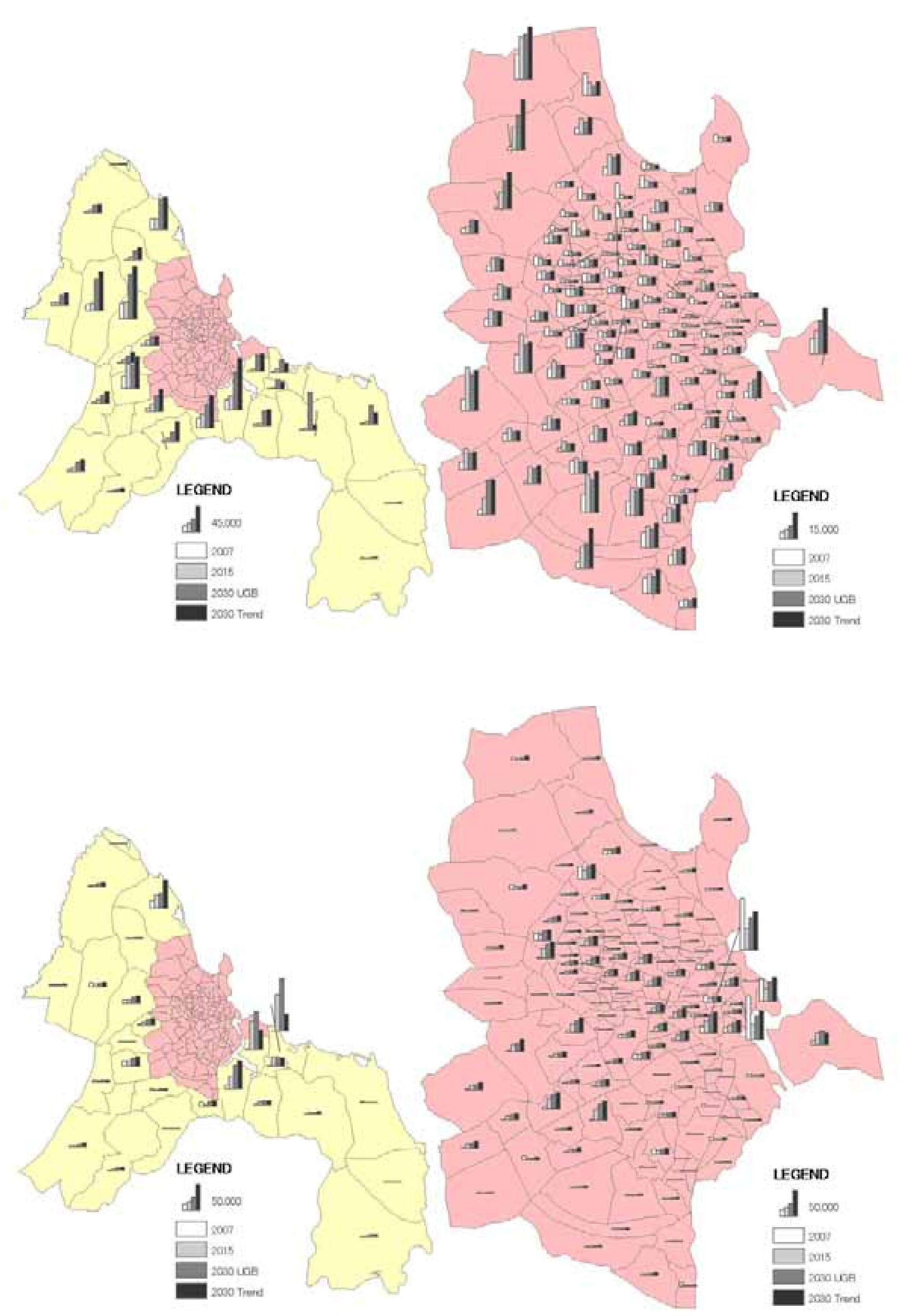


Figure 1.5.2 Trip Production (upper) and Attraction (lower) of Home to Work Place Purpose

1.5.2 Future Trip Distribution

Based on the trip distribution model, person trip O-D matrices are built by car ownership and trip purposes. Figure 1.5.3 and 1.5.4 show current (2007) and forecasted future trip distribution by desire line.

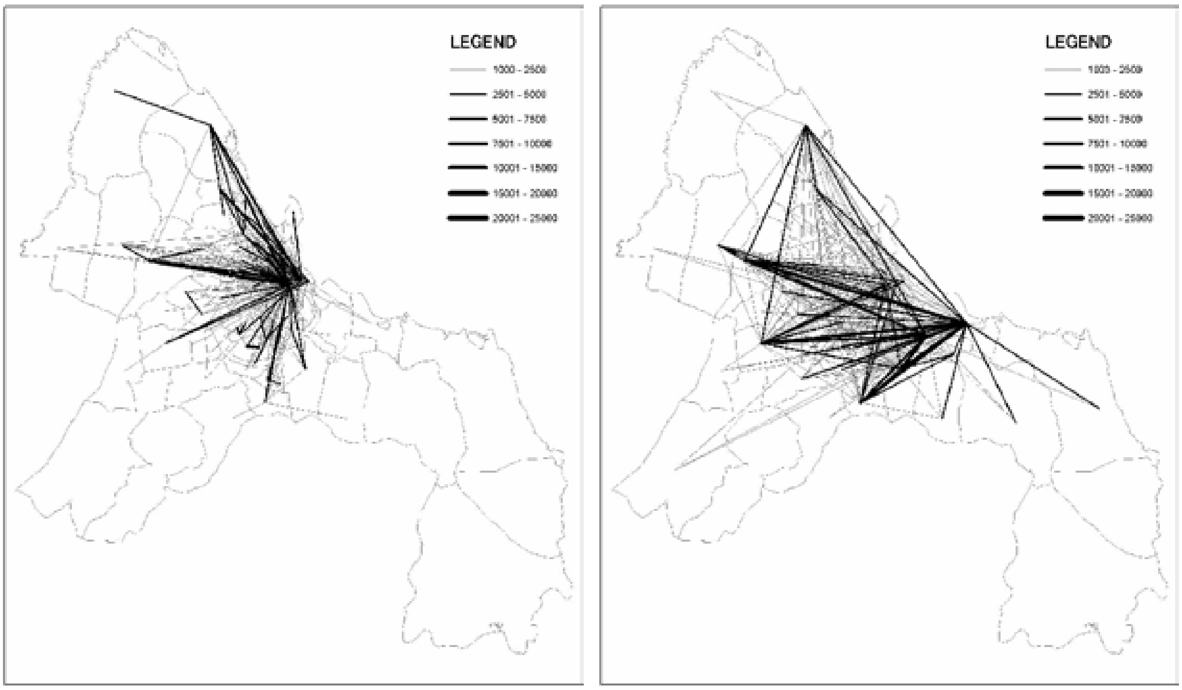


Figure 1.5.3 Desire Line of All Purpose (left: 2007, right:2015)

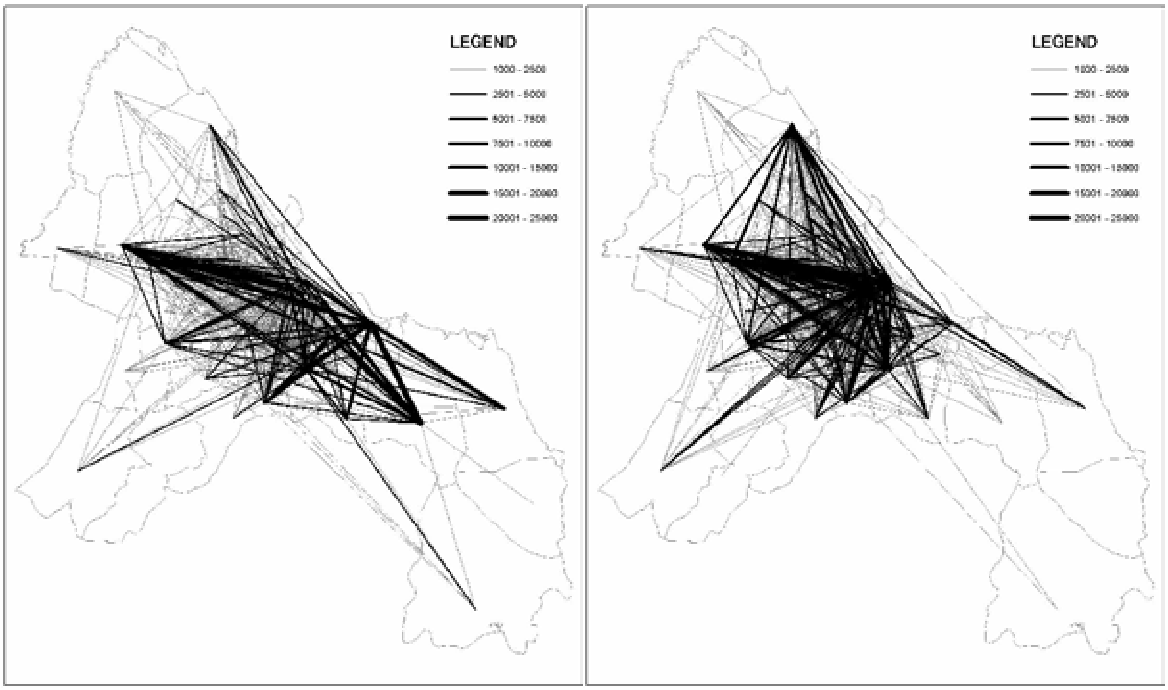


Figure 1.5.4 Desire Line of All Purpose (left: 2030 with UGB, right:2030 Trend Case)

1.5.3 Future Modal Share

Future O-D matrices by mode are estimated by applying modal split models. Figure 1.5.5 and 1.5.6 show the current (2007) and forecasted future person trip by mode and modal share respectively. It is expected that the share of private car increase to 25 - 28% in 2030 from 7% in 2007, however, public transport such as BRT and other buses will be still major transportation in Dar es Salaam in future.

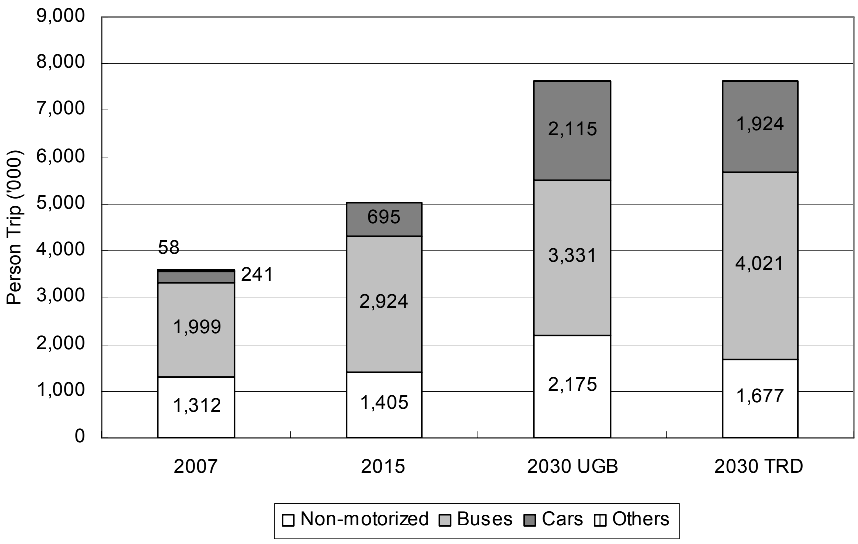


Figure 1.5.5 Current and Estimated Future Person Trip by Mode

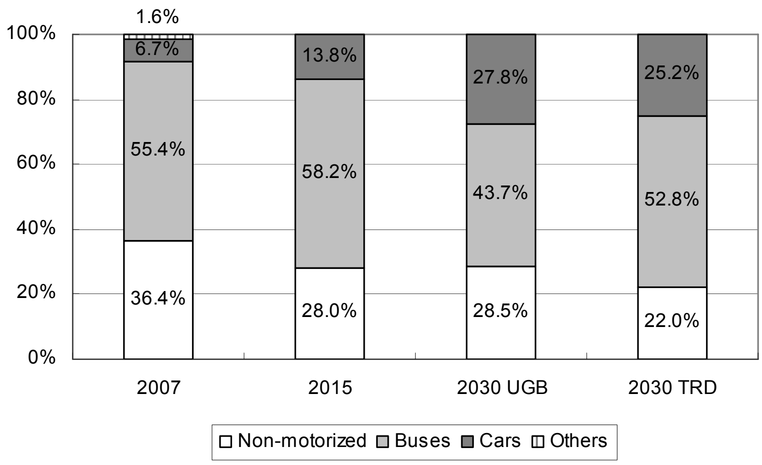


Figure 1.5.6 Current and Estimated Future Modal Share

1.5.4 External Trips and Heavy Vehicle

Future external trip concerning passenger car and bus passenger is estimated by expanding of existing external trip assumed by the results of cordon line survey. A expansion factor for external trip is population growth rate in Dar es Salaam from 2007.

Future heavy vehicle demand consists of 2 or 3 axles truck and trailer is also estimated by present pattern and expansion factor except Dar es Salaam Sea Port. Present heavy vehicle O-D is estimated by cargo survey, cordon line survey and screen line survey. Expansion factor for heavy vehicle is GDP growth rate in Tanzania namely 5.5% annual. According to the "Brief on Dar es Salaam Port (Tanzania Port Authority, Jan 2007)", the volume of handling container in 2006 almost exceed the capacity of existing container terminal. On the assumption that container cargo is carried by trailer, future trailer demand relevant to Sea Port is not increase. On the other hand, other general cargo volume is almost 61% of capacity in 2006. Future truck volume relevant to Sea Port is increase by 5.5% annual until future general cargo volume exceeds the capacity of Sea Port.

1.5.5 Results of Traffic Assignment

Table 1.5.3 shows the summary of traffic assignment by case. In 2007 existing case, average volume capacity ratio (VCR) is 0.66 and average travel speed is 25.6 km/h. Proposed road network in 2015 and 2030 base cases enable to maintain current condition.

Table 1.5.3 Summary of Traffic Assignment

	Travel Distance (PCU*km)	Travel Time (PCU*hr)	Capacity*Length (PCU*km)	Road Length (km)	Ave. VCR	Ave. Travel Speed (km/h)
2007 Existing Case	4,790,442	187,005	7,305,131	783	0.66	25.6
2015 Without Case	10,054,140	647,281	7,305,131	783	1.38	15.5
2015 Base Case	8,008,715	263,979	12,485,079	959	0.64	30.3
2030 Without Case	23,688,605	2,379,228	7,305,131	783	3.24	10
2030 Base Case	22,012,455	871,949	24,741,882	1,215	0.89	25.2
2030 Without Expressway	20,951,285	1,007,062	20,262,879	1,142	1.03	20.8

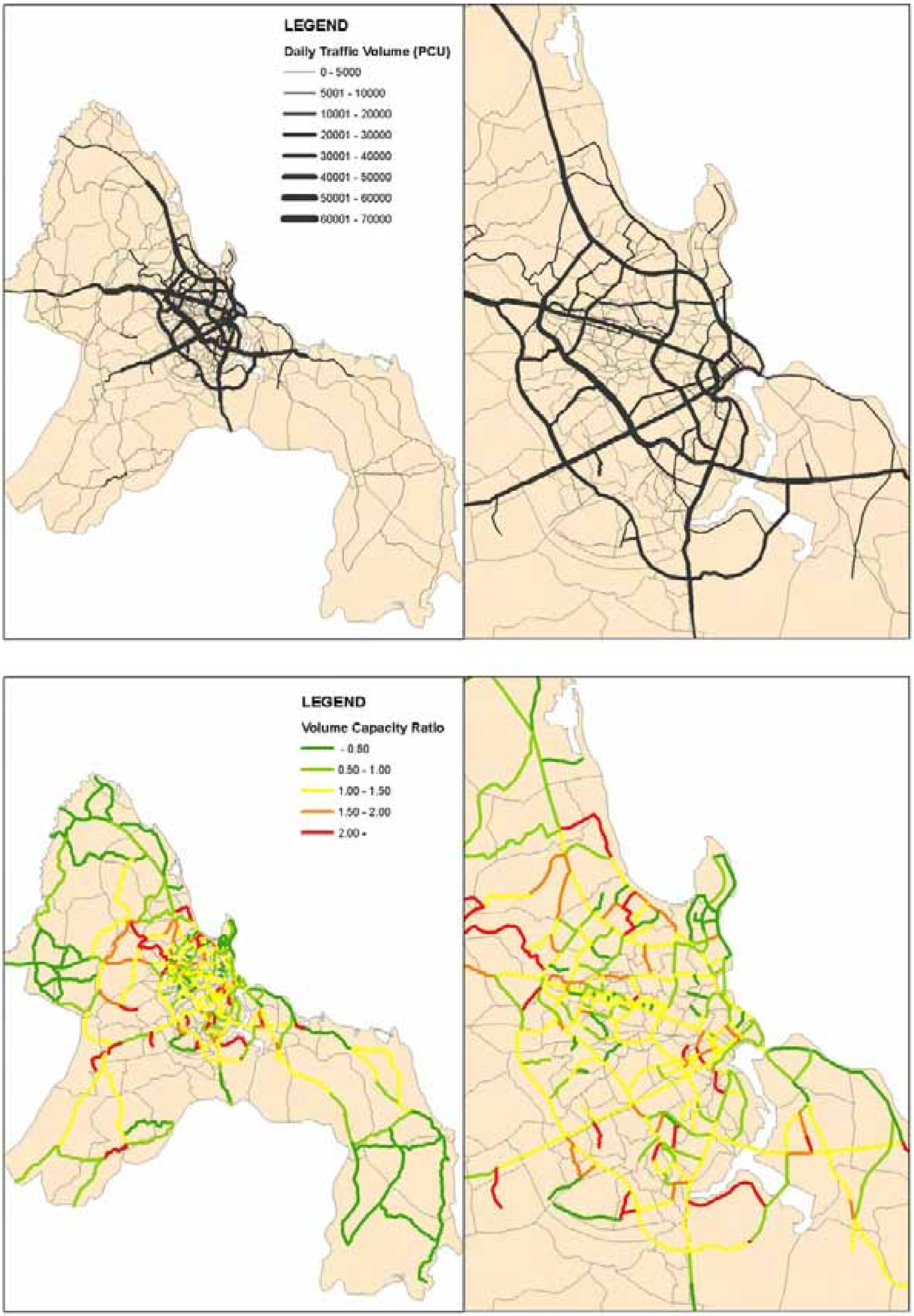


Figure 1.5.7 Future Traffic Demand and Volume Capacity Ratio in 2015 Base Case

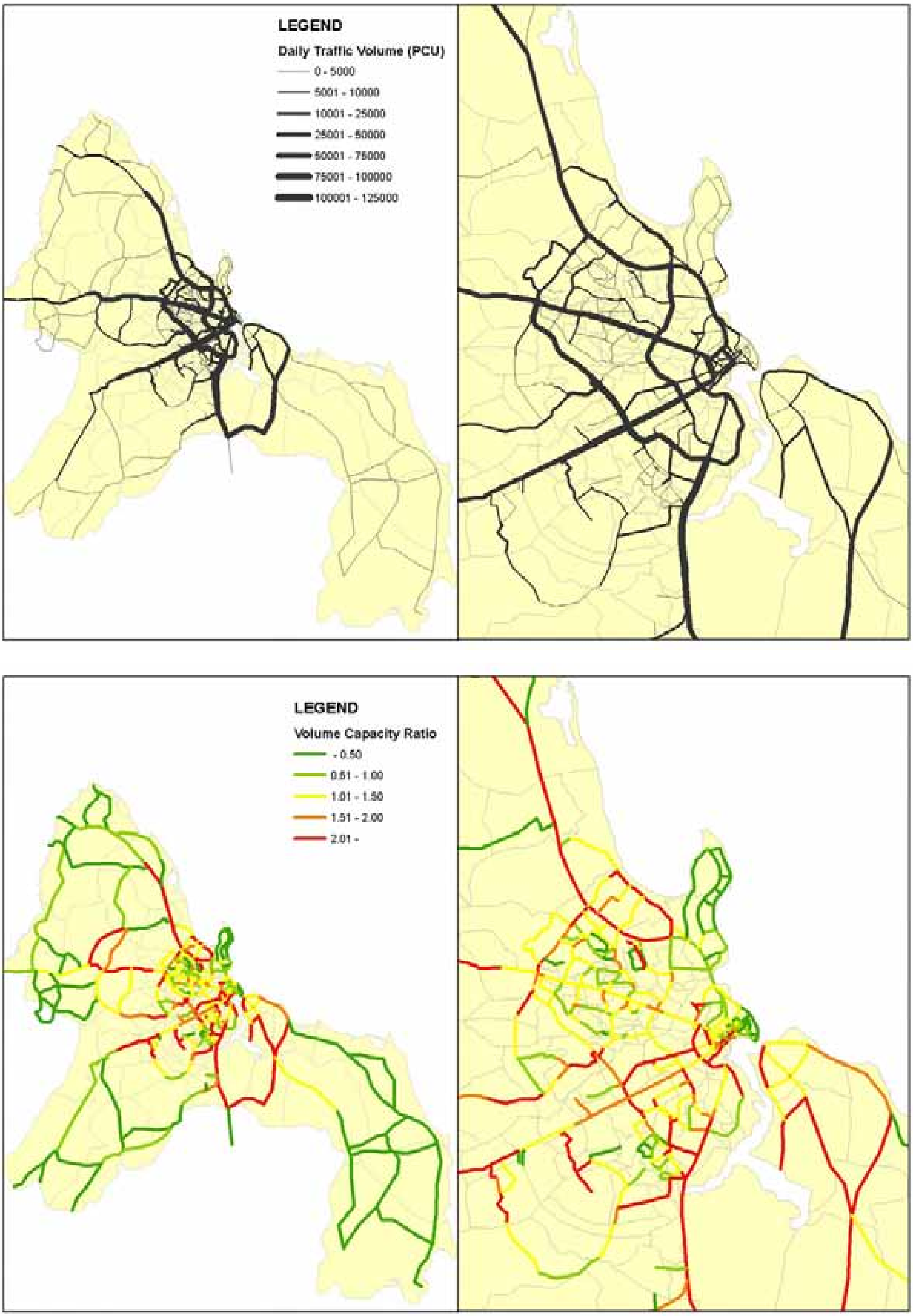


Figure 1.5.8 Future Traffic Demand and Volume Capacity Ratio in 2015 Without Case

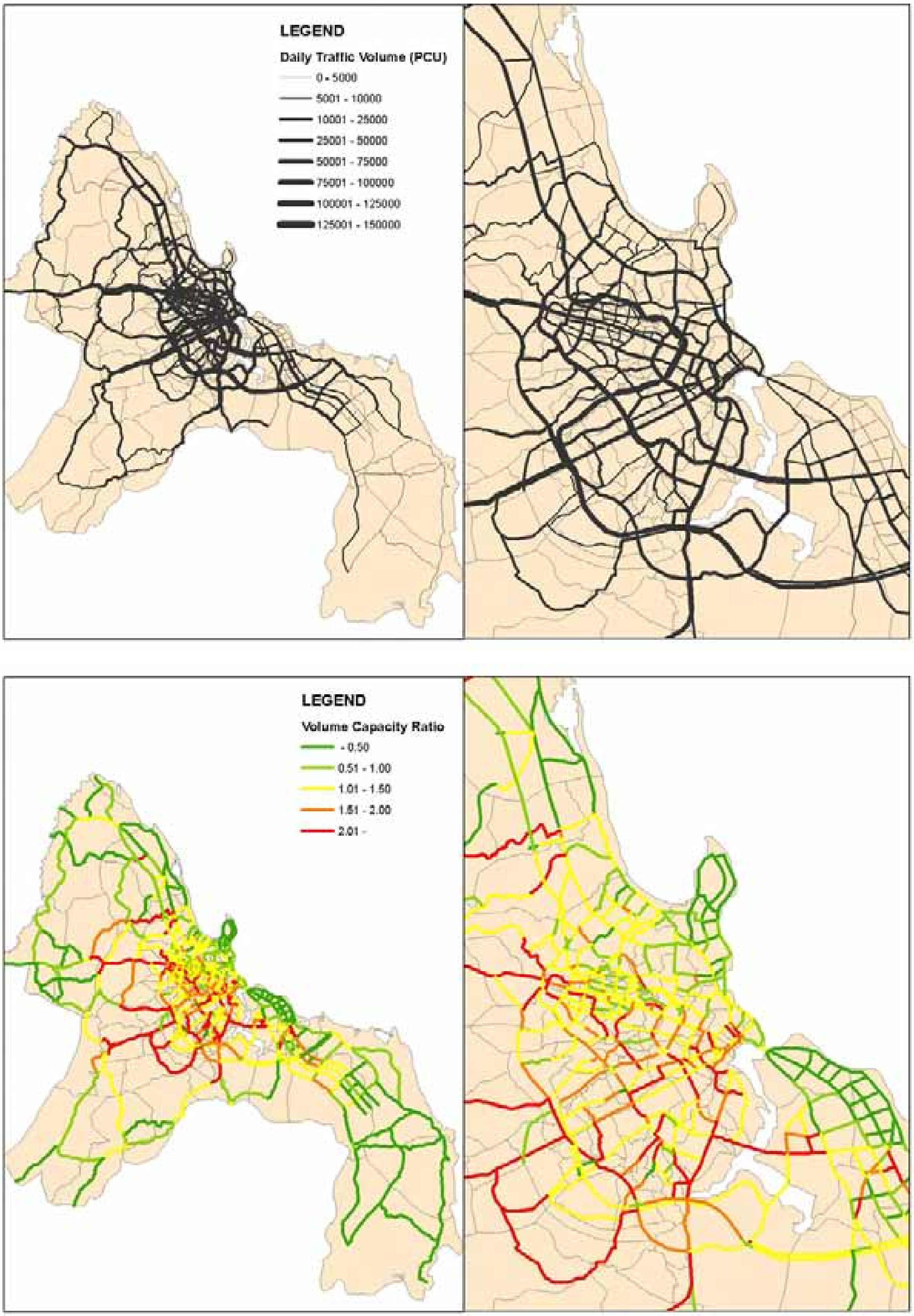


Figure 1.5.9 Future Traffic Demand and Volume Capacity Ratio in 2030 Base Case

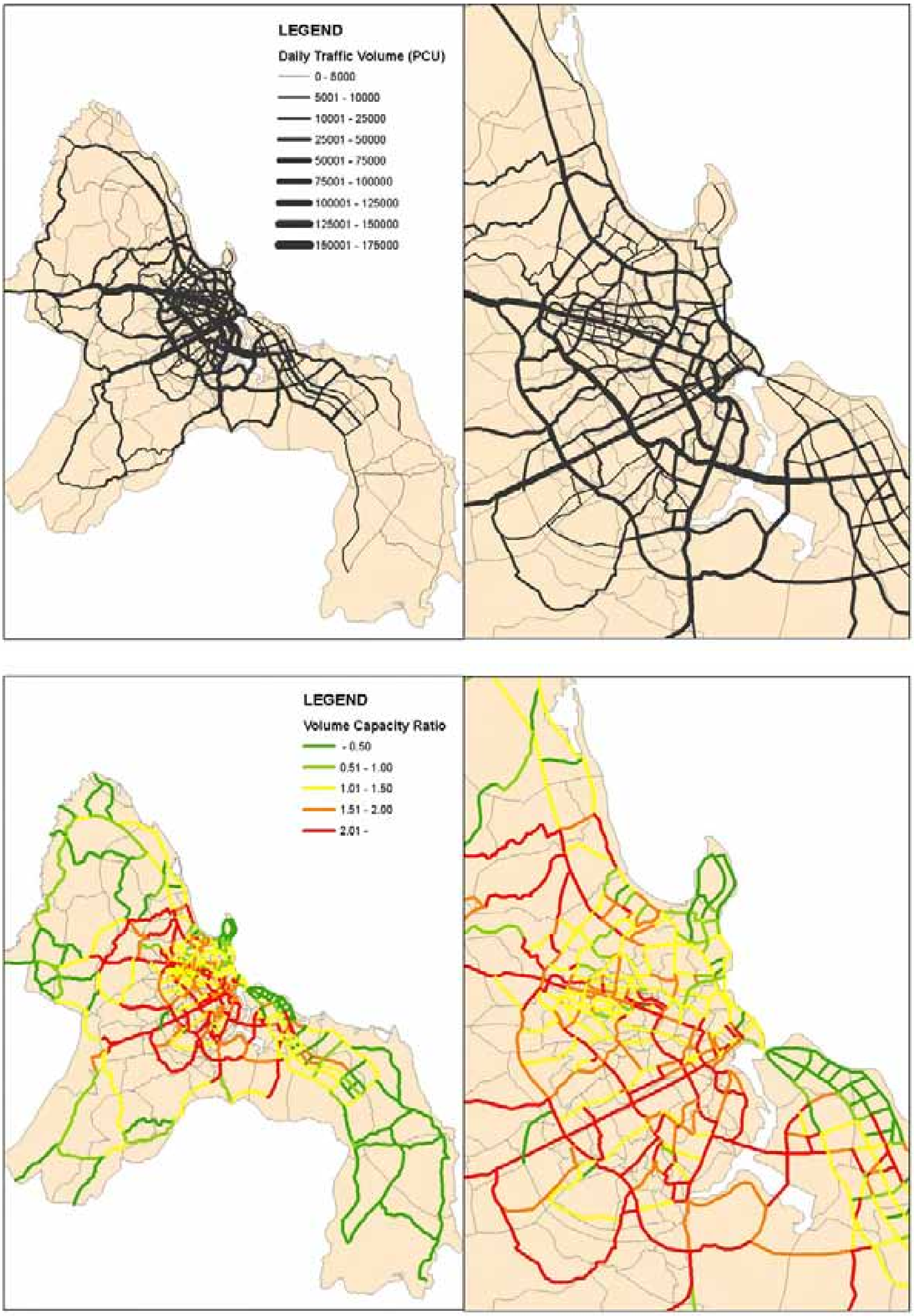


Figure 1.5.10 Future Traffic Demand and Volume Capacity Ratio in 2030 Without Expressway

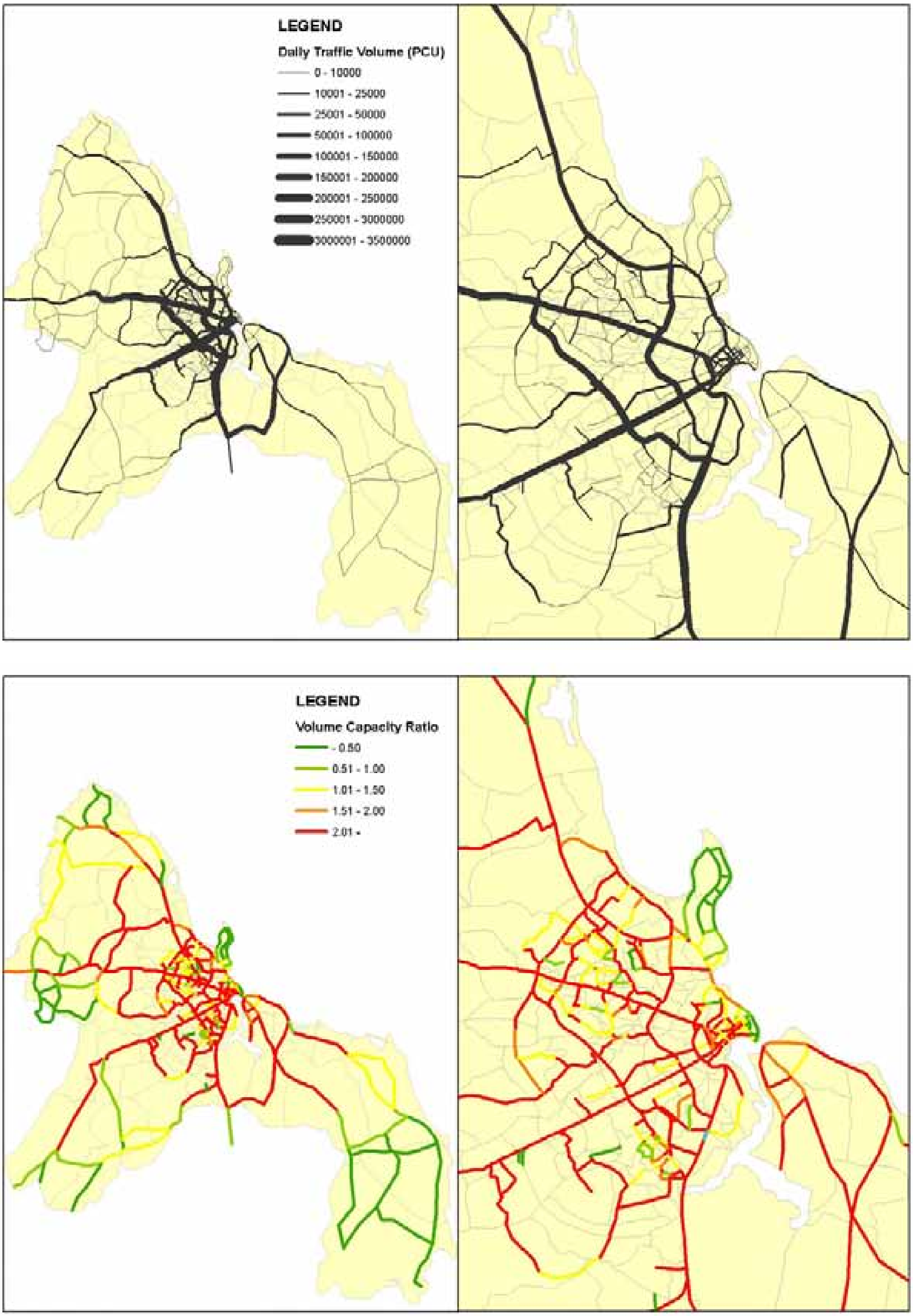


Figure 1.5.11 Future Traffic Demand and Volume Capacity Ratio in 2030 Without Case

1.5.6 Future Public Transport Volume

Figure 1.5.12 to 1.5.16 are the results of transit assignment of each simulation case.

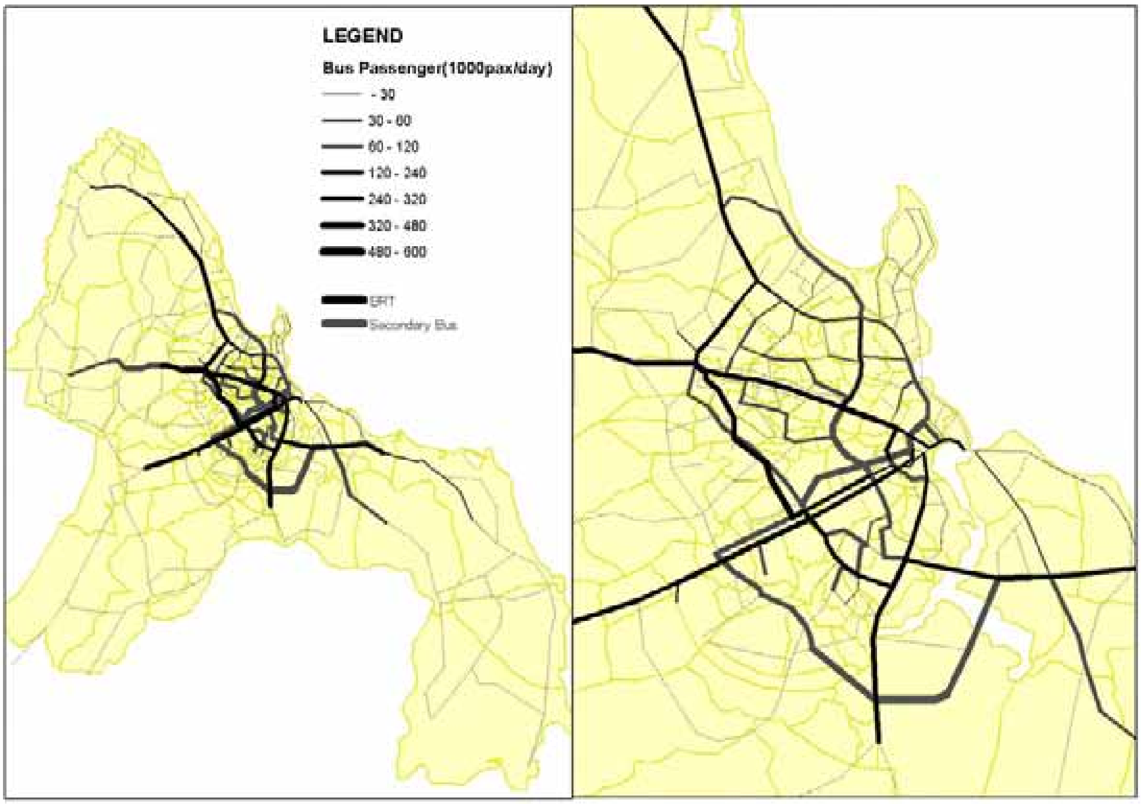


Figure 1.5.12 Future Bus Passenger Volume in 2015 Base Case

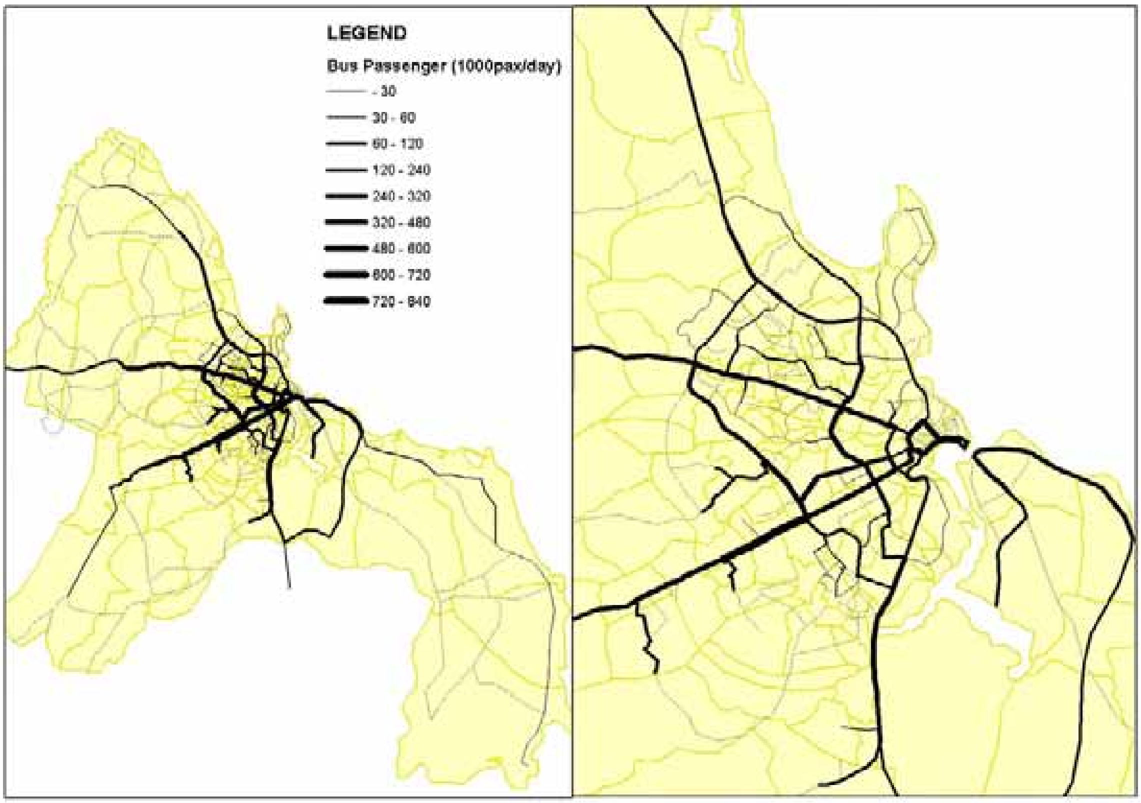


Figure 1.5.13 Future Bus Passenger Volume in 2015 Without Case

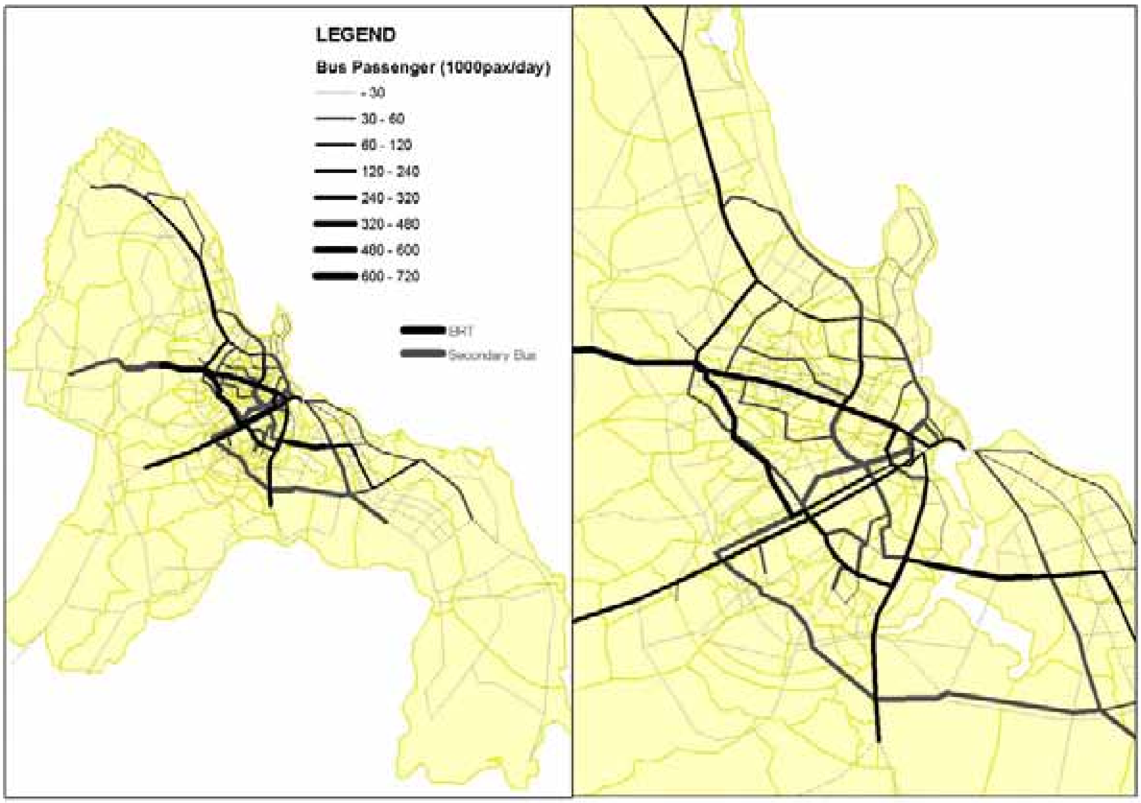


Figure 1.5.14 Future Bus Passenger Volume in 2030 Base Case

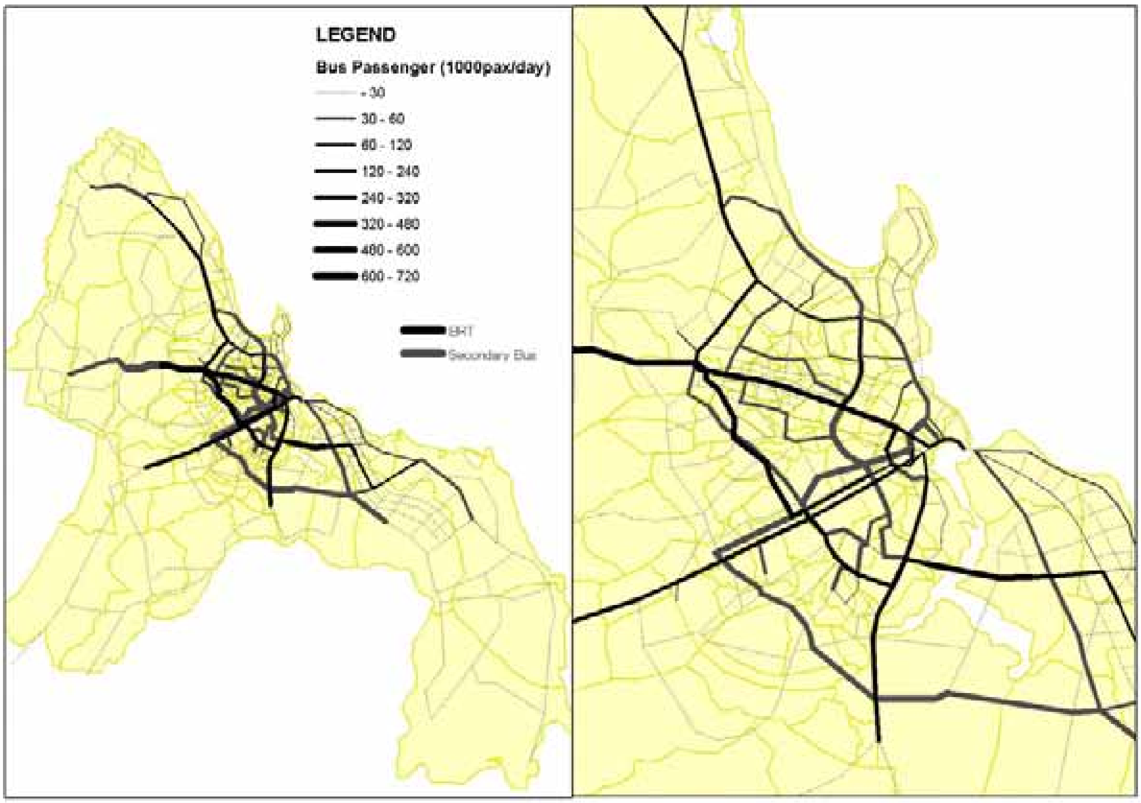


Figure 1.5.15 Future Bus Passenger Volume in 2030 Without Expressway Case

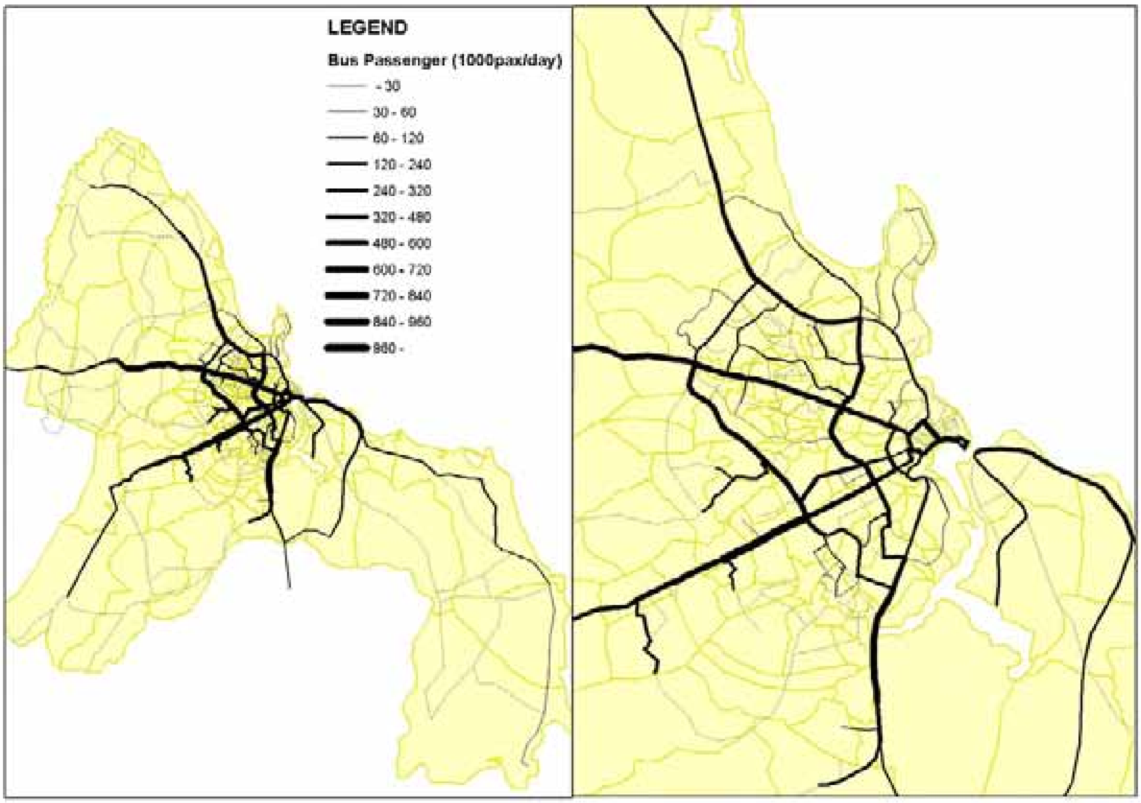


Figure 1.5.16 Future Bus Passenger Volume in 2030 Without Case