CHAPTER 3

TRAFFIC DEMAND FORECAST

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3.1 PROCEDURE

Based on the present OD tables estimated in Chapter 1 for person trips per trip purpose and mode, as well as the future socioeconomic framework presented in Chapter 2, future OD matrices were forecasted through the use of trip generation and attraction models for inter-zonal trips. Generated and attracted trips are next distributed on zonal basis and intra-zonal trips were estimated for each zone for traffic assignment purposes and to identify the magnitude of potential traffic problems in the future in order to establish required transport improvement components of master plan projects up to the target year 2020.

Socioeconomic data utilized to establish the future framework include available information from different resources and collected data through home interview and other field surveys. The framework is based mainly on zonal socioeconomic data of estimated population, registered number of students in schools and universities, and the number of employees that is estimated based on the number of establishments and average employees per establishment.

This chapter is to analyze traffic demands model based on the traffic survey data conducted in this Study and to forecast future traffic demand under do-nothing situation. In the traffic demand forecast, the traffic is divided into three areas such as person trips within the study area, truck trips, and trips in outer area as presented in Figure 3.1-1. As for person trip demand forecast, the following four-step traffic forecast method is used:

Step 1 Trip generation and attraction including trip production
Step 2 Trip distribution
Step 3 Modal split
Step 4 Traffic assignment

There are many models to apply for the modal choice of person trip such as trip production model, trip end model, trip interchange model, etc. In this Study, the modal split in between trip end model and trip interchange model will be employed.

As for the truck trip demand forecast, a simple forecast method using the growth rate is adopted. In this case, the GDP growth rate of Lebanon was used as the growth rate. As for trips to/from the external area of the Study Area, a growth rate method using the growth rate of trip generation/attraction and vehicle trips is adopted.

The traffic demand under do-nothing situation means that the traffic demand is forecasted if there will not be transport investments by the year 2020. From this forecasted traffic volume under do-nothing situation, it can be identified future transport problems and issues. This forecasted traffic volume is also used for the economic evaluation as without the master plan case.

3.2 TRIP PRODUCTION

The results of the Person Trip survey indicated that trip production rate (number of trips / person/day) is 2.287. It can be judged from the similar person trip surveys conducted in cities of the Middle-east countries that the trip production rate in Tripoli is high enough. Future total trip production in the Study Area was estimated by using trip production rates on the assumption that rates will be an unchangeable factor in the future.

Total trips produced = 2.287 x number of population above 6 years olds

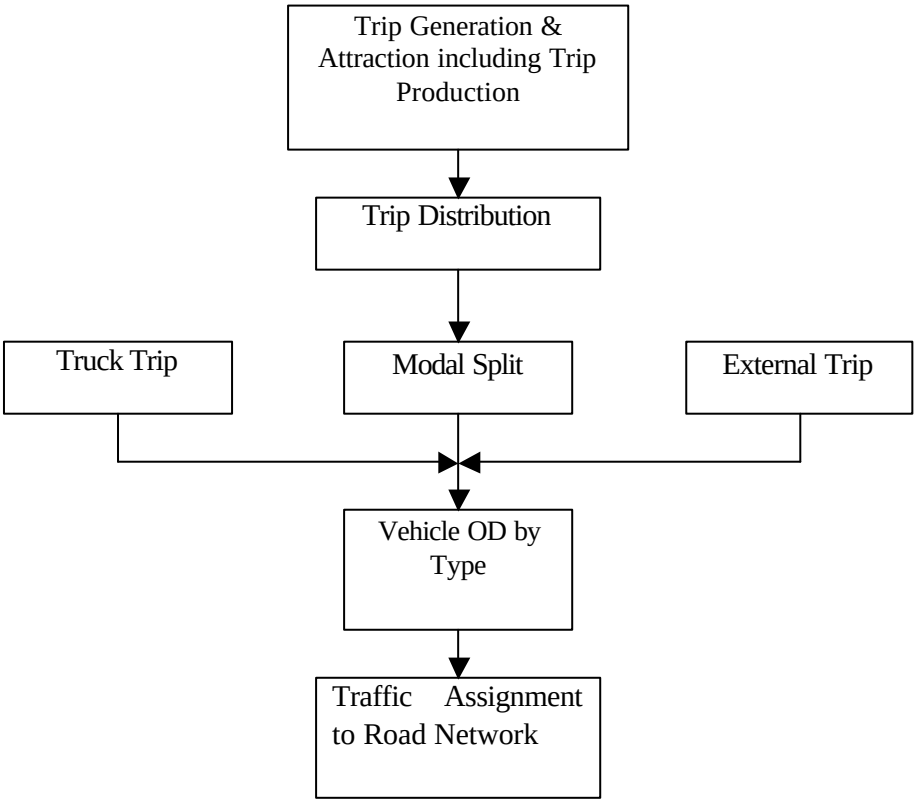


Figure 3.1-1 Traffic Demand Forecasting Procedure

The number of person trips in the Greater Tripoli Area in 2020 is expected to increase from 694,423 trips in 2000 to 978,864 trips in 2020 as presented in Table 3.2-1.

	Person trip within the Study Area	Population above 6 years old	Trip Production Rate
Year 2000	694,423	297,840	2.332
Year 2020	978,864	408,780	2.395

Table 3.2.1 Number of Trip Production By Trip Purpose

Trip purpose	2000		2020	
	No.	%	No.	%
To Work	137,169	19.8	231,016	23.6
To School	146,949	21.2	221,833	22.7
Others	79,100	11.4	102,449	10.5
To home	331,205	47.7	423,566	43.2
Total	694,423	100.0	978,864	100.0

3.3 TRIP GENERATION AND MODAL SPLIT

3.3.1 Trip Generation and Attraction Model

For generation and attraction trip forecast, multiple linear regression models that have as their explanatory variables the population and other indices determined for the future socioeconomic framework, are used to forecast the future number of trips. Multiple-variable models were developed to forecast generated and attracted person trips. The model structure is developed through the utilization of the most highly associated independent variables, based on the following formula:

$$Gi = a\ Xi_1 + ß\ Xi_2 + ?\ Xi_3 + K$$

Where; G*i* = Generated trips at zone *i*
Xi_1, Xi_2, Xi_3 = Independent variables, which represent the followings:
P*i* = Population of zone *i*
E*i* = Employees of zone *i*: work place (WP) / resident place (RP)
S*i* = Students of zone *I*: school place (SP) / resident place (RP)
a, ß, ? & K = Parameters

For the generation trip models, residency-base independent variables of employees and students are applied, while in the attraction trip models the work place and school place are applied. Values of model parameters are presented in Table 3.3-1. For zones with special characteristics for the land use or urban function that cannot be expressed by the applied independent variables, adjustment are done through the use of dummy variables in the modeling procedure.

Table 3.3-1 Parameters of Trip Generation / Attraction Models per Purpose

Purpose	a	*ß*	?	*K*	*R*	Variables
Generation						
To Home	1.0627	0.0440	0.0267	-198.801	0.952	P*i* , E*i* (WP), S*i* (SP)
To Work	0.4214	-	-	-38.859	0.914	P*i*
To School	2.7750	-	-	-419.858	0.925	S*i*(RP)
Others	0.0923	0.8500	-	348.630	0.999	P*i*, Dummy
Attraction						
To Home	0.9524	-	-	-142.949	0.952	P*i*
To Work	0.8294	0.8500	-	867.089	0.999	E*i*(WP), Dummy
To School	1.1959	-	-	1135.12	0.728	S (SP)
Others	-0.2303	0.8500.	-	456.438	0.999	E*i*(WP),Dummy

3.3.2 Forecasted Generated and Attracted Person Trips

Table 3.3-2 shows the trips generated and attracted by zone in 2000 and 2020. Since overall trip generation in a zone is more or less proportionate to the zone's population, those zones where a sharp increase in population is forecasted, also expect to have sharp increase in the number of trips generated. Zones where trip generation will increase rapidly are Zone No.5, 6, 7, 8, 9, 31, 53, and 54. Figure 3.3-1 shows the present and future zonal generated and attracted trips for grouped zones.

3.4 TRIP GENERATION OF INTRA-ZONAL TRIPS

A log-linear model is applied to estimate intra-zonal trips based on the total generated and attracted trips as well as the area in each zone. Parameters of the developed model, which has the following formula, are as follows:

$$lnTii = a\ lnGi + ß\ lnAi + ?\ lnZi + d\ lnD + lnK$$

Where; T*ii* = Intra-zonal trips in zone *i*
G*i* = Trip generation in zone *i*
A*i* = Trip attraction to zone *i*
Z*i* = Area of zone *i*
D = Adjustment Coefficient
a, ß, ?, d & K = Parameters

The parameters used in the models are shown in Table3.4-1.

Table 3.3-2 Trip Generation and Attraction by Zone, 2000 and 2020

	2000		2020		Growth Rate	
	Generation	Attraction	Generation	Attraction	Generation	Attraction
1	35,824	35,824	41,412	41,339	1.156	1.154
2	23,711	23,711	30,555	30,313	1.289	1.278
3	2,703	2,703	32,914	32,722	12.177	12.106
4	10,533	10,533	10,205	10,636	0.969	1.010
5	21	21	9,852	9,668	469.143	460.381
6	0	0	14,609	14,740	-	-
7	268	268	36,750	37,274	137.127	139.082
8	2,132	2,132	24,641	26,817	11.558	12.578
9	2,543	2,543	53,363	54,141	20.984	21.290
10	29,937	29,937	24,499	24,667	0.818	0.824
11	35,292	35,292	23,900	23,853	0.677	0.676
12	3,579	3,579	12,496	12,407	3.491	3.467
13	2,608	2,608	14,274	14,123	5.473	5.415
14	36,922	36,922	23,408	23,540	0.634	0.638
15	11,515	11,515	17,809	17,717	1.547	1.539
16	47,323	47,323	27,281	26,821	0.576	0.567
17	3,571	3,571	26,255	25,862	7.352	7.242
18	36,319	36,319	34,569	34,396	0.952	0.947
19	1,401	1,401	7,112	6,874	5.076	4.906
20	6,323	6,323	25,865	25,360	4.091	4.011
21	27,472	27,472	29,079	29,151	1.058	1.061
22	10,832	10,832	17,092	16,760	1.578	1.547
23	11,592	11,592	27,413	27,819	2.365	2.400
24	25,203	25,203	15,595	15,250	0.619	0.605
25	42,641	42,641	15,080	15,483	0.354	0.363
26	13,693	13,693	13,089	13,399	0.956	0.979
27	20,622	20,622	17,000	17,419	0.824	0.845
28	13,579	13,579	22,645	23,300	1.668	1.716
29	15,253	15,253	11,356	11,641	0.745	0.763
30	15,767	15,767	26,936	27,725	1.708	1.758
31	0	0	7,223	7,138	-	-
32	1,204	1,204	7,654	7,494	6.357	6.224
33	5,767	5,767	15,041	15,447	2.608	2.679
34	13,823	13,823	18,437	18,630	1.334	1.348
35	6,833	6,833	10,209	10,295	1.494	1.507
36	14,101	14,101	13,938	14,062	0.988	0.997
37	10,956	10,956	12,894	12,680	1.177	1.157
38	2,776	2,776	4,451	4,277	1.603	1.541
39	5,788	5,788	12,070	11,865	2.085	2.050
40	11,925	11,925	1,341	1,254	0.112	0.105
41	1,270	1,270	4,035	4,066	3.177	3.202
42	11,180	11,180	10,713	10,545	0.958	0.943
43	8,099	8,099	23,323	23,365	2.880	2.885
44	24,492	24,492	26,282	25,095	1.073	1.025
45	4,862	4,862	9,935	10,050	2.043	2.067
46	13,439	13,439	17,240	16,363	1.283	1.218
47	7,941	7,941	11,588	11,247	1.459	1.416
48	18,869	18,869	8,005	7,723	0.424	0.409
49	2,888	2,888	6,477	6,477	2.243	2.243
50	2,952	2,952	8,185	7,779	2.773	2.635
51	22,477	22,477	4,827	4,506	0.215	0.200
52	0	0	2,746	2,748	-	-
53	95	95	6,953	6,601	73.189	69.484
54	130	130	4,079	3,776	31.377	29.046
Total	681,046	681,046	934,700	934,700	1.372	1.372

Note: 1) Excluding person trips using truck trips
2) Internal trips only

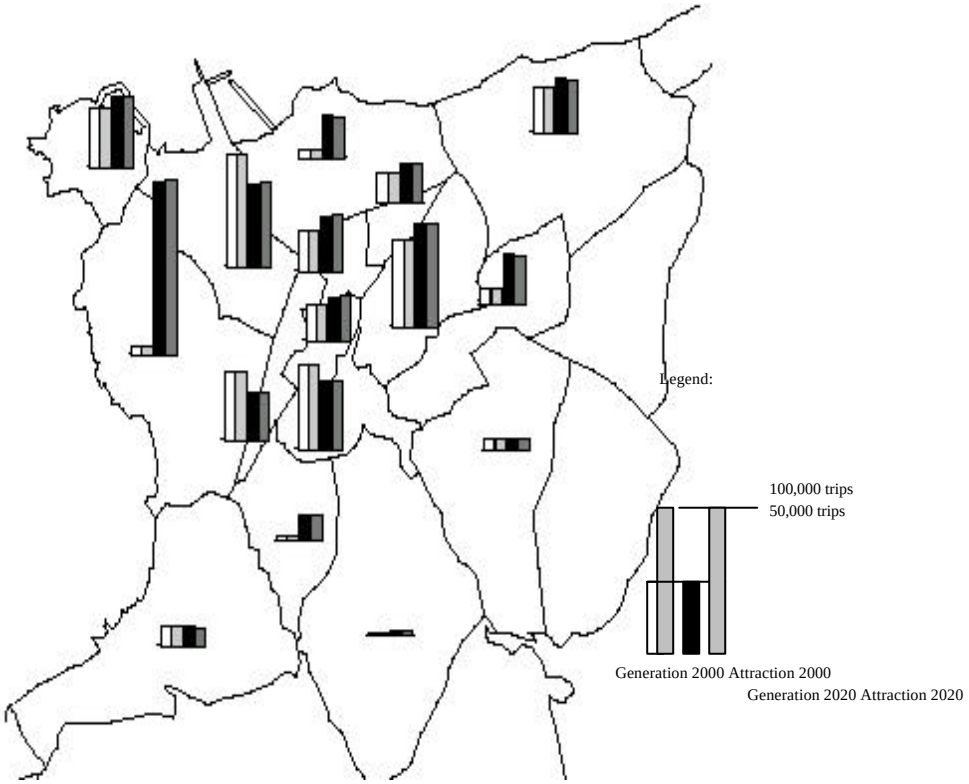


Figure 3.3-1 Trip Generation and Attraction by Zone in 2000 and 2020

Table 3.4-1 Parameters of Intra-zonal Models by Trip Purpose

Purpose	a	ß	?	*K*	*R*
To Work	0.8160	0.9160	-	-0.0753	0.9234
To School	0.1614	1.0138	-	-0.0372	0.9176
Others	0.1584	0.0703	1.252	-0.0693	0.9238
To Home	0.4817	0.2684	-1.1393	-0.4397	0.7573

3.5 OD DISTRIBUTION

Trip generation estimates the total number of trips originated and terminating in the different zones, while this stage of trip distribution is the process of computing the number of trips between each individual zone and all others.

The developed trip distribution procedure provides full matrices of trips between all zones. The model functions for forecasting the OD trip distribution are calculated through the OD model builder of JICA STRADA Model. This model builder is a specialized tool for the types of regression analysis needed to build forecasting model of trip distribution.

The OD model builder of STRADA has four model types for inter-zonal trips, out of which the BPR gravity model gives the most fitting in calculating the model parameters. The model has the following formula:

$$Tij = Gi\ Aj\ f(dij)\ Kij\ /\ S\ (Aj\ f(dij)\ Kij)$$

Where; *Tij:* Total number of trips made by individuals living in zone *i* to zone *j*
Gi: Total number of trips generated from zone *i*
Aj: Total number of trips attracted to zone *j*
d: inter-zonal impedance (a trip index, which is expressed by the distance between zones *i* and *j*)
K: Zonal parameters,

The zonal parameters are generally developed as a matrix synthesizing the future trip-interchange magnitude and overcoming imbalances in the trip-distribution so that interchanges ultimately balance by direction.

The results of trip distribution analysis produce the interzonal trip pattern in the form of OD matrices for trip purposes as well as for each vehicle category. Figure 3.5-1 presents the desire-line chart for the zonal trip pattern of the total number of vehicular trips between zones.

3.6 MODAL SPLIT

(1) Modal Choice between Walking/2-Wheel Mode and Transport Mode

The modal choice between walking/2-wheel mode and transport mode is forecasted by applying a set of multi-variable models and a calibration procedure is done and shown in Table 3.6-1.

The following linear models are used to forecast trip generation and attraction by modes.

$$Gi = a\ Xi_1 + ß\ Xi_2 + ?\ Xi_3 + K$$

Where; G*i* = Generated trips at zone *i*
Xi_1, Xi_2, Xi_3 = Independent variables, which represent the followings:
P*i* = Population of zone *i*
E*i* = Employees of zone *i*: work place (WP) / resident place (RP)

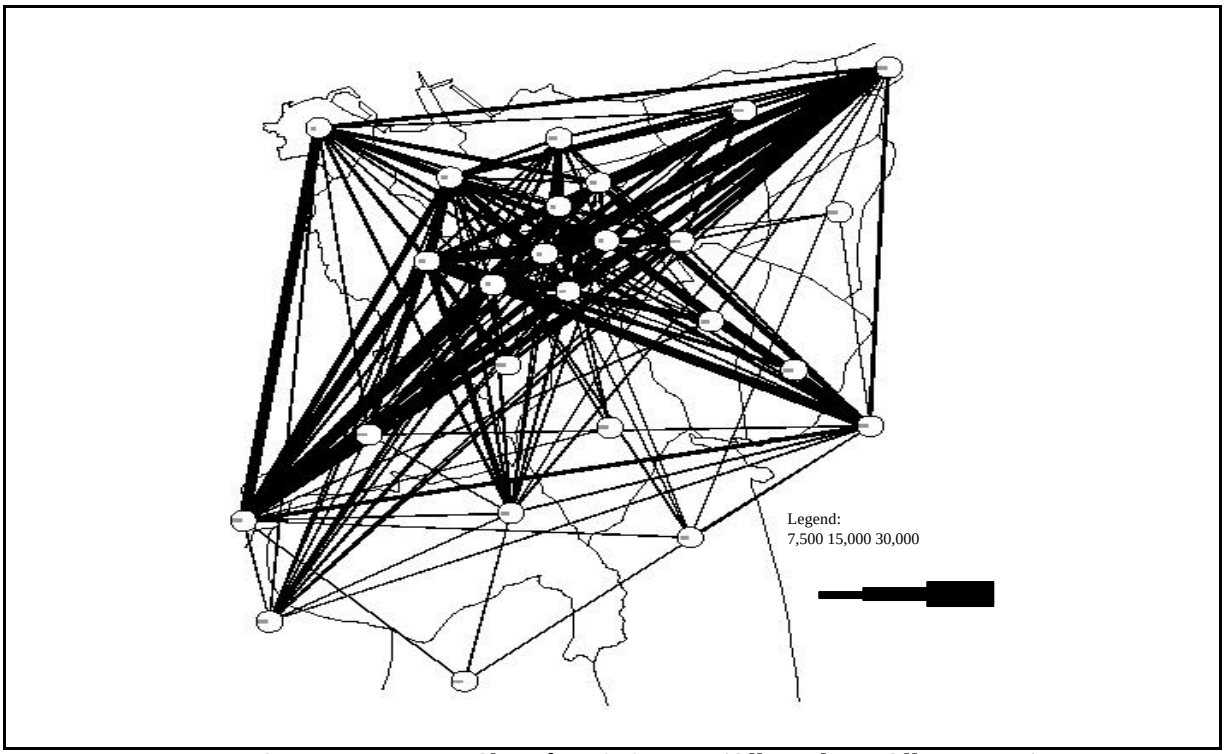


Figure 3.5-1 Desire Line Chart for 2020 Trips (All Modes – All Purposes)

S*i* = Students of zone *I*: school place (SP) / resident place (RP)
a, *ß*, *? & K* = Parameters

Table 3.6-1 Parameters of Transport Mode Choice Models (1)

Purpose	a	*?*	?	*K*	*R*	Variables
Generation						
Walking/ 2 Wheel	0.2669	0.4943	0.4621	71.7165	0.8286	P*i* , E*i* (WP), S*i* (SP)
Using transport mode	0.7326	1.1836	1.2488	652.053	0.8085	P*i* , E*i* (WP), S*i* (SP)
Attraction						
Walking/ 2 Wheel	0.2486	0.5467	0.4825	82.856	0.8148	P*i* , E*i* (WP), S*i* (SP)
Using transport mode	0.6785	1.3687	1.3120	573.755	0.8005	P*i* , E*i* (WP), S*i* (SP)

(2) Modal Choice between Passenger Car and Public Transport

The modal choice between passenger car mode and public transport mode is forecasted by applying a set of multi-variable models and a calibration procedure is done and shown in Table 3.6-2.

Table 3.6-2 Parameters of Transport Mode Choice Models (2)

Purpose	?	*?*	?	*K*	R^2	Variables
Generation						
Passenger Car	0.3309	0.6189	0.5252	363.351	0.794	P*i* , E*i* (WP), S*i* (SP)
Public transport	0.6644	0.3143		-26.905		P*i* , S*i* (SP)
Attraction						
Passenger Car	0.3064	0.7074	0.5719	298.141	0.783	P*i* , E*i* (WP), S*i* (SP)
Public transport	0.3721	0.6641	0.4013	275.615	0.766	P*i* , E*i* (WP), S*i* (SP)

(3) Modal Choice between Taxi and Bus Transport

The modal choice between bus transport mode and taxi mode in the public transport users is forecasted by applying a set of multi-variable models and a calibration procedure is done and shown in Table 3.6-3.

Table 3.6-3 Parameters of Transport Mode Choice Models (3)

Purpose	?	ß	G	*K*	*R*	Variables
Generation						
Bus	0.3062	0.4601	0.3814	-506.542	0.795	P*i* , E*i* (WP), S*i* (SP)
Taxi	0.0873	0.2872	0.3617	289.854	0.704	P*i* , E*i* (WP), S*i* (SP)
Attraction						
Bus	0.2780	0.5427	0.3887	-475.795	0.789	P*i* , E*i* (WP), S*i* (SP)
Taxi	0.0878	0.2854	0.3665	295.407	0.7045	P*i* , E*i* (WP), S*i* (SP)

(4) Results of Modal Split

Results of modal choice in the two target years of 2000 and 2020 are presented in Table 3.6-4.

Table 3.6.4 Number of Person Trips by Trip Purpose and Mode

	2000		2020	
	Trips	%	Trips	%
Trip purpose				
To Work	137,169	19.8	231,016	23.6
To School	146,949	21.2	221,833	22.7
Others	79,100	11.4	102,449	10.5
To home	331,205	47.7	423,566	43.2
Mode				
Walking	193,587	27.9	265,507	27.1
Passenger Car	228,494	32.9	330,535	33.8
Bus	97,641	14.1	129,150	13.2
Taxi	161,324	23.2	209,514	21.4
Truck	13,377	1.9	43,958	4.5
Total	694,423	100.0	978,864	100.0

3.7 FORECAST OF TRUCK TRIP

In this Study, it is forecasted person trips using passenger car, bus and taxi using person-based traffic demand forecasting process. However, this could not be forecasted truck trip. Therefore, the truck trip will be forecasted using commodity survey data.

As for the truck trip demand forecast, a simple forecast method using the growth rate is adopted. In this case, the GDP growth rate of Lebanon was used as the growth rate.

3.8 FORECAST OF EXTERNAL TRIPS

As for trips to/from the external area of the study area, a growth rate method using the growth rate of trip generation/attraction and vehicle trips is adopted.

$$Xij = xij \times \frac{Fgi + Fai}{2}$$

Where, Xij = Future external trips between zones (ij)
xij = Existing external trips between zones (ij)
Fgi = Growth rate of trip generation in zone i
Fai = Growth rate of trip attraction in zone I

3.9 TRAFFIC ASSIGNMENT

The vehicular OD traffic volume is forecasted using person trip OD by vehicle types, truck trip OD and external trip OD made by the previous section using average occupancy rate and passenger car unit (PCU) as shown in Tables 3.9-1 and 3.9-2. Table 3.9-3 summarizes number of vehicular trips in the years 2000 and 2020. The traffic demand for the year 2020 is assigned both on the existing network, and the results are presented in Table 3.9-4. Table 3.9-5 presents the road length by traffic congestion degree, in which about 30 kilometers of streets have a V/C over 1.0. Figure 3.9-1 shows the assignment results graphically for the target years.

Table 3.9-1 Vehicle Occupancy Rate (Passenger/vehicle)

Vehicle Category	Occupancy Rate
Passenger car	1.818
Taxi	2.917
Bus	18.696

Source: Data from traffic survey by JICA Study Team

Table 3.9-2 Passenger Car Unit (PCU)

Vehicle Category	PCU
Passenger car	1.00
Taxi	1.00
Bus	1.50
Truck	2.00

Table3.9-3 Summary of Vehicular Trips in 2000 and 2020

		2000	2020	2020/2000
Internal Trip		176,418	270,732	1.535
	Passenger Car	125,688	181,871	1.447
	Taxi	33,466	44,283	1.323
	Bus	8,626	11,204	1.299
	Truck	8,638	33,428	3.870
External Trip		105,712	143,670	1.359
	Passenger Car	79,275	110,812	1.398
	Taxi	18,846	24,721	1.312
	Bus	2,771	3,317	1.197
	Truck	4,820	4,820	1.000
Total		282,130	428,233	1.518
	Passenger Car	204,963	292,629	1.428
	Taxi	52,312	69,004	1.319
	Bus	11,397	14,521	1.274
	Truck	13,458	52,079	3.870

Table 3.9-4 Results of Traffic Assignment under Do-nothing Case

Year	PCU-Kms	PCU-Hours	Capacity-Kms	Av. Congestion Degree	Average Travel Speed (km/h)
2000	1,454,932	27,192	3,582,567	0.406	53.5
2005	1,789,023	36,341	3,582,567	0.499	49.2
2010	2,136,209	48,435	3,582,567	0.596	44.1
2020	2,788,483	74,557	3,582,567	0.778	37.4

Table 3.9-5 Road Lengths by Traffic Congestion Degree under Do-Nothing Case (Unit: Kms)

Congestion Degree	2000	2005	2010	2020
>0.5	87.2	68.3	61.5	47.5
0.5-0.8	25.2	33.6	27.4	26
0.8-1.0	12.4	13.3	14.8	18.3
1.0-1.2	4.5	11.5	14.9	12.1
1.2-1.5	0.8	2.7	7.6	13.1
>=1.5	0.6	1.3	4.5	13.7
Total	130.7	130.7	130.7	130.7

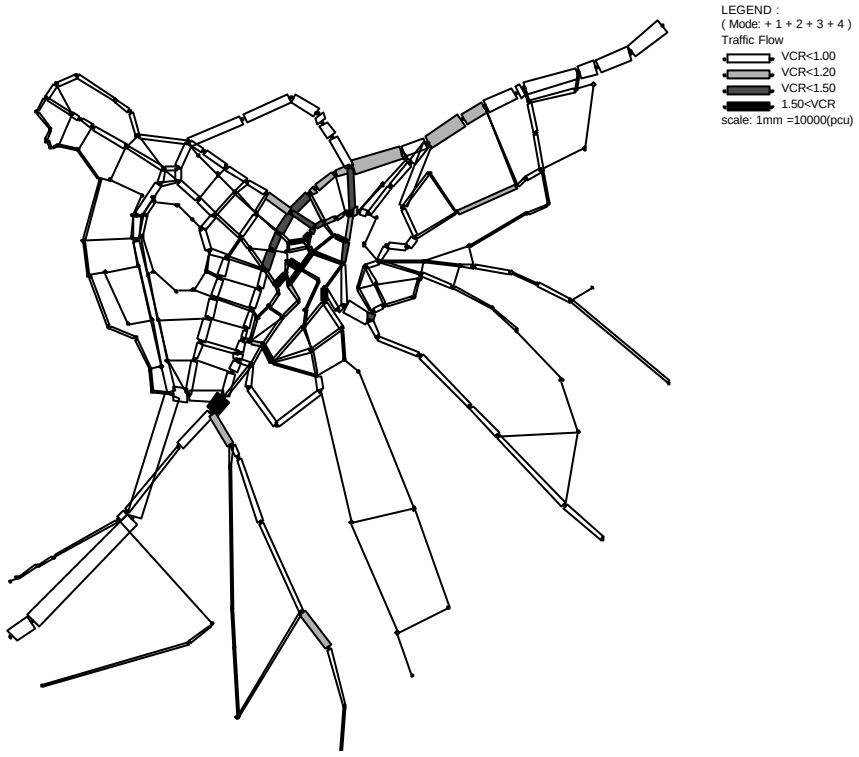
The present road network is used for the assignment of these future trips for the "Do Nothing" case in order to clarify the potential of traffic and transport problems in the future. Figure 3.9-1 and Figure 3.9-2 present the assignment results based on both parameters of congestion rate and travel speed, in which it is clear that the speed is decreasing gradually in the future. The main results that can be observed from this figure can be summarized as follows:

Year 2000: The highest daily traffic volumes are those on the expressway to Beirut with a little more than 40,000 vehicles and followed by volumes on the northern highway to Syria with a little less than 40,000 vehicles. Most of the streets in the newly developed areas provide travel speed over 30 km/hr, while streets in the central areas have average speeds between 20 and 30 km/hr. On the other hand, most of the sections of the northern road going to Syria have speeds less than 20km/hr.

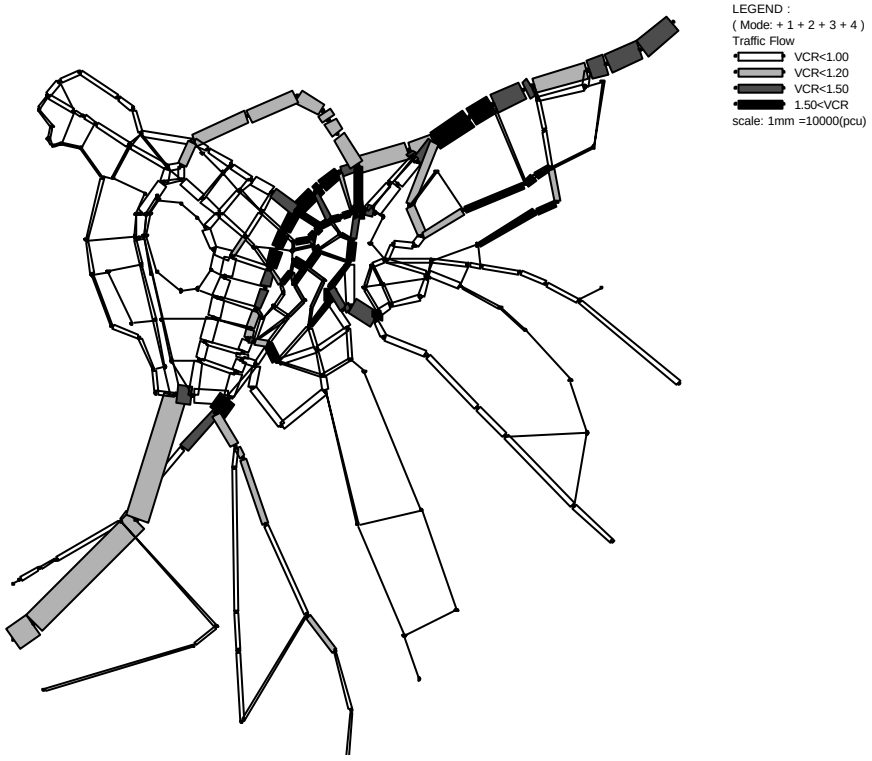
Year 2005: Daily traffic volumes on both south and north directions are exceeding 40,000 vehicles. With the increase in traffic volumes on many streets, speeds are gradually decreasing on most of the central areas as well as on Azmy street between Tripoli and El-Mina. Speed on this street decreased to be less than 30 km/hr on two segments and less than 20 km/hr on another two segments. On the northern road going to Syria, only one segment has a speed between 20 and 30 km/hr while speeds on all other segments are dropped to be less than 20 km/hr.

Year 2010: Average daily traffic volumes on most segments of the northern highway to Syria exceed 50,000 vehicles, which will result in decreasing the speed to be less than 20 km/hr. The southern expressway handles also about 50,000 vehicles, however, the travel speed is higher than 30 km/hr due to its larger number of lanes and higher capacity. Volumes on the main boulevard in the central area are increasing to more than 30,000 vehicles and the speeds are mostly less than 20 km/hr on its northern segments and a little higher on the southern segments.

Year 2020: The northern highway to Syria will handle high daily traffic volumes of more than 60,000 vehicles and the speed is less than 20 km/hr on all the segments. On the expressway to Beirut, volumes are a little lower than 60,000 vehicles and speeds are still over 30 km/hr. Almost all of the streets in the central and northern areas well as roads connecting the Study Area with other neighboring municipalities have speeds less than 20 km/hr. Speeds higher than 30 km/hr exist only on the expressway to Beirut and coastal roads in the municipality of El-Mina.

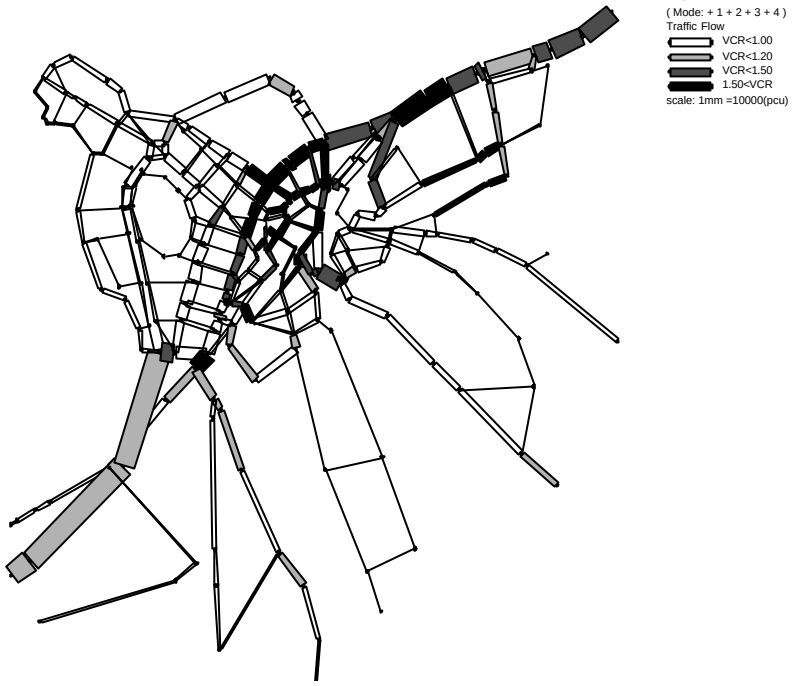


Present – 2000

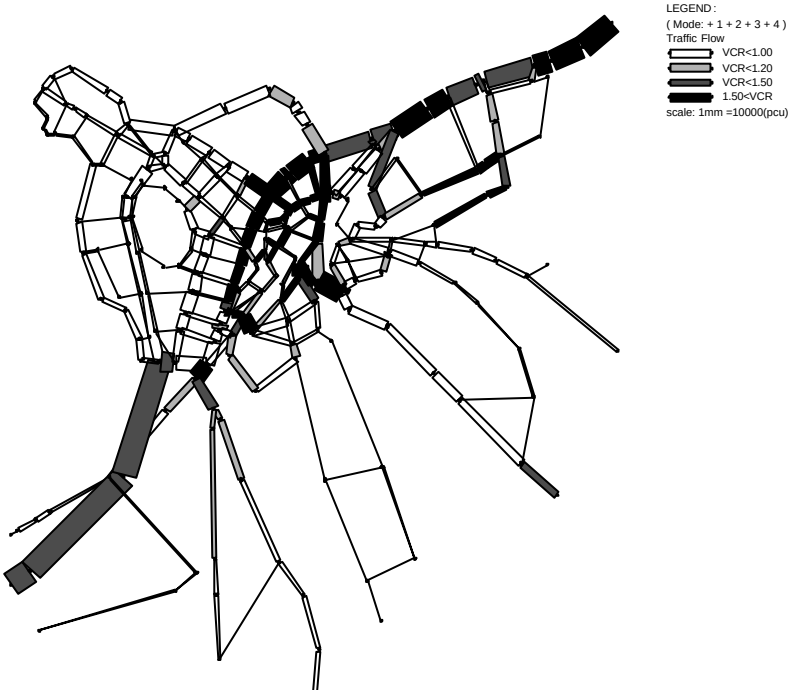


Do Nothing Case – 2005

Figure 3.9-1 Traffic Assignment Result – Congestion Rate (1/2)

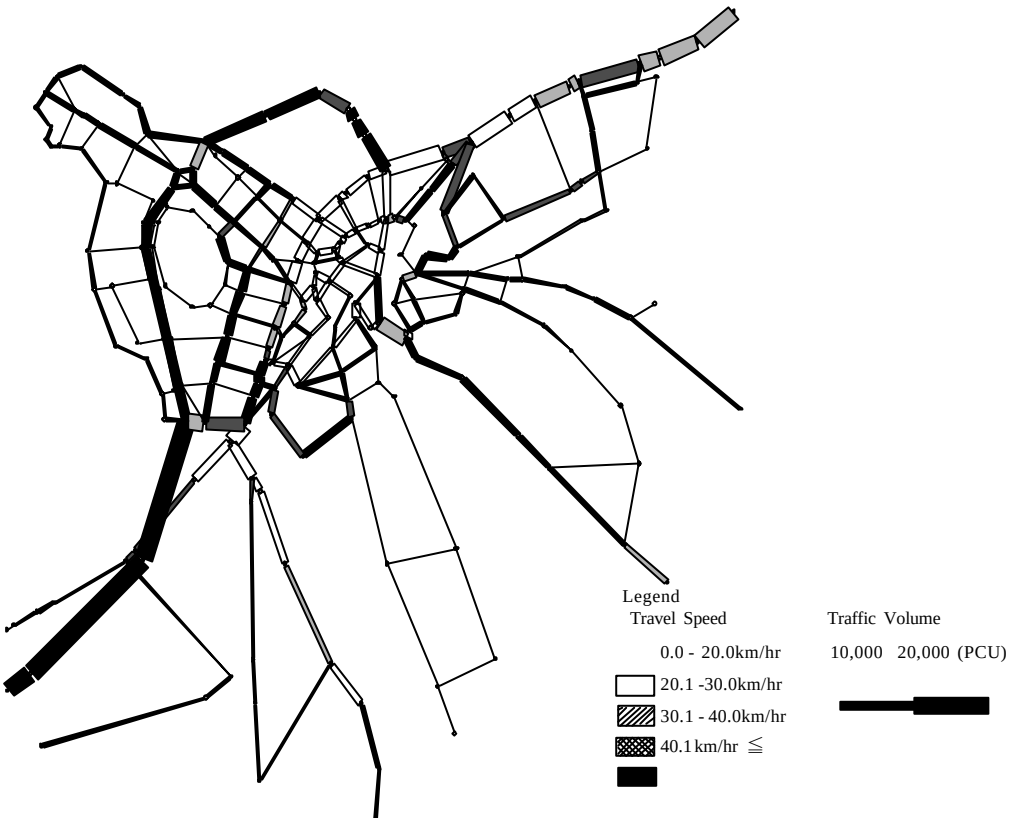


Do Nothing Case – 2010

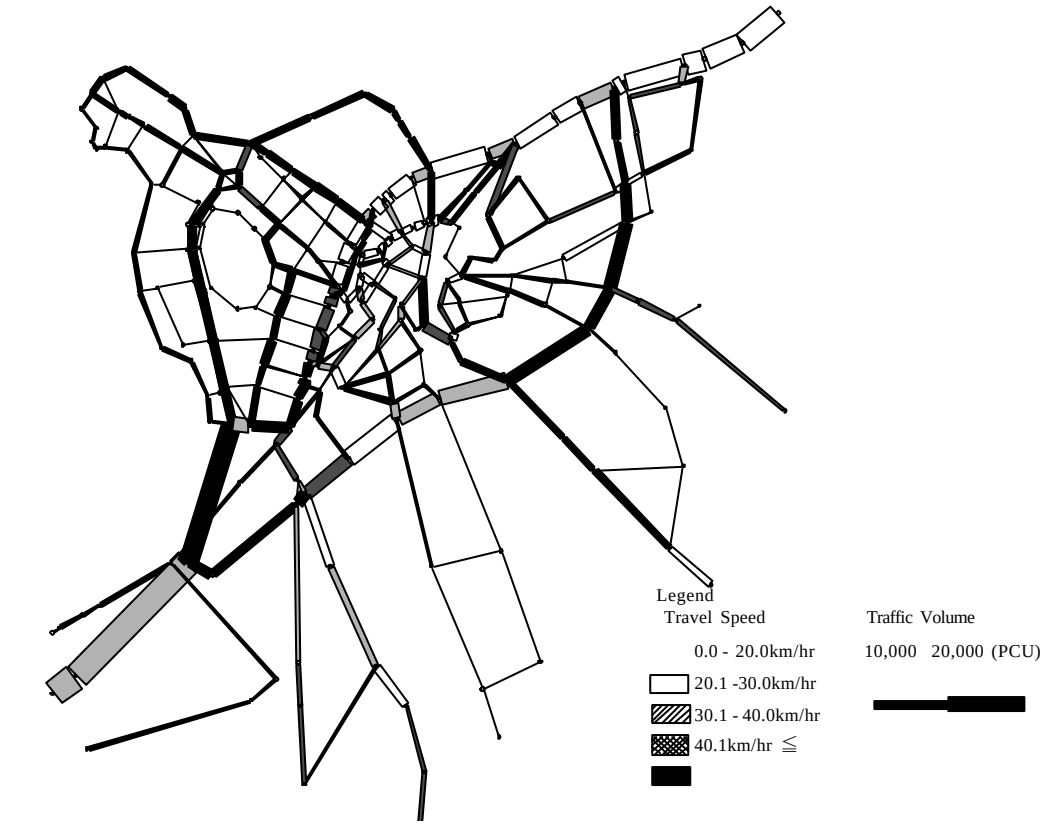


Do Nothing Case – 2020

Figure 3.9-1 Traffic Assignment Result- Congestion Rate (2/2)

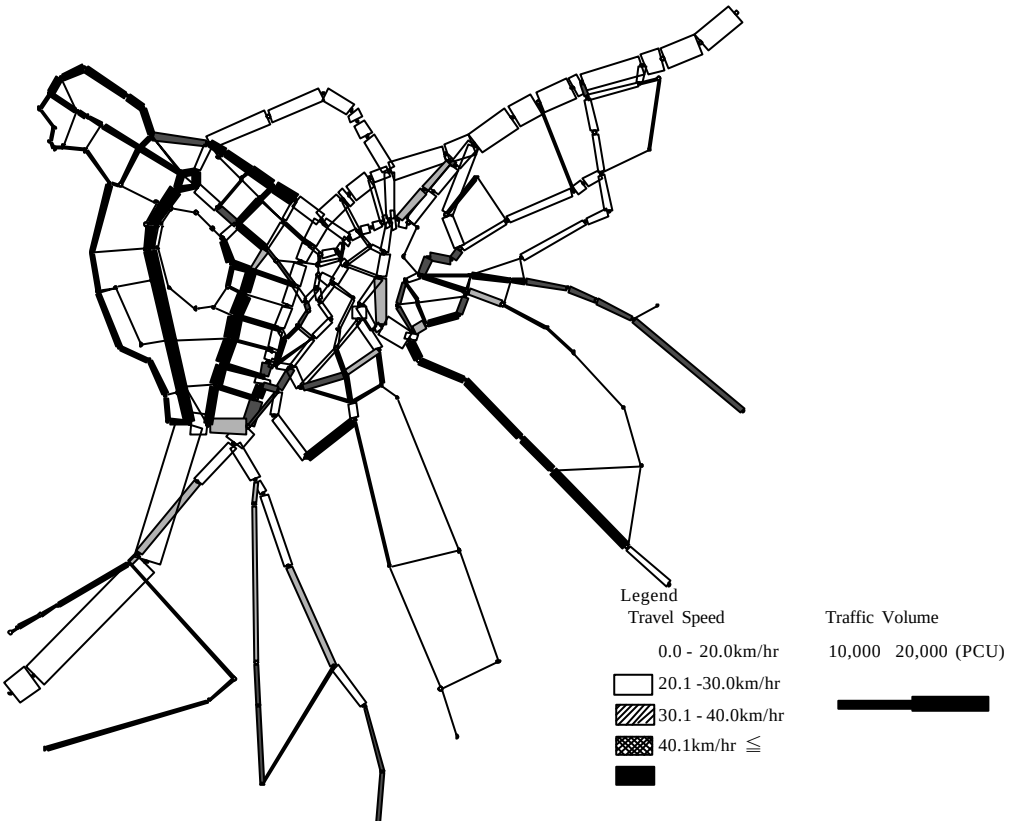


Do-Nothing – 2000

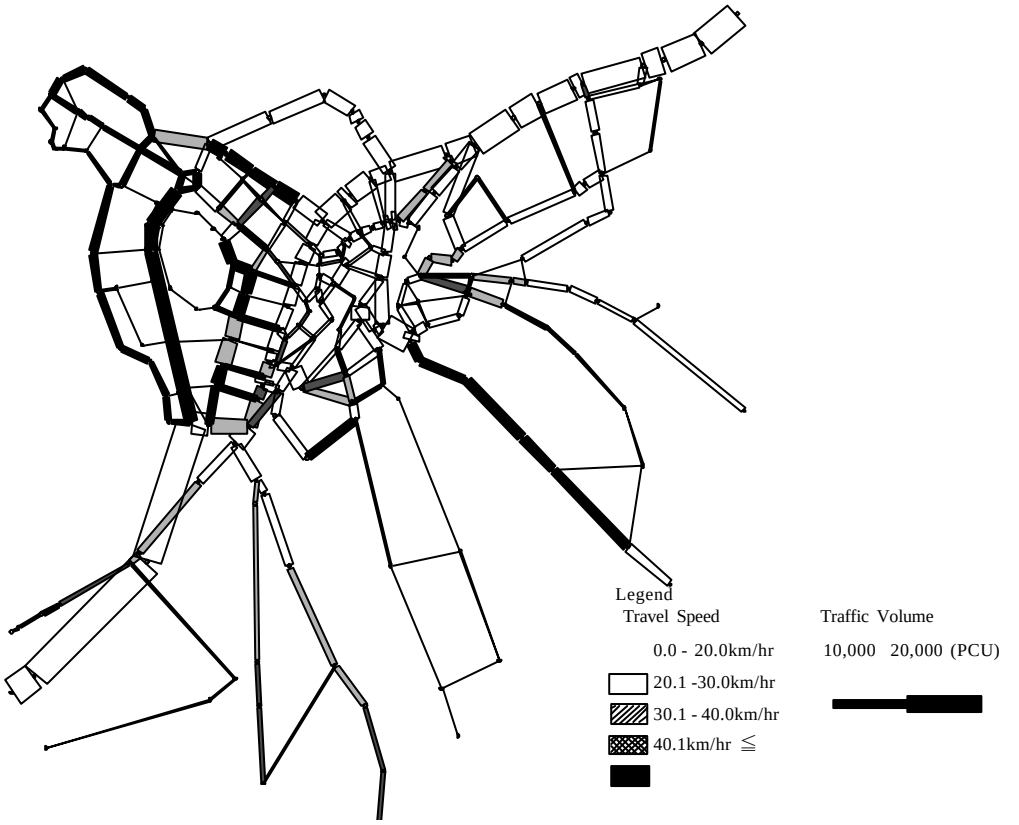


Do Nothing Case – 2005

Figure 3.9-2 Traffic Assignment Result – Travel Speed (1/2)



Do Nothing Case – 2010



Do Nothing Case – 2020

Figure 3.9-2 Traffic Assignment Result – Travel Speed (2/2)