The Present and Expected Future Structure and Operation of Traffic in Sakarya: Based on Transportation Master Plan

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Abstract

Sakarya Metropolitan Municipality is conducting a master plan to determine the future transportation strategies as far as city network is concerned as a whole. During this study the present characteristics of the network-based main components of the system were investigated and related parameters were revealed. This paper principally evaluates and investigates the present and future parameters of the city transportation system based on the present data obtained both from home-based surveys and site observations during master plan.

Keywords: Transportation network analysis, trip distribution, future travel demand

1.Introduction

With the expansion of the boundaries of the Sakarya Metropolitan Municipality, the future transportation planning investments, unlike the previous piecewise solutions, need to be combined and managed from a single centre. Thus, it is necessary to determine the present general physical, social and economic data of Sakarya, along with the data related to road infrastructure inventory, public transport services, interim management, intercity terminals, cycling, parking and pedestrian access to the information about the system. In this way, the solution to the city's main transport related problems and deficiencies are identified and the priorities may be decided.

Following, the goals of short and medium term of the city`s transportation projects will be based on these very vital data in order to use of public resources for efficient transportation investments. So, by taking into account the land use and economic structure of the city, a comfortable, safe, environmentally friendly and demand responsive affordable transportation system is aimed to be created.

The year 2023 was selected as the year of the projection target and the short, medium and long-term sustainable transport policies and plans were determined on a macro scale in transportation concept for the next 10-year period. The detailed applications of micro-projects in the areas of critical corridors were also prepared in accordance with construction and environmental development framework plans.

This study explains in detail the basic structures and relationship between the present and future macro and micro plans in the short and long range in terms of motorized and non – motorised private vehicles, local or long-distance passenger and freight transport by road or sea, and wheel or rail based public transport as far as the aspects of the Sakarya`s transportation and traffic for the year of 2023 are concerned. In addition, scientific transportation policies were explained after the transport model calibration has been done.

2. Study Area

Total working area of the study has an area of 4,817 m^2 with 16 towns. The following figure illustrates the study area in terms of city as a whole and the towns.

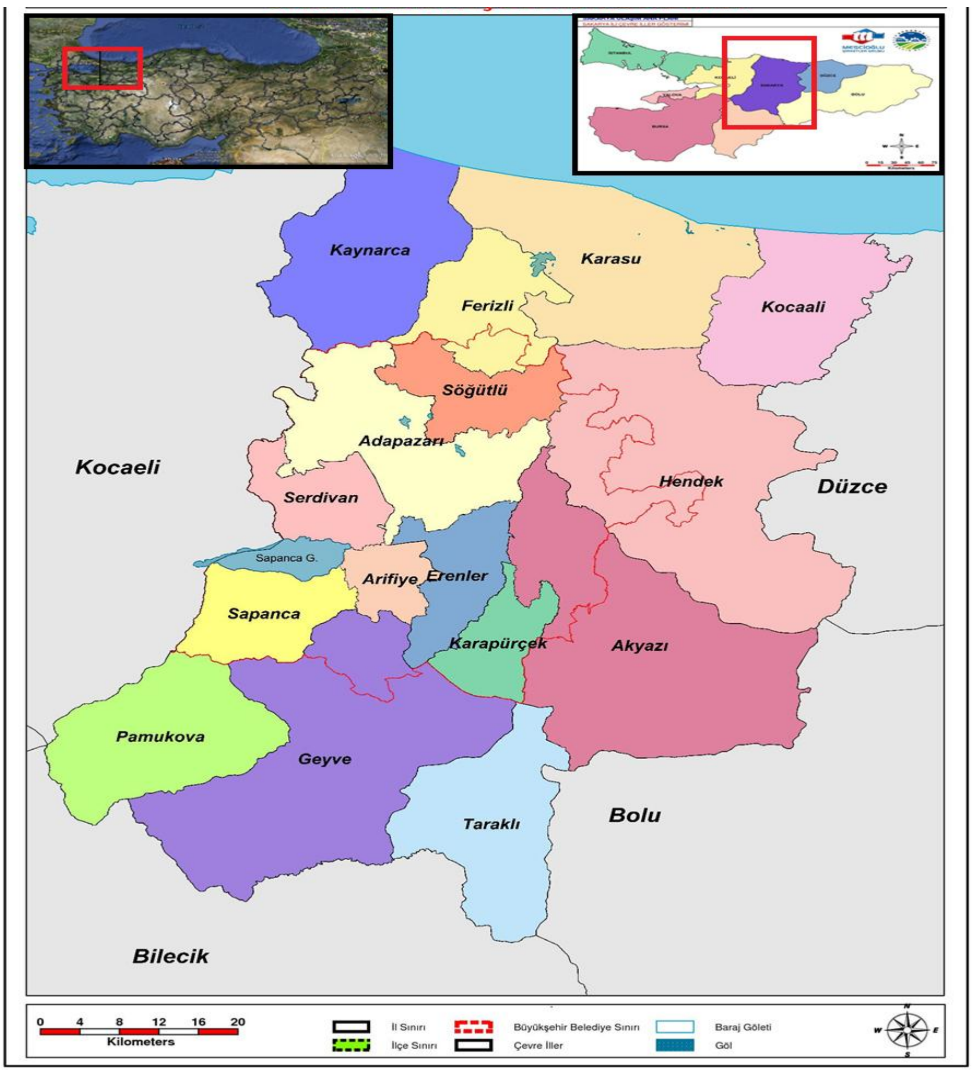

Figure 1. The Location of City of Sakarya with Towns

Table 1 given below illustrates the general information within the administrative border of Sakarya. The population data from the year 2011 states that the total number of people living in the city is 888.556. About 75 per cent of this population dwells in city and town centres rather than rural areas.

Table 1. Sakarya Province Administrative Boundary Information

Population	888.556
City Population Ratio (%)	75
Rural Population Ratio (%)	25
Annual Population Growth Rate (%)	1.8
Area (km^2)	4.817
Order in terms of Area (in Turkey)	66
Population Density (km^2)	184
Total Number of Towns	16
Total Number of Municipalities	29
Total number of Villages	426

The following figure displays the population density growth rate since 1980

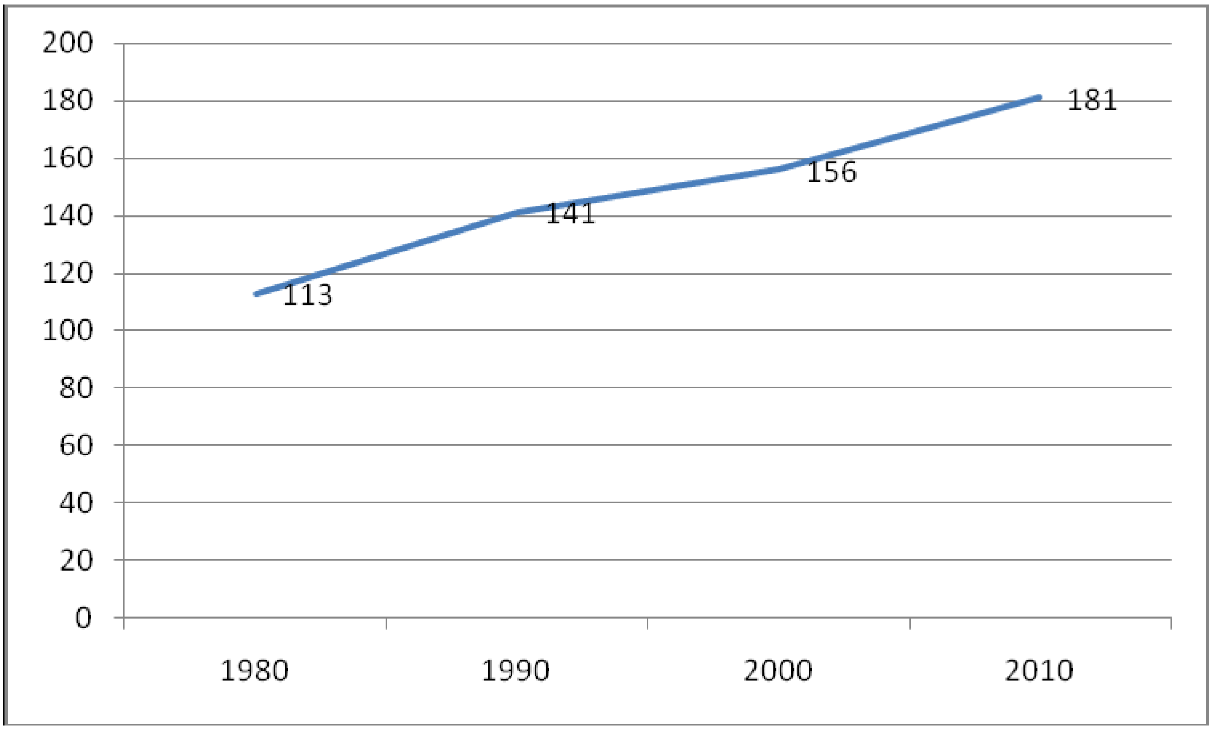

Figure 2. Population Density by Years (person / hectare)

The annual population growth rate of Sakarya has a fluctuated structure. Whereas the increase between 1955 and 1960 was 39.51 per cent, the rate reduced to 10.17 per cent between 1990 and 2000. Figure 3 below shows the general structure of annual population growth rate of the city.

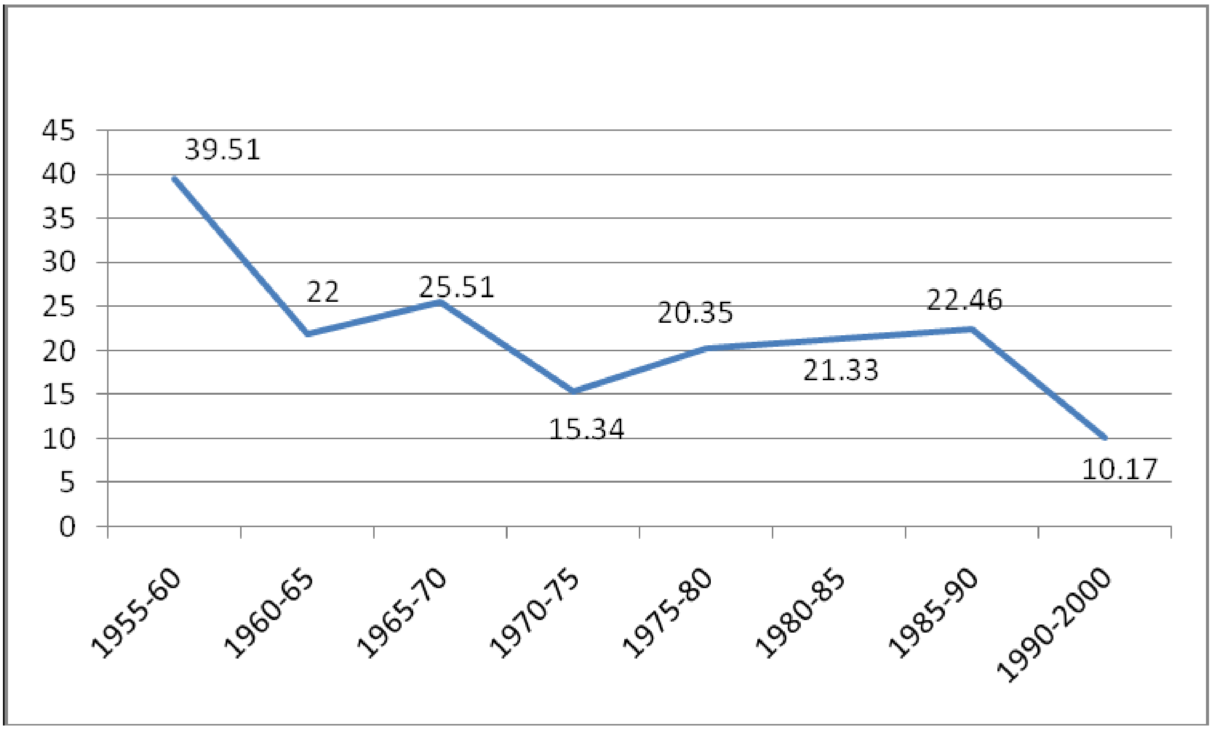

Figure 3. Annual Population Growth Rate Chart for Sakarya

2.3. Transportation Road Network Infrastructure

Total road length in the province of Sakarya is about 6.013 km. The road network comprises the motorways, state roads, provincial roads, streets and all sorts of village roads.

The most important arterial highway within the city is the transit traffic class service type TEM, which divides the city in east-west axis and has the length of 140km along with connecting roads. Another important road artery of the city is the state road, D-100 and has approximately more or less the same length of TEM.

The following table demonstrates the different types of roads within the city together with their total lengths.

Table 2. Types of Sakarya Province Road Lengths

Type of Road	***Length (km)***
Motorways	139
State Roads	540
Provincial Roads	354
Avenues and Streets	407
Village Roads	2085
District Roads	2488
Total	6013

3. Transportation Surveys

This study basically uses the data from Household Transport Survey, 2012 obtained through face-to-face questionnaires with 26.291 people from 7.320 different houses in Sakarya. Thanks to these questionnaires, the entire journey information of these households has been obtained in the last 24 hours.

Through the survey, the information of the surveyed people regarding their education-employment status and transport related characteristics such as car ownership, trip types, trip rates, travel times, trip distributions etc. was obtained.

3.1. Trip mobility rates

The mobility rates obtained from the survey can be tabulated as follows.

Table 3. City-wide Mobility Rates

The Purpose of the Trip	***Gross Mobility Rate***	***Net Mobility Rate***
Home Based Work Trips	0.42	1.98
Home Based School Trips	0.37	2.07
Home Based Other Trips	0.89	2.28
None Home-Based Trips	0.18	1.60
Total Trips	1.86	2.72

The survey results were categorised to see the general framework of the number of trips done among the towns in terms of the types of the trips.

The following table displays the trips produced and attracted by the towns of Sakarya

Table 4. Trips: Produced and Attracted by the Towns

Towns	Home - Work Prodction	Home - Work Attrction	Home-School Prodction	Home-Scholl Attrction	Home – Other Prodction	Home Other Attration	Other Production	Other Attraction	Total Production	Total Attraction
Adapazarı	109981	94968	95923	103396	244133	299702	73453	96664	523490	594730
Akyazı	33925	31984	32131	30393	74022	72408	12175	11476	152253	146261
Arifiye	16797	43524	16492	14371	36196	36308	9744	8634	79228	102837
Erenler	31608	38701	33079	28002	78590	68748	21176	18499	164452	153950
Ferizli	8118	4446	8897	8524	23926	21169	2865	2146	43806	36285
Geyve	18982	17298	17435	16110	56797	48700	7564	6972	100779	89080
Hendek	27955	30944	28273	29875	90113	87856	10927	10136	157268	158811
Karapürçek	4643	2600	4919	3248	13727	10058	2017	1181	25305	17087
Karasu	19385	18546	26028	23703	52907	46168	6853	6488	105173	94905
Kaynarca	8756	13188	8790	11280	28185	32693	4589	5951	50320	63112
Kocaali	4526	4711	9192	9499	20993	20498	2276	2844	36987	37552
Pamukova	11652	11910	13675	14043	32768	30182	4783	5470	62879	61605
Sapanca	15519	13679	14842	15219	47819	40612	7189	5578	85370	75088
Serdivan	39725	28822	37574	37534	106631	82129	37265	21929	221195	170414
Söğütlü	5404	2787	3638	5152	20120	26614	2938	2145	32100	36698
Taraklı	2159	1016	1308	1867	6906	10020	538	268	10910	13171
Total	**359135**	**359124**	**352196**	**352216**	**933832**	**933865**	**206352**	**206381**	**1851514**	**1851586**

3.2. Travel times

The average travel times for journeys in Sakarya were calculated as 20 and 26 minutes on foot and by vehicles, respectively. The least travel time was observed from Home-Other journeys as 17 minutes. This is followed by other-type journeys with the travel time of 19 minutes. However, the average travel time for journeys done by vehicles for any purposes exceeded 20 minutes. The longest journey time was obtained for the Home-School type trips as having an average of 29 minutes. When pedestrıan and vehicle travel times are compared, the biggest difference appears to be at Home-Other trips. This may be attributed to the fact that people tend to go shopping on foot rather than use their vehicles if the locations are close enough.

The table below shows the city-wide average journey times.

Table 5. City-Wide Average Travel Times

	All journeys including on foot		Journeys by vehicles	
	Average Time (minutes)	Standard Deviation	Average Time (minutes)	Standard Deviation
Home-Work	24	20	27	18
Home-School	20	16	29	18
Home-Other	17	15	25	18
Other	19	15	23	17
Weighted Average	**20**	**17**	**26**	**18**

3.3. Modal Distribution

Table 6 illustrates the obtained data from a multi-answer question for the journeys of all types of transportation modes. This is simply because a journey may be completed by to some extend on-foot along with private car, buses or minibuses. Thus, this table represents this sectional structure of the journeys.

Table 6. Modal Splits of the Journeys (**%**)

	Within Municipality	Outside of Municipality	Total
On Foot	46.0	55.9	48.6
Private Car (Driving Alone)	7.4	5.6	6.9
Private Car Shared (As Driver)	4.1	3.8	4.0
Private Car Shared (As Passenger)	6.3	6.9	6.4
Taxi	0.3	0.4	0.3
Service	9.9	10.3	10
Taxi Dolmus	7.7	3.0	6.5
Minibus	4.7	2.2	4.1
Publicly Owned Buses	5.0	1.7	4.2
Privately Owned Buses	3.9	2.4	3.5
Motorcycles	0.8	0.9	0.8
Bicycles	1.7	0.5	1.4
Other	2.3	6.5	3.4
TOTAL	100	100	100

As can be seen from the table above, on-foot journeys represent nearly half of the all types of the journeys. Journeys with services denote at about the 10 per cent of the all journeys in both within and outside of the municipality. The usage of private cars for the journeys is 18 and 16 per cent within and outside of the municipality, respectively.

4. Development and Calibration of Transportation Model

Traffic analysis zones, transport network setting up steps, development of network database and link capacity functions are all used for the calibration of the model.

4.1 Traffic analysis zones

For the model creation and calibration, traffic analysis zones are identified as the components of the study area and based on the district and village settlements within the municipal boundaries of the metropolitan.

The study area covers all the boundaries of Sakarya Municipality consists of,

- 11 towns
- 104 traffic analysis zones
- 189 residential neighbours
- 117 villages

The traffic analysis zones were determined according to the following criteria.

- The smallest administrative units were considered as residential neighbours
- The neighbours having similar geographical, demographic and economic characteristics were taken into account in a single traffic analysis zone.
- Utmost care was paid to represent the real case in the model as realistic as possible by obtaining socially and economically homogenous zones.

The following table illustrates numbers and sizes of the traffic analysis zones of the towns within Municipality.

Table 7. Numbers and Sizes of the Zones of the Towns

Towns	**Number of Zones**	**Min Area and Population of the Zones (km^2)**	**Max.Area and Population of the Zones (km^2)**	**Average Zone Area and Population (km^2)**	**Total Zone Area and Population (km^2)**
Adapazarı	31	0.45 - 3195	62.54 – 18236	10.16 – 8119	315.07 – 251.680
Akyazı	12	0.36 - 3095	43.85 – 5209	11.47 – 4042	137.66 – 48.504
Arifiye	7	3.04 - 3333	26.93 – 8240	10.07 – 5413	70.01 – 37.889
Erenler	12	0.41 - 2467	57.13 – 11478	10.95 – 6307	131.33 – 75.682
Ferizli	3	2.40 - 3445	19.76 – 5593	10.76 – 4353	32.28 – 13.058
Hendek	9	0.52 - 2398	85.87 – 10836	10.40 – 5495	124.89 – 49.454
Karapurçek	3	8.03 - 2690	85.49 - -	34.74 – 4104	104.17 – 12.311
Sapanca	9	1.44 - 1588	101.27 – 10645	16.70 – 4232	150.25 – 38.089
Serdivan	12	1.04 - 1488	37.41 – 18288	10.40 – 8087	124.79 – 97. 044
Sogutlu	4	18.64 – 3353	61.00 – 3981	34.53 – 3557	138.06 – 14.229
Geyve	2	25.80 - 2423	52.44 - 2388	39.11 - 2631	78.23 – 5261
Total	**104**				**1406.74 – 643.201**

4.2 Trip distribution modelling

The main purpose of the distribution model is to determine the production and attraction trips among the zones for different journey purposes. Hence, the model eventually produces the Production-Attraction matrices for the zones of the study area.

Gravity and Growth Factor models are among those commonly used for the trip distribution modelling. Gravity model employed in this study to determine the amount of trips among the zones is proportional to the production of the origin point and attraction of the destination point but inversely proportional to the distance between the origin and destination points.

4.2.1 Calculation of gravity model parameters

The following mathematical structure of gravity model is used to estimate the trips among the zones.

$$T_{ij}^{p} = a_i * b_j * G_i^{p} * A_j^{p} * f^{p}(t_{ij})$$

where;

T_{ij}^{p} is the number of trips between the zones i and j for the trip purpose of p

G_i^{p} is the number of trips produced by zone i for the trip purpose of p

A_j^{p} is the number of trips attracted by zone j for the trip purpose of p

$f^{p}( )$ is the trip resistance function between zones i and j for the purpose of p

t_{ij} is the total travel time between the zones i and j

a_i and b_j are the constants.

There are also two constraints of this equation;

The first one is related to the productions of the zones;

$$\sum_j T_{ij}^{p} = G_i^{p}$$

The second one, on the other hand, is related to the attractions of the zones;

$$\sum_i T_{ij}^{p} = A_j^{p}$$

The resistance function here is considered to be related to the travel times among the traffic analysis zones. The calibration of the model produced good results when the travel times determined according to the free flow speeds. The travel times were based upon the network structure throughout the city. The shortest path algorithm is determined by giving extra 0.5 minute for the left turn and 0.25 minute for the right turns.

The following table displays average travel times obtained from the observations and calibrated model. As can be seen from the table, the calculated values remain little bit high compare to the observed ones.

Table 8. Comparison of Average Travel Times for Observed and Calibrated Model Data

Average Travel Times (minutes)		
Trip Purpose	Observed	Calibrated Model
Home - Work	24.3	29.5
Home - School	18.8	26.4
Home - Other	19.0	26.8
Other	21.5	26.6
Total	20.4	27.2

Using the calibrated model, total trips were determined as far as each town is concerned in terms of trip production and attraction. The following table gives these results.

Table 9. Town Based Trip Distributions

TOWNS	ADPZ	AKYZ	ARFY	ERNLR	FRZL	GYVE	HNDK	KRPRC	SPNC	SRDVN	SGTL	**TOTAL**
ADPZ	320.438	19.691	31.528	48.191	5.212	2.522	21.319	3.342	14.369	61.230	14.326	542.169
AKYZ	17.926	38.396	5.089	6.931	553	556	10.627	2.681	2.901	5.308	1.428	92.398
ARFY	25.892	4.505	26.711	9.451	645	1.355	4.684	896	5.341	9.934	1.573	90.988
ERNLR	62.613	8.697	12.979	41.460	1.258	1.038	8.649	1.844	4.842	16.891	3.011	163.282
FRZL	6.231	793	1.093	1.369	7.514	91	929	135	499	1.547	2.261	22.459
GYVE	3.131	823	1.167	979	106	1.897	803	166	973	1.056	309	11.410
HNDK	18.115	9.634	4.778	6.530	610	475	57.146	1.174	2.544	5.388	1.516	107.910
KRPRC	5.532	4.642	1.654	2.484	177	189	2.095	4.729	816	1.696	456	24.472
SPNCA	18.679	4.215	7.202	6.023	524	1.203	4.085	733	32.863	7.412	1.401	84.340
SRDVN	85.906	7.335	13.289	18.032	1.603	1.278	8.037	1.309	7.129	63.742	4.405	212.066
SGTL	11.010	1.239	1.516	2.083	1.414	163	1.386	215	787	2.553	9.460	31.825
TOTAL	**575.473**	**99.971**	**107.006**	**143.533**	**19.616**	**10.766**	**119.761**	**17.226**	**73.064**	**176.759**	**40.145**	**1,383.319**

5. Determination of The Present and Future Problems and Discussions

Being on the corridors of roadway- seaway and railway intersection points, the transportation problems become more complicated with the development of city of Sakarya.

There are two main roads, Adnan Menderes and Sakarya Avenues , to reach the city centre from the city entrance and exit roads. Since there are no alternatives of these two roads and these roads reach at the heart of the city, there appear serious traffic congestions on these roads. The intersection point of these two roads, Yeni Cami Junction, experiences unbearable traffic flows with huge delays.

When signalisation network is considered as a whole, there are serious signal optimisation problems. The fact that there is an imbalance between the main and secondary roads in terms of the available green times causes the main roads operate with lower capacity level.

Another important point to be mentioned is related to harmony of the ring road and the connecting roadways. The reduction in the lane number and the quality of the road surface adversely affects the level of the service provided by the transportation network.

One of the main purposes of this study to determine the possible problems to be faced on the transportation network in the near future based on the trends in city development and network topology. The calibrated model is the main tool used for this purpose.

The results indicate that for do-nothing scenario, the flows on main arterials will be either at or mostly above the capacity levels of the roads. However, it should be mentioned that even in this scenario, the traffic related problems will not be as serious as Istanbul and Ankara experience.

The main approach to the city transportation problems should be related to the increase of the effectiveness and accessibility of the public transportation systems. The present uncontrolled public transportation operation system seems to be contributing to increase the traffic problems, too. A city council directed public transportation system as a whole might be the first step to organise the public transportation system in the near future.

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