Urban Mobility Indicators for Thessaloniki

Evangelos Mitsakis, Iraklis Stamos, Josep Maria Salanova Grau, Evangelia Chrysochoou, Panagiotis Iordanopoulos, and Georgia Aifadopoulou
Centre for Research and Technology Hellas/Hellenic Institute of Transport, Thessaloniki, Greece
Email: {emit, stamos, jose, echrysochoou, panior, gea}@certh.gr

Abstract—**This paper aims at presenting up-to-date urban mobility and traffic related indicators for the city of Thessaloniki, Greece. Insights are provided on the modeling approach and the methodologies used for the calculation of the mobility indicators, in regard to travel demand estimation and assignment of traffic in the network. Travel demand and supply data used for modeling urban mobility are presented, together with the processes followed and their outputs. Car ownership, vehicle occupancy, modal split and hourly traffic volumes are among the examined indicators.**

Index Terms—**Mobility indicators, transport modeling, travel demand, urban mobility.**

I. Introduction

This paper aims at presenting up-to-date urban mobility indicators for the city of Thessaloniki, related to network's operational characteristics, travel demand and supply. The urban mobility modeling approach is also presented.

The paper is structured as follows: Under the background information section, a brief description of Thessaloniki in terms of demographical and traffic related characteristics is given, along with the study context, in the framework of which the results of this paper are based. The urban mobility modeling section presents the input data and methodological approach followed for estimating travel demand, correcting trip matrices and assigning traffic in the network. Finally, the output section includes results both from the developed models as well as from two mobility surveys, providing an overview of the current (2012) mobility and traffic conditions in Thessaloniki.

II. Background Information

A. Demographics

Thessaloniki is the second largest city in Greece, currently accommodating 1.006.730 citizens in its greater area [1]. Situated in Northern Greece, Thessaloniki covers a total of 1.455,68 km^2 with an average density of 665,2 inhabitants per km^2. Due to its geographical location, Thessaloniki plays an important social, financial, and commercial role in the national and greater Balkan region, also due to the development of a transportation hub within the city's limits. According to the General Secretariat, the total number of vehicles in the city exceeds 777.544, including private cars, heavy vehicles and motorcycles [1].

Manuscript received December 31, 2012; revised February 15, 2013.

B. Study Context

The research presented herein has been conducted within the framework of the "Intelligent Urban Mobility Management and Traffic Control System for the improvement of the urban environment quality in the central area of Thessaloniki's agglomeration" project. The project aimed to provide a suite of services for travelers, in order to assist them in everyday mobility related decisions by providing real time mobility related- and environmental conditions information, optimal route planning based on traveler-defined criteria (fastest, shortest, cost efficient and environmental friendly routing), public transport information and routing services, ride sharing and user awareness tools [2] and [3].

III. Urban Mobility Modeling

A. Input Data and Methodology

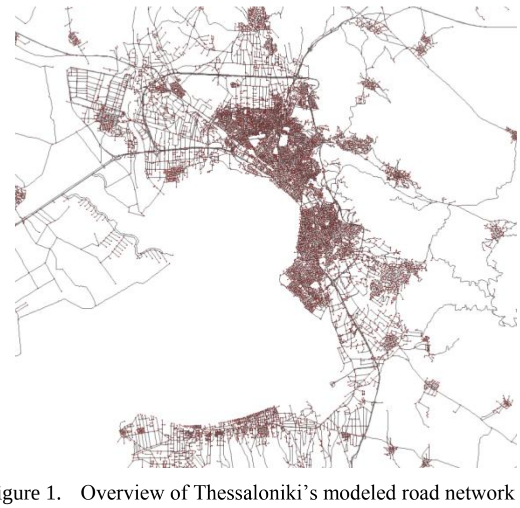

Figure 1. Overview of Thessaloniki's modeled road network

The urban mobility model for Thessaloniki [4] has been developed with the use of open-source GIS data [5] fused with traffic related parameters. The supply side of the transportation model includes 47.807 intersections, which contain detailed information about the geometry, allowed movements and control type, and 137.854 directed links, bearing geometric (length, location in the network) and traffic related characteristics (number of lanes, free flow speed, capacity, direction, allowed transportation modes, existence of dedicated lanes,

doi: 10.12720/jtle.1.2.148-152

parking prohibition). Links' capacity has been reduced, based on the number of hourly public transport transits [6], so as to account for the use of the road network by public transport vehicles. Fig. 1 depicts Thessaloniki's modeled road network.

Links are classified in 6 categories, depending on their capacity and free flow speed. Each road category has a unique Volume-Delay function (BPR). Fig. 2 depicts the curves of the volume-delay functions used for the urban mobility model of Thessaloniki.

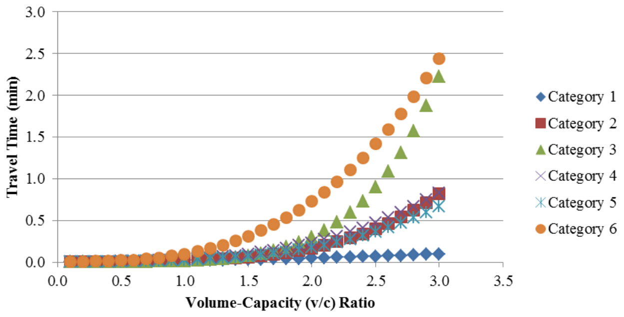

Figure 2. Volume-Delay functions' curves per road category

The network consists of 359 traffic analysis zones, 306 of which are used for describing the metropolitan area of Thessaloniki, while the rest are external zones. A total of 3.508 connectors are used for connecting zones to physical nodes of the road network, according to their accessibility index [7], avoiding connections with nodes of high hierarchy links.

The demand side consists of 24 hourly Origin-Destination (O-D) matrices for private vehicle trips.

B. Processes

1) Travel demand estimation

Travel demand estimations have been based on 5.000 household phone surveys and Road Side Surveys (RSS) at 40 locations with 33.000 participants, executed between October and November 2010. Using a production-attraction model, the information collected by the surveys has been extrapolated on zone populations, employment rates and land uses. The resulting O-D matrix has then been temporally segmented in hourly intervals based on the profile of the RSS and the household phone survey data for each O-D pair, so that each trip is attributed to the respective time interval.

2) O-D matrix correction

In order to calibrate the estimated travel demand, the surveys' obtained O-D matrices have been corrected based on measured, hourly volume data with an average goodness-of-fit of 0,97. The correction has been performed with a fuzzy-set based matrix correction procedure [8].

3) Traffic assignment

The user equilibrium traffic flow estimation, based on Wardrop's user equilibrium principle [9], has been solved with an implementation of the Linear User Cost Equilibrium algorithm [10], terminating at pre-specified goodness-of-fit criteria for the resulting traffic volumes [11].

C. Outputs-Results

4) Surveys

Based on the household phone surveys, the average number of persons in a household is estimated at 3,03 and the respective average of driving license holders per household at 1,75. Additionally, 58% of all citizens hold a driving license and 71% of the population owns at least one private car. Fig. 3 depicts the respective percentages of car ownership per number of owned cars.

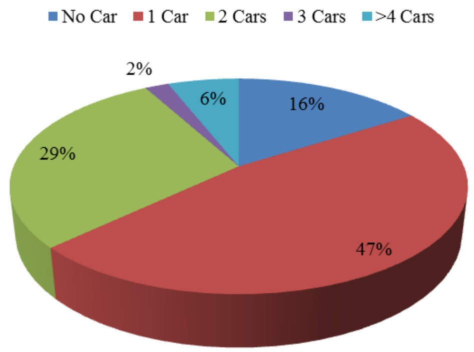

Figure 3. Car ownership in Thessaloniki

The average number of trips per person is 2,08. 89,4% of the survey participants stated that they usually execute up to two trips per day: one trip for various purposes (work, education, leisure, etc.) and one trip for returning home. As depicted in Fig. 4, among various trip purposes, 47,6% of the trips are conducted for work and 26,8% for leisure. The percentages for shopping, education and other purposes are 12,9%, 5,8% and 6,8% respectively.

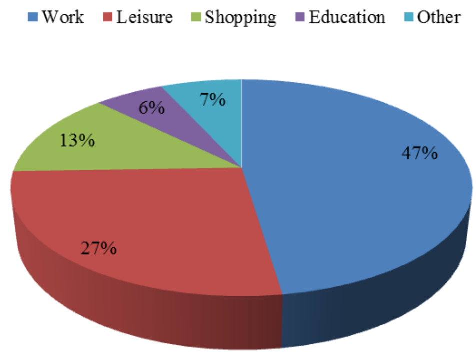

Figure 4. Trip purpose in Thessaloniki

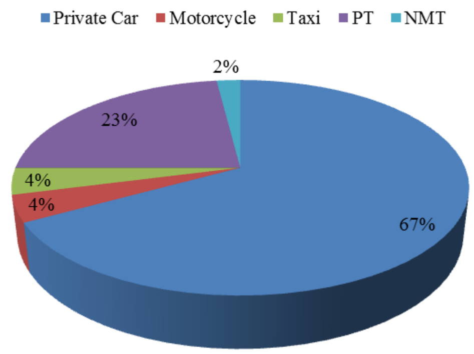

Figure 5. Modal split in Thessaloniki

The modal split analysis, presented in Fig. 5, shows that the majority of trips is conducted with private vehicles (67% private cars, 4% motorcycles and 4% taxis), while 23% is conducted with public transport (PT) and 2% with non-motorized modes of transport (NMT).

Based on the RSS results, the average vehicle occupancy is 1.44. As depicted in Fig. 6, 65% are single occupancy vehicles, while 28% and 6% of the vehicles travel with 2 and 3 passengers respectively.

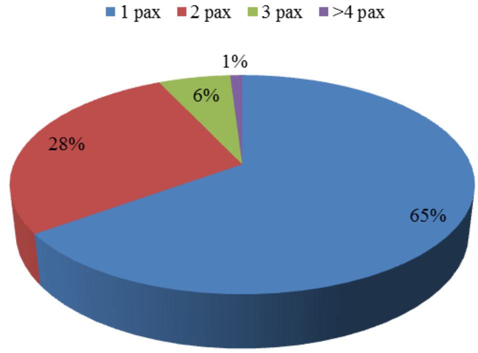

Figure 6. Vehicle occupancy in Thessaloniki

Concerning the vehicle type distribution, this is estimated as follows: 77% private vehicles, 5% motorcycles, 2% taxis, 11% vans and 5% trucks.

The temporal profile of the measured traffic volumes is presented in Fig. 7, where the morning and afternoon peak traffic hours are observed between the 08:00-09:00 and 16:00-17:00 time intervals respectively.

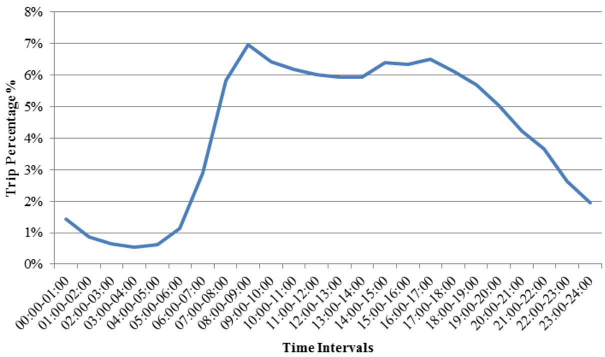

Figure 7. Trip percentage distribution over 24 hourly intervals

5) *O-D matrix correction*

The O-D matrices estimated through the surveys have been further corrected using hourly volume data measured by 557 inductive loops installed throughout the network and 33 traffic cameras, mainly located in the city center. The data used for correcting the O-D matrices refer to November 2012. Table I presents the temporal distribution of travel demand in Thessaloniki (total number of trips per time interval) before and after the O-D matrices correction process.

TABLE I. TOTAL AMOUNT OF TRIPS IN THE INITIAL AND FINAL O-D MATRICES

	Total number of trips in the Initial O-D	Total number of trips in the Final O-D	% Difference Final vs. Initial O-D
00:00-01:00	16.054	21.436	25%
01:00-02:00	6.927	11.503	40%
02:00-03:00	5.464	11.503	52%
03:00-04:00	3.778	7.531	50%
04:00-05:00	3.228	6.921	53%
05:00-06:00	3.715	11.248	67%
06:00-07:00	18.113	28.165	36%
07:00-08:00	65.950	66.954	1%
08:00-09:00	74.059	94.580	22%
09:00-10:00	58.013	82.539	30%
10:00-11:00	54.246	79.401	32%
11:00-12:00	52.520	76.044	31%
12:00-13:00	51.907	79.666	35%
13:00-14:00	52.904	79.540	33%
14:00-15:00	54.034	81.586	34%
15:00-16:00	63.529	90.447	30%
16:00-17:00	59..145	75.912	22%
17:00-18:00	55.558	76.009	27%
18:00-19:00	51.186	73.845	31%
19:00-20:00	44.854	70.937	37%
20:00-21:00	35.044	60.034	42%
21:00-22:00	29..260	53.820	46%
22:00-23:00	21.946	37.983	42%
23:00-24:00	15.610	28.687	46%

Fig. 8 shows the hourly distribution of the total number of trips of the initial and final O-D matrices.

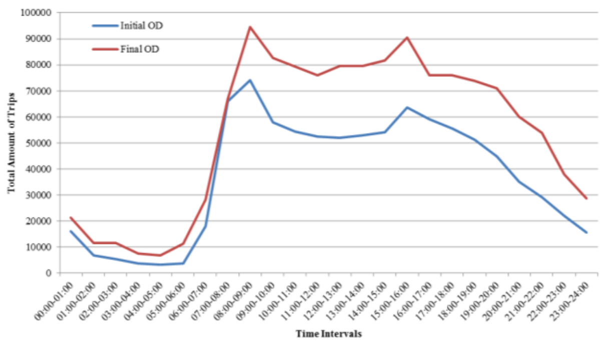

Figure 8. Initial and Final O-D matrices

The total travel demand for a typical weekday is estimated in the range of 1.300.000 vehicle trips. On a daily average, the city center attracts a total of 11,5% of all trips. Table II shows the respective attraction percentages for all municipal departments (MD), depicted in Fig. 9.

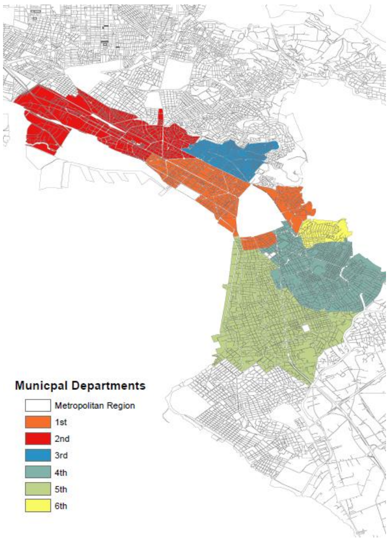

Figure 9. Municipal Departments of the Thessaloniki's municipality

TABLE II. DAILY NUMBER OF ATTRACTED TRIPS PER MUNICIPAL DEPARTMENT (IN THOUSANDS)

Typical Weekday Number of Trips	1.306	
MD 1	132	10,1%
MD 2	76.3	5,8%
MD 3	40.8	3,1%
MD 4	100.9	7,7%
MD 5	155.2	11,9%
MD 6	10.8	0,8%

Concerning the morning peak hour traffic, 32% of all trips originate from the municipality of Thessaloniki and 37% of all trips have a destination within the same area. The percentage of trips originating and ending in the city center (MD 1) are 4,9% and 8,7% respectively.

Based on the available traffic measurements, a weekly profile for the travel demand is presented in Fig. 10.

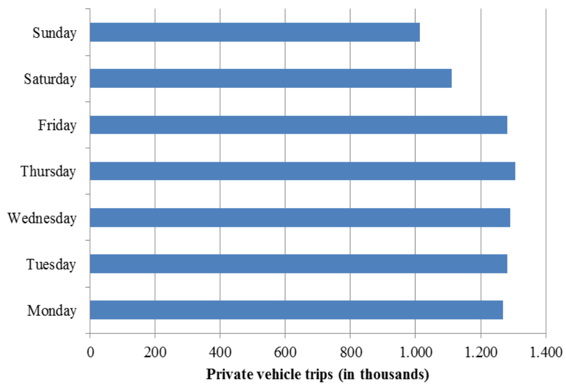

Figure 10. Travel demand (private vehicles) per weekday

6) *Traffic assignment*

During the morning peak hour of a typical weekday, average travel time for all trips conducted in the network of Thessaloniki is 33,13 minutes and the average vehicle speed is 37,8km/h.

TABLE III. MEASURED AND MODELED HOURLY TRAFFIC VOLUME IN MAIN AXES

Road Axis	From	To	Measured Volume	Modeled Volume	% Difference Modeled vs. Measured Volume
26 Oktovriou	Sapfous	Aisopou	1.150	1.114	-3,2%
Aggelaki	Svolou	Egnatia	-	821	-
Ag. Dimitriou	Zografou	Aminis	1.008	998	-1,0%
Ag. Dimitriou	Aminis	Zografou	1.316	1.291	-1,9%
Svolou	Apellou	Germanou	610	617	1,1%
Andronikou	3 Septemvriou	YMCA	2.897	2.816	-2,9%
V. Olgas	Sofouli	25 Martiou	-	2.259	-
V. Olgas	Sindika	Mpotsari	-	2.378	-
Venizelou	Ermou	Egnatia	-	469	-
3 Septemvriou	Egnatia	Ag. Dimitriou	-	1.203	-
Egnatia	Venizelou	Ag. Sofias	-	1.032	-
Egnatia	3 Septemvriou	E. Aminis	-	1.893	-
Egnatia	Ekthesi	Sintrivani	1.579	1.617	2,4%
Aminis	Svolou	Tsimiski	-	611	-
Venizelou	V. Irakleiou	Ermou	488	482	-1,2%
Ermou	Aristotelous	K. Ntil	395	395	0,0%
Dragoumi	Tsimiski	Mitropoleos	554	563	1,6%
Kountouriwtou	Dikastirion	N. Limnou	1.551	1.617	4,1%
L. Nikis	Gounari	Foka	1.329	1.315	-1,1%
L. Stratou	Dragoumi	Venizelou	2.032	1.977	-2,8%
L. Stratou	YMCA	3 Septemvriou	545	565	3,5%
L. Stratou	3 Septemvriou	YMCA	1.704	1.651	-3,2%
Mitropoleos	Venizelou	Komninon	345	350	1,4%
N. Germanou	L. Pirgos	YMCA	653	629	-3,8%
Mela	M. King	Germanou	494	497	0,6%
Mela	Tsimiski	Mitropoleos	-	495	-
Ring Road	Center	Touba	-	3.430	-
Ring Road	Touba	Center	-	3.520	-
Politexneiou	Limnou	Dikastirion	3.412	3.490	2,2%
Tsimiski	YMCA	Dialetti	2.105	2.093	-0,6%
Tsimiski	Komninon	Venizelou	3.575	3.490	-2,4%
Tsimiski	Ntil	Venizelou	-	3.178	-
Tsimiski	Ag. Sofias	Ntil	-	3.784	-

Table III presents modeled hourly traffic volumes along the main road axes of Thessaloniki's network (Fig. 11) on a typical weekday during morning peak hour. When available, measured traffic volumes at respective locations are also presented.

Figure 11. Main road axes of Thessaloniki's network

IV. CONCLUSIONS

This paper presented up-to date urban mobility and traffic related indicators for the city of Thessaloniki, Greece and provided insights on the methodology with which these indicators were obtained. These indicators can provide a clear overview on the current mobility situation in Thessaloniki and can be a common database used for further analysis and research by various stakeholders (policy makers, authorities and private companies).

REFERENCES

[1] 2011 Census Data. (2012). [Online]. Available: www.statistics.gr

[2] M. Morfoulaki, E. Mitsakis, K. Chrysostomou, and I. Stamos, "The contribution of urban mobility management to trip planning and the environmental upgrade of urban areas," *Procedia: Social and Behavioral Sciences* (20), pp.162-170, 2011.

[3] E. Mitsakis, J. M. Salanova Grau, E. Chrysohoou, and G. Aifadopoulou, "A robust method for real time estimation of travel time for dense urban road networks using point-to-point detectors," in *Proc. TRB Annual Meeting*, Washington D.C., 2013.

[4] M. Friedrich, "A multi-modal transport model for integrated planning" in *Selected Proceedings from the Eighth World Conference on Transport Research*, Elsevier, Antwerp, Belgium H. Meersman, E. Van de Voorde, W. Winkelmans (Eds.), vol. 2, 1999.

[5] Geodata. (2012). [Online]. Available: http://www.geodata.gov.gr/geodata/

[6] Organization of Urban Transportation of Thessaloniki. (2012). [Online]. Available: www.oasth.gr

[7] M. Friedrich and M. Galster, "Methods for generating connectors in transport planning models," in *Proc. TRB Annual Meeting*, Washington D.C., 2009.

[8] J. Rosinowski, "Entwicklung und Implementierung eines ÖPNV-Matrixkorrekturverfahrens mit Hilfe von Methoden der Theorie unscharfer Mengen (Fuzzy-Sets-Theorie)," M.S. thesis, University of Karlsruhe, 1994.

[9] J. G Wardrop, "Some theoretical aspects of road traffic research," in *Proceedings of the Institute of Civil Engineers*, 1952, Part II, pp. 325–378.

[10] G. Gentile and K. Noekel, "Linear User Cost Equilibrium: the new algorithm for traffic assignment in VISUM," in *Proceedings of European Transport Conference*, Leeuwenhorst Conference Centre, Netherlands, 2009.

[11] Highway Agency, "Design manual for roads and bridges," Traffic appraisal of road schemes, vol. 12, Section 2.5, Part I, Traffic appraisal in urban areas, The Stationery Office, London, 1996.

E. Mitsakis holds a PhD in civil and transportation engineering from the Aristotle University of Thessaloniki, Greece. Since 2005 he works as a post-doctoral researcher for the Hellenic Institute of Transport of the Centre for Research and Technology Hellas in Thessaloniki, Greece. During the last three years he has been working on the analysis and optimization of transportation networks with the use of modelling techniques and has published several related scientific papers as well as book chapters. Dr. Mitsakis is a member of several scientific and professional societies in Greece and abroad, as well as an active member of working groups in European transport research organizations

I. Stamos is a PhD candidate in transportation engineering at the Aristotle University of Thessaloniki, Greece. He holds an M.Sc. degree in transportation systems from the Technical University of Muenchen. Since 2011 he works as an associate researcher at the Hellenic Institute of Transport, Centre for Research and Technology Hellas, in Thessaloniki, Greece.

J.M.. Salanova holds a Civil engineering diploma from the Polytechnic University of Catalonia in Barcelona and a MSc in civil and transportation engineering from the Aristotle University of Thessaloniki, Greece. Since 2008 he works as researcher for the Hellenic Institute of Transport of the Centre for Research and Technology Hellas in Thessaloniki, Greece.

E. Chrisohoou graduated from the Department of Mathematics of the Aristotle University of Thessaloniki in 2003. She obtained the MSc degree in Statistics and Operation Research of the Aristotle University of Thessaloniki in 2006. Since 2005 she works as a research associate of the Hellenic Institute of Transport of the Centre for Research and Technology Hellas in Thessaloniki, Greece.

P. Iordanopoulos a MSc in civil and transportation engineering from the Aristotle University of Thessaloniki, Greece. He is a PhD candidate at the Democritus University of Thrace in Greece. Since 2010 he works as researcher for the Hellenic Institute of Transport of the Center for Research and Technology Hellas in Thessaloniki, Greece.

G. Aifadopoulou holds a PhD in civil and transportation engineering from the Aristotle University of Thessaloniki, Greece, a Postgraduate diploma in Informatics at the University of PARIS VII and Transportation Planning and Engineering Diploma from the Ecole Nationale des Ponts et Chausees of Paris. Since 2001 she works as a post-doctoral researcher for the Hellenic Institute of Transport of the Centre for Research and Technology Hellas in Thessaloniki, Greece. During the last three years he has been working on the urban mobility model of the city of Thessaloniki and has published several related scientific papers as well as book chapters.