

TeMA

Journal of
Land Use, Mobility and Environment

CITIES, ENERGY AND MOBILITY

3 (2015)

Published by

Laboratory of Land Use Mobility and Environment
DICEA - Department of Civil, Architectural and Environmental Engineering
University of Naples "Federico II"

TeMA is realized by CAB - Center for Libraries at "Federico II" University of Naples using Open Journal System

Editor-in-chief: Rocco Papa
print ISSN 1970-9889 | on line ISSN 1970-9870
Licence: Cancelleria del Tribunale di Napoli, n° 6 of 29/01/2008

Editorial correspondence

Laboratory of Land Use Mobility and Environment
DICEA - Department of Civil, Architectural and Environmental Engineering
University of Naples "Federico II"
Piazzale Tecchio, 80
80125 Naples
web: www.tema.unina.it
e-mail: redazione.tema@unina.it

Cover Image:

TeMA. Journal of Land Use, Mobility and Environment offers researches, applications and contributions with a unified approach to planning and mobility and publishes original inter-disciplinary papers on the interaction of transport, land use and environment. Domains include: engineering, planning, modeling, behavior, economics, geography, regional science, sociology, architecture and design, network science and complex systems.

The Italian *National Agency for the Evaluation of Universities and Research Institutes* (ANVUR) classified TeMA as scientific journal in the Area 08. TeMA has also received the *Sparc Europe Seal for Open Access Journals* released by *Scholarly Publishing and Academic Resources Coalition* (SPARC Europe) and the *Directory of Open Access Journals* (DOAJ). TeMA is published under a Creative Commons Attribution 3.0 License and is blind peer reviewed at least by two referees selected among high-profile scientists. TeMA has been published since 2007 and is indexed in the main bibliographical databases and it is present in the catalogues of hundreds of academic and research libraries worldwide.

EDITOR IN-CHIEF

Rocco Papa, University of Naples Federico II, Italy

EDITORIAL ADVISORY BOARD

Mir Ali, University of Illinois, USA
Luca Bertolini, University of Amsterdam, Netherlands
Luuk Boelens, Ghent University, Belgium
Dino Borri, Polytechnic University of Bari, Italy
Enrique Calderon, Polytechnic University of Madrid, Spain
Roberto Camagni, Polytechnic University of Milan, Italy
Derrick De Kerckhove, University of Toronto, Canada
Mark Deakin, Edinburgh Napier University, Scotland
Aharon Kellerman, University of Haifa, Israel
Nicos Komninos, Aristotle University of Thessaloniki, Greece
David Matthew Levinson, University of Minnesota, USA
Paolo Malanima, Magna Græcia University of Catanzaro, Italy
Agostino Nuzzolo, Tor Vergata University of Rome, Italy
Rocco Papa, University of Naples Federico II, Italy
Serge Salat, Urban Morphology and Complex Systems Institute, France
Mattheos Santamouris, National Kapodistrian University of Athens, Greece
Ali Soltani, Shiraz University, Iran

ASSOCIATE EDITORS

Rosaria Battarra, National Research Council Institute of Studies on Mediterranean Societies, Italy
Luigi dell'Olio, University of Cantabria, Spain
Romano Fistola, University of Sannio, Italy
Adriana Galderisi, University of Naples Federico II, Italy
Carmela Gargiulo, University of Naples Federico II, Italy
Thomas Hartmann, Utrecht University, Netherlands
Markus Hesse, University of Luxemburg, Luxemburg
Seda Kundak, Technical University of Istanbul, Turkey
Rosa Anna La Rocca, University of Naples Federico II, Italy
Houshmand Ebrahimpour Masoumi, Technical University of Berlin, Germany
Giuseppe Mazzeo, National Research Council Institute of Studies on Mediterranean Societies, Italy
Nicola Morelli, Aalborg University, Denmark
Enrica Papa, University of Westminster, United Kingdom
Dorina Pojani, University of Queensland, Australia
Floriana Zucaro, University of Naples Federico II, Italy

EDITORIAL STAFF

Gennaro Angiello, PhD student at University of Naples Federico II, Italy
Gerardo Carpentieri, PhD student at University of Naples Federico II, Italy
Raffaella Niglio, PhD student at University of Naples Federico II, Italy
Stefano Franco, PhD student at Luiss University Rome, Italy
Laura Russo, PhD student at University of Naples Federico II, Italy
Andrea Tulusi, PhD at University of Naples Federico II, Italy

CITIES, ENERGY AND MOBILITY 3 (2015)

Contents

- 261** EDITORIAL PREFACE
Rocco Papa

FOCUS

- 263** **A Markov Chain Model of Land Use Change**
Michael Iacono, David Levinson, Ahmed El-Geneidy, Rania Wasfi
- 277** **A Tool for Appraising Mobility Environment with a Perfect Based Index Measure**
AbdulMajeed Olaremi Shittu, Muhammad Zaly Shah
- 293** **A Land-Use Approach for Capturing Future Trip Generating Poles**
Iraklis Stamos, Aifadopoulou Georgia,
Evangelos Mitsakis, Maria Morfoulaki, Iasonas Tamiakis
- 311** **Tourism and Mobility.
Best Practices and Conditions to Improve Urban Liveability**
Rosa Anna La Rocca

LAND USE, MOBILITY AND ENVIRONMENT

- 331** **Council Tax Policies and Territorial Governance:
Analysis and Outlook of a Difficult Relationship**
Simone Rusci

347 REVIEW PAGES
Gennaro Angiello, Gerardo Carpentieri,
Raffaella Niglio, Laura Russo, Andrea Tulisi

TeMA

Journal of
Land Use, Mobility and Environment

TeMA 3 (2015) 293-310
print ISSN 1970-9889, e- ISSN 1970-9870
DOI: 10.6092/1970-9870/2922

review paper received 6 February 2015, accepted 9 November 2015
Licensed under the Creative Commons Attribution – Non Commercial License 3.0
www.tema.unina.it

How to cite item in APA format:

Stamos, I., Aifadopoulou, G., Mitsakis, E., Morfoulaki, M., Tamiakis, I., Iordanopoulos, G. (2015). A land-use approach for capturing future trip generating poles. *Tema. Journal of Land Use, Mobility and Environment*, 8 (3), 293-310. doi: <http://dx.doi.org/10.6092/1970-9870/2922>



A LAND-USE APPROACH FOR CAPTURING FUTURE TRIP GENERATING POLES

I. STAMOS^a, G. AIFADOPOULOU^b, E. MITSAKIS^c, M. MORFOULAKI^d,
I. TAMIAKIS^e, P. IORDANOPOULOS^f

^{a,b,c,d,e,f}Centre for Research and Technology Hellas, Thessaloniki, Greece

^ae-mail: stamos@certh.gr; ^be-mail: gea@certh.gr; ^ce-mail: emit@certh.gr;
^de-mail: marmor@certh.gr; ^ee-mail: tamiakis@certh.gr; ^fe-mail: panior@certh.gr

ABSTRACT

Changes in the usage of a particular urban or regional area have immediate effects on transportation, such as the development of a new multimodal terminal within a city, or the creation of a business park in its outskirts. Thus far, this correlation has been under-researched at a national level in Greece. As a result, its effects on trip generation and passenger flows has been underestimated at the planning level, leading to the implementation of projects that are neither viable nor sustainable. This paper proposes that land use changes ought to be considered in tandem with transport-related changes at the planning stage. To this effect, we present a three-step methodology for an integrated approach to capturing future trip generation: the identification of future trip-generating poles within the study area; the development of scenarios related to the probability of these changes occurring and their potential magnitude; an estimation of future trends in passenger flows. The methodology is applied to the Metropolitan area of Thessaloniki, Greece. Using data obtained from development plans, national statistical services and research projects' and studies' findings, we estimate future trip-generation subsequent to land use change. Data is processed and evaluated by a local experts' group, representing various key-disciplines of the area's planning stakeholders.

KEYWORDS:

trip generating poles, land use and transport interaction, data driven approach, expert assessment, Thessaloniki

TeMA

有关土地使用、交通和环境的杂志

TeMA 3 (2015) 293-310
print ISSN 1970-9889, e- ISSN 1970-9870
DOI: 10.6092/1970-9870/2922

review paper received 6 February 2015, accepted 9 November 2015
Licensed under the Creative Commons Attribution – Non Commercial License 3.0
www.tema.unina.it

How to cite item in APA format:

Stamos, I., Aifadopoulou, G., Mitsakis, E., Morfoulaki, M., Tamiakis, I., Iordanopoulos, G. (2015). A land-use approach for capturing future trip generating poles. *Tema. Journal of Land Use, Mobility and Environment*, 8 (3), 293-310. doi: <http://dx.doi.org/10.6092/1970-9870/2922>



用土地利用的方法 找到未来出行生成极

I. STAMOS^a, G. AIFADOPOULOU^b, E. MITSAKIS^c, M. MORFOULAKI^d,
I. TAMIAKIS^e, P. IORDANOPOULOS^f

^{a,b,c,d,e,f}Centre for Research and Technology Hellas, Thessaloniki, Greece

^ae-mail: stamos@certh.gr; ^be-mail: gea@certh.gr; ^ce-mail: emit@certh.gr;
^de-mail: marmor@certh.gr; ^ee-mail: tamiakis@certh.gr; ^fe-mail: panior@certh.gr

ABSTRACT

特定城市或地区性区域用途的改变（如在城市中建设新的多模式终端或在市郊创建商务园区）会立即对交通产生影响。但在希腊全国层面，人们对它们之间的关联到目前为止并未进行充分研究。因此，在规划层面低估了土地利用改变对出行生成和乘客流量产生的影响，导致实施了既不可行又不可持续的项目。本文认为，在规划阶段，考虑土地利用的变化时，应与交通相关的变化一起进行考虑。为此，我们提出用一个包含三步的综合方法来捕捉未来的出行生成：在研究区域内识别未来的出行生成极；创建与出现变化的概率及其潜在量级有关的情景；估计乘客流量的未来趋势。这个方法应用于希腊塞萨洛尼基的大城市区域。通过利用从开发计划、国家统计局以及研究项目结果和学习结果中获得的数据，我们在土地利用变化之后对未来的出行生成进行估计。数据的处理和评估由代表该地区规划利益相关者各主要学科的一个本地专家组进行。

KEYWORDS:

出行生成极, 土地利用与交通互动, 数据驱动的方法, 专家评估, 塞萨洛尼基

1 INTRODUCTION

Land use and transportation are two core factors whose interaction is directly linked to sustainability of modern cities (Wegener, 2004). According to the European Environment Agency (EEA, 2010) one of the goals to make urban environment more sustainable is to ensure equal access to resources and services and thus enhance accessibility that is the general measurement of spatial separation of human activities (Morris et al., 1979). Concerning passenger transport, accessibility is the degree to which land use and transport systems enable people to reach specific activities or destinations (Litman, 2003; Geurs and van Wee 2004a). Apart from transport and land use components, Geurs and van Wee (2004a) identify temporal constraints (availability of opportunities at different times of the day etc.) and individuals' characteristics as the four components that affect accessibility.

Enhanced accessibility is a key element that affects trip generation and distribution. However, travel behavior is equally affected by other socio-economic (price of travel, income level of household) and socio-demographic (gender, age, education level) factors as well as land use and urban design characteristics (Boarnet and Crane, 2001). Cervero (1998) estimate trip frequency based on socio-demographic, land use and street connectivity variables. Socioeconomic changes directly affect the number of trips conducted within an area according to Preston (2001). To an extent, this number is determined by factors such as area population and population density (Boarnet and Crane, 2001; Levinson, 1976). Other socioeconomic changes include income, vehicle ownership and employment status (Koppelman and Pas, 1984).

These changes account for increased/decreased mobility within an area and therefore influence the total number (and purpose) of trips conducted. Van Wee (2002) indicates that density, land use mix, neighborhood design and distance to public transport connections are the main land use characteristics that affect travel behavior. Cervero (1996) concludes that neighborhood design and land use mix influence at various degrees motorized and non-motorized commuting mode choice.

The same author studied the influence of neighborhood on mode choice for non-motorized trips and identified that land use mix can improve urban mobility through reducing motorized traffic, encourage car sharing and promote shared-use parking schemes (Cervero and Radisch, 1996). Based on each land use (either existing or future), different trip generation rates are produced, and therefore an analysis of such changes is necessary. It becomes obvious that trip generation is directly affected by land use in a complicated way.

The interest in the interaction of land use and transport has risen since the mid-60s, when it was established that land use inventories, future land use demand and land use plans along with socio-economic indicators (employment, population forecasts, etc.) are an integral part of the transportation planning process (Schlager, 1965). During the same period, Schlager identified the forecasting of population and employment as the first function of any planning sequence (including that of transportation), succeeded by the determination of future land use changes.

By then it was already evident that the advent of mechanized transport means, had and would continue to significantly shape the way space is structured. Had it not been for the revolutionary change transport mechanization brought to travel speed, the effects on land use and land cover would not have been correspondingly large (Webster's and Paulley, 1990). Understanding the nature of this bidirectional link, where changes in any transportation-related aspect (extending from transport mode based technological advances to car-ownership rates) are responded by land use, and vice-versa, is thus central if policies of either discipline are to be reliably predicted.

The impacts of land use and transport planning on transport demand can be estimated through three distinct methods (Wegener, 2004): by asking people regarding their travel behavior in relation to alternation in certain factors; by observing the transport decisions of travelers under different conditions and by simulating human decision making through models. A number of mathematical models exists that try to

identify the effects of land use on transport at both aggregate and disaggregate levels using well-established methodologies. However, there is no established representation of the converse relationship (Mackett, 1993).

Geurs and van Wee (2004b) identified the framework for Sustainability Impact Assessment by reviewing various operational land-use/transport interaction models based on land use, transport, accessibility, economic, environmental and social impacts definition (Geurs and van Wee, 2004b). Advances in mathematics support progress in modelling land use and transport interaction. However, a widely applied general model for addressing properly the issue does not exist (Wilson, 1998).

Badoe and Miller (2000) purport that the main reason for this methodological weakness is the existence of gaps in our understanding of the interaction. The main drawbacks of the current models include according to Hunt et al. (2005): excessive spatial aggregation, excessive reliance on static equilibrium assumptions (with associated assumptions of large time steps and lack of path dependencies), overly aggregate representations of households and firms, as well as a lack of representation of individuals as decision-making units separable from their households, lack of endogenous demographic processes, lack of endogenous car ownership processes and reliance on four-stage travel demand modelling methods.

Taking into account that trip generation is a decisive parameter for all planning activities related to future investments and policy interventions on a national, regional and urban level, as the literature suggests, it is a field where authorities often use forecast and estimates (Gordon, 1994; Giuliano and Hanson, 2004). Trip generation is therefore an issue whose thorough and detailed investigation can justify efforts towards a certain direction or predict the future sustainability of a project (Ortuzar and Willumsen, 2001). Moreover, it is a crucial element of land-use development, as the identification of future demand for travel can help determine whether a planning measure ought to be implemented in a certain location. It can also serve to prioritize measures in order of significance, so as to provide planners and stakeholders with guidance through selected measures when planning, but also while implementing those measures.

In the current study, an effort has been made towards the capturing of trip generation through methodological framework of land-use approach. More specifically, future trends in passenger flows are estimated through the identification of existing and potential trip generating poles and the development of various future scenarios. The proposed methodology manages to relate land use changes in tandem with transport-related changes at the planning stage. In the next parts, the proposed methodological approach is being elaborated. Then, the methodology is being applied in the Metropolitan area of Thessaloniki, Greece resulting in useful outcomes.

2 METHODOLOGICAL APPROACH

The basic rationale for the development of the methodology, depicted in Figure 1, is the combination of various parameters and sectors related with trip generation (either directly or indirectly), such as land use, transport planning and economy. These sectors act as sources of information that thoroughly map the existing situation and any change in the latter will provide a detailed insight on future trends in passenger flows. The methodology consists of three steps, which are discussed in detail in the following sections.

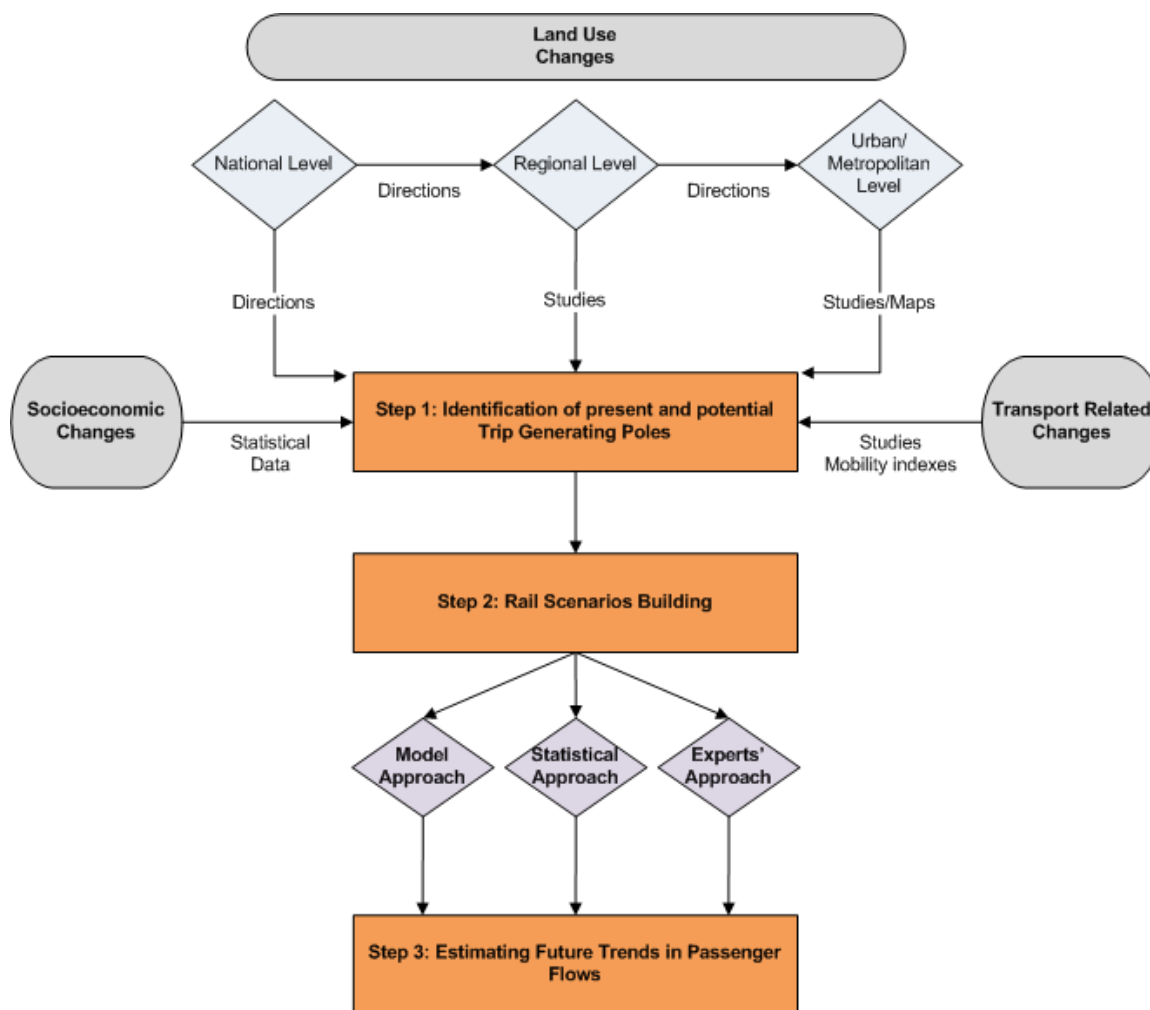


Fig. 1 Proposed methodology for identifying trip-generating poles and estimating future trends in passenger flows

2.1 STEP1 - IDENTIFYING EXISTING AND POTENTIAL TRIP GENERATING POLES

The first step of the methodology deals with the identification of present and potential trip-generating poles. As depicted in Figure 1, the following areas are directly associated with trip generation:

- Land-use changes;
- Socioeconomic changes;
- Transport related changes.

2.1.1 LAND-USE CHANGES

In order to accurately estimate future trends in passenger flows, it is important to map land uses, whose change directly influences the number of trips conducted within an area.

According to the Institution of Transport Engineers (ITE, 1976), land uses related to business, industry, education, health and leisure account for the highest trip generation rates in urban environments. Moreover, it is important to define the magnitude of each land use change in spatial terms (international, national, regional, and urban/metropolitan).

Land use changes are often included in national, regional and urban development plans of each country, depending on the population and extent of the area they refer to (Figure 2). Such plans include national development plans (e.g. General Plans for Spatial planning and Sustainable development (GPSPSD), Special Plans for Spatial planning and Sustainable Development (SPSPSD)), which provide guidelines and determine

strategic directions of planning on a national level. General plans concern a wide variety of sectors and refer to a target year, in which the desired change/measure is planned to be implemented (approximately a period of 15-20 years since the development of the plan). Special Plans are dedicated to specific sectors and the respective changes therein (business, tourism, aqua/agriculture, renewable energy sources). On a national level, regarding sectorial planning and development, National Operational Plans are also conducted, including sectors such as transport, environment, energy, telematics and tourism.

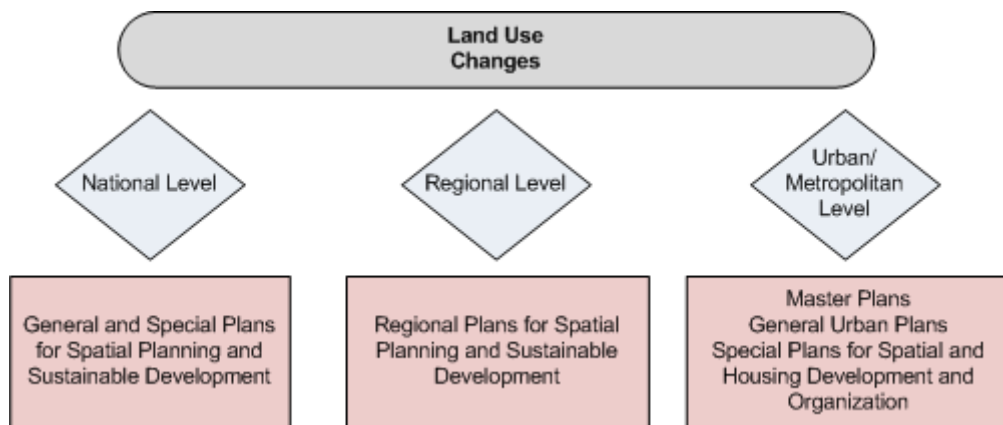


Fig.2 Identification of Land use changes at various levels

Such plans also include regional development plans (Regional Plan for Spatial Planning and Sustainable Development (RPSPSD)), which contain specifications of the General plans at regional level and provide analyses of the current situation and proposals concerning urban organization, land use definition and transport infrastructure. Also at regional level, Operational Plans are conducted, concerning geographic regions not always in compliance with administrative region boundaries.

Finally, urban/metropolitan development plans also contain information on land use changes (Master Plans (MP), General Urban Plan (GUP) and Operational Plans of each municipality). In detail, Master Plans provide general guidelines concerning metropolitan areas while General Urban Plans provide analyses of the current situation and direct suggestions concerning house organization, transport infrastructure and land uses. Regarding the lowest planning level, municipalities lay out the strategy, developmental vision and specific actions and measures, as well as funding sources, through operational plans.

2.1.2 SOCIOECONOMIC CHANGES

Figure 3 summarizes various socioeconomic characteristics whose change would significantly influence future flows of passengers.

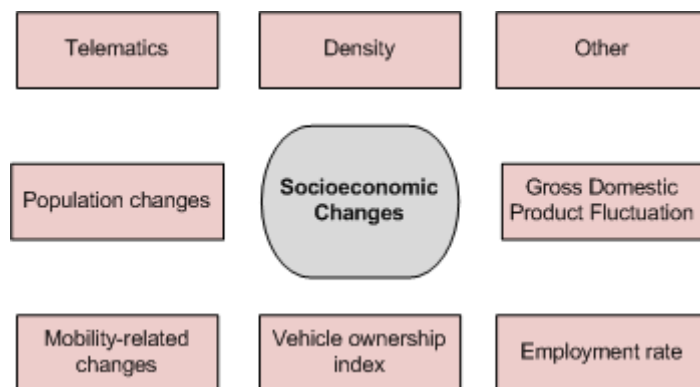


Fig. 3 Identification of socioeconomic changes

Data regarding socioeconomic characteristics of areas and regions are often found within national statistical services or in specific surveys, statistical institutes and intergovernmental organizations (ELSTAT, 2014). These services include detailed, yet often not analyzed, data on potential trip-generating parameters such as population, vehicle ownership, changing density in certain areas, and employment. Studies at regional and urban level, often financed through national funds, may also contain similar data. In addition, certain data concerning the demography of areas and regions are often contained (in numerical form) in the Development Plans identified above, as well as in Operational Plans conducted by each municipality. Operational plans contain analyzed demographic characteristics both at regional and urban/metropolitan level and provide further data concerning fields of employment, business and population changes.

3.1.3 TRANSPORT RELATED CHANGES

Transport-related changes concerning the implementation of new infrastructure or the modification of existing ones (e.g. turning a railway station in a multimodal hub), the introduction of new transport services or lines and connections (both for public and private transport), are directly associated with generation of trips and are depicted in Figure 4.

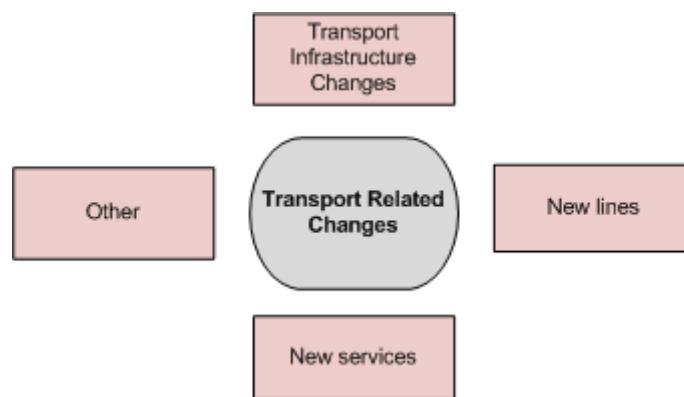


Fig. 4 Identification of transport related changes

Development plans described in previous sections are not limited to reporting on land use changes, future planning directions or residential developments, but also contain information related to transport issues. As all of the above poles are correlated rather than being isolated from one another, similar sources may be drawn upon to identify trip-generating poles.

3.2 STEP 2 - SCENARIOS DEVELOPMENT

As it is rather unrealistic to assume that all actions and measures described in development plans or studies will be implemented in the future, scenarios can be developed based on the probability that certain changes might be realized or not. This probability can be assessed by relevant experts (Hsu, 2007) who can evaluate the changes identified in Step 1 and decide on the probability of a change being implemented based on various factors, such as:

- Support in the planned change by the private sector;
- Accomplished legal procedure for the implementation of the change;
- Size of change;
- Political and societal support in favor of the change.

In addition, the significance of these changes should also be taken into consideration, as some changes are more important than others are, and should thus be examined separately. In that sense, it is proposed that developed scenarios describing the changes identified in Step 1 are classified based on a probability-

significance index into 3 classes as depicted in Figure 5. The development of the probability-significance index can be an output of experts' opinions or can be stated within Development Plans as priorities for each change.

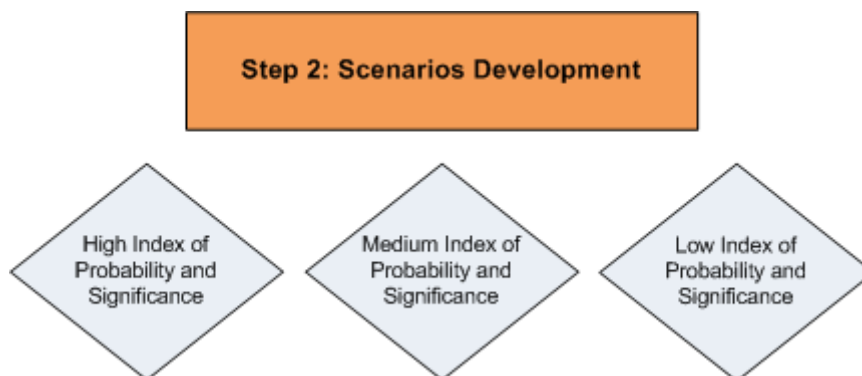


Fig. 5 Scenarios classification based on Probability-Significance Index

Another important aspect that has to be taken into consideration is the target year these scenarios refer to, in order to assure a common approach for the final evaluation.

3.3 STEP 3 - ESTIMATING FUTURE TRENDS IN PASSENGER FLOWS

The issue of quantifying future trends in passenger flows, based on trip generating poles identified at the previous step, is rather challenging and demanding. Data are not often available, or when available, not in a format easily quantifiable. Figure 6 summarizes several approaches for estimating future trends in passenger flows.

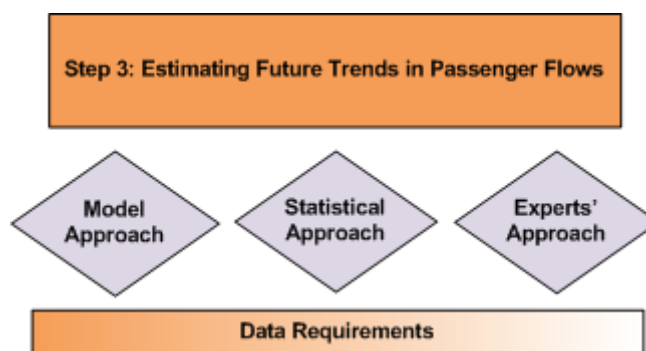


Fig. 6 Approaches for estimating future trends in passenger flows

Models able to integrate land use data (e.g. extent of area, number of places of employment), transport-related data (e.g. trips per citizen according to age) and socioeconomic data (e.g. income per citizen) can be used in this step to quantify future passenger flows. Models have the advantage of being able to accurately predict future trends in passenger flows, by taking into account several parameters. However, data requirements are significantly high, rendering the process difficult and labor-intensive. Alternatively, a statistical approach can be followed. Such an approach involves exploiting data (to the extent that they are available) and estimating future passenger flows based on general assumptions that reveal overarching trends. For instance, based on income change, population change and vehicle ownership, a future trend can be deduced, revealing the tendencies of a particular region in these areas. Therefore, future trends can be calculated by taking into account the particular identity of the region. Finally, experts from various related sectors, such as business, academia, research, public authorities, can be recruited in order to assess

available information (for instance a city's planning direction towards becoming an industrial area) and estimate passenger flows in a percentage format, indicating future changes (e.g. +5%).

4 AN APPLICATION

In order to assess the applicability of the proposed methodology, a case study is presented under this section.

4.1 THE CASE OF THESSALONIKI, GREECE

Thessaloniki is the second largest city in Greece, currently accommodating 1.006.730 citizens in its metropolitan area. Situated in Northern Greece, Thessaloniki covers a total of 1.455,68 km² with an average density of 16.703 inhabitants per km² (Stamos et al., 2012). Due to its geographical location, Thessaloniki plays an important social, financial, and commercial role in the national and greater Balkan region, in part because of the development of a transportation hub within the city's limits. According to the General Statistical Secretariat, the total number of vehicles in the city exceeds 777.544, including private cars, heavy vehicles and motorcycles, while approx. 1,8M trips are conducted in the city on a daily basis (Politis et al., 2012; Stamos et al., 2013; Mitsakis et al., 2013). Figure 7 depicts the municipalities of the Metropolitan area of Thessaloniki that are examined herein.

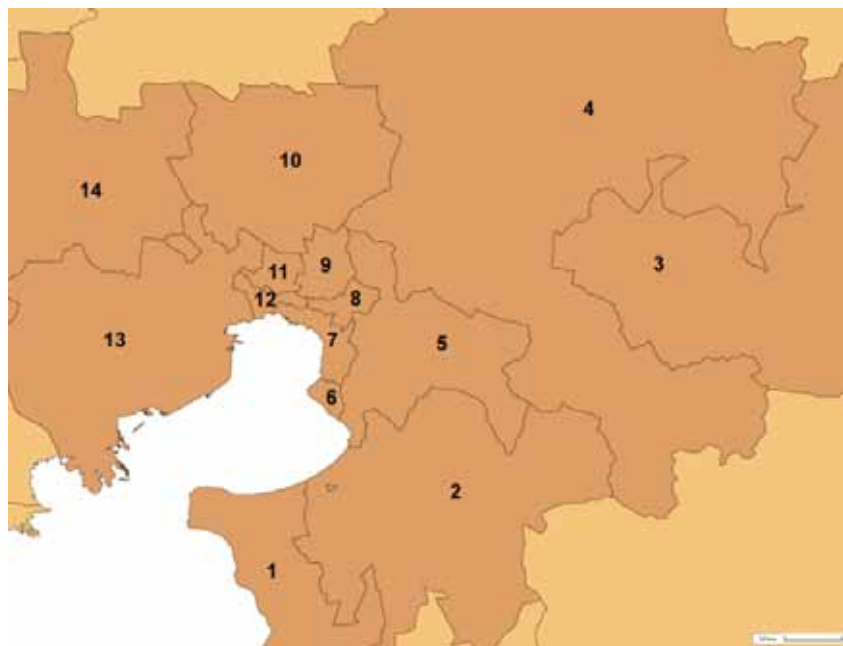


Fig. 7 Municipalities within Thessaloniki prefecture (scale refers to 10km)

4.2 MAPPING OF TRIP GENERATING POLES

4.2.1 LAND-USE CHANGES FOR MUNICIPALITIES

With regard to the metropolitan area of the city, the Master Plan (MP) suggests the conservation of the industrial area and the reinforcement of competitiveness among the industries and smaller craft businesses. Furthermore, a sound allocation of scattered industries throughout Thessaloniki's metropolitan area is advocated in order to minimize negative impacts to the urban environment. The MP also suggests the promotion of research and innovation and the utilization of natural resources, historical environments and business activities in order to create and promote new forms of tourism within the area (City of Thessaloniki,

2009). Besides the MP, which is generally considered as a guideline for strategic development, specialized General Urban Plans (GUP) have been developed for each municipality included in Thessaloniki's Greater Area. The GUPs conducted for the municipalities suggest the development of business centers, such as malls, in the western part of the city and the organization of an industrial area, again in western Thessaloniki.

In addition, a concentrated allocation of business hosts in the western part of the metropolitan area is suggested, e.g. of universities and technological institutes. Furthermore, the development of health-related units in the western part of Thessaloniki is recommended in order to provide all citizens with equitable access to health services, which are currently concentrated in the Eastern part of the metropolitan area of Thessaloniki. In order to provide citizens with proper athletic facilities, the GUP suggests the development of athletic cores in specific urban centers within the region. Finally, regarding the touristic development of the metropolitan area, the promotion of special forms of tourism such as agro-tourism and spa-tourism are proposed and allocated circumferentially in the greater region. Table 1 summarizes the most characteristic land use changes for municipalities within the hub of Thessaloniki.

NAME	CHANGE	SECTOR	TARGET YEAR	SOURCE	PROBABILITY	MAGNITUDE
Greater Thessaloniki area	Conservation and organization of industrial area and reinforcement of competitiveness of industries and smaller craft businesses	Industry	2022	MP	H	Regional
Greater Thessaloniki area	Consolidation of scattered industries	Industry	2022	MP	L	Local
Greater Thessaloniki area	Research infrastructure development	Business	2022	MP	L	Regional
Delta	Displacement of Thessaloniki's international fair to the western part of the agglomeration	Business	2022	MP	H	Local
Lagkada	Promotion of spa-tourism infrastructure	Tourism	2022	MP	H	Regional
Pylaia	Creation of hospitals exclusively related to oncology	Health	2022	GUP	L	International
Thermaikos	Creation and organization of an area concerning fish products	Business	2022	MP	L	Regional
Lagkada	Creation of new veterinary university in the eastern part of the agglomeration	Education	2022	GUP	L	International

Pylaia	Creation of new Polytechnic university in the northern part of the agglomeration	Education	2022	GUP	L	International
Thermi	Creation of new geologic university in the eastern part of the agglomeration	Education	2022	GUP	L	International
Ampelokipoi-Menemeni	Creation of a business park in Laxanokipoi area	Business	2022	GUP	H	Regional
Eastern Thessaloniki area	Development of commercial center	Business	2022	MP	M	Regional
Thermi	Organization of an innovation business zone	Business	2022	MP	L	Regional
Delta	Promotion of sports tourism and agro-tourism	Tourism	2022	MP	H	Regional
Western Thessaloniki area	Development of commercial center	Business	2022	MP	M	Regional

Table 1 Land use changes for municipalities within the hub of Thessaloniki

4.2.2 SOCIOECONOMIC CHANGES FOR MUNICIPALITIES WITHIN THE HUB OF THESSALONIKI

Information and data described herein are obtained from a research project recently conducted for Thessaloniki's agglomeration (Morfoulaki et al., 2011). 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 environmentally friendly routing), public transport information and routing services, ride sharing and user awareness tools.

In the framework of this project, 5.000 household phone surveys and Road Side Surveys (RSS) at 40 locations with 33.000 participants were executed between October and November 2010. Based on the 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 (Mitsakis et al., 2013).

The average number of trips per person is 2,08. About 89% 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. 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 (Mitsakis et al., 2013).

The modal split analysis reveals 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. 65% are single occupancy vehicles, while 28% and 6% of the vehicles travel with 2 and 3 passengers respectively. Concerning the vehicle type distribution, this is estimated as follows: 77% private vehicles, 5%

motorcycles, 2% taxis, 11% vans and 5% trucks. 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 (Mitsakis et al., 2013).

4.2.3 TRANSPORT RELATED CHANGES FOR MUNICIPALITIES WITHIN THE HUB OF THESSALONIKI

As mentioned above, transport-related changes concern the implementation or modification of transport infrastructure and the introduction of transport lines and services. Regarding transport infrastructure-related changes, the MP for the city of Thessaloniki proposes the overall reinforcement of the role of public transport in high-density areas so as to provide equitable access to all citizens.

The promotion of multimodality is a crucial part of future transport planning in Thessaloniki, in order to increase the effectiveness of public transport and address passenger safety issues. Additionally, the MP provides directions concerning the organization of municipal mobility centers in order to control traffic and minimize congestion at a local level. The upgrade of Thessaloniki's airport and harbor is also included, as well as the upgrade of the rail and bus station into regional transport stations. Table 2 summarizes the most characteristic transport-related changes planned for municipalities within the hub of Thessaloniki.

4.3 SCENARIOS DEVELOPMENT

At this step, changes that are both highly probable and of regional to international magnitude are isolated, so that they can be handed over to experts for assessment (Table 3).

NAME	CHANGE	TARGET YEAR	SOURCE	PROBABILITY	MAGNITUDE
Thessaloniki	Reinforcement of the role of public transports	2022	MP	H	Local
Thessaloniki	Equitable access for all citizens, throughout networks and public infrastructure, and formation of a fair pricing system	2022	MP	H	Local
Thessaloniki	Promotion of multimodality in transports in order to increase effectiveness and safety	2022	MP	M	Local
Thessaloniki	Reinforcement of Thessaloniki's role as an international node of freight transport	2022	MP	M	International
Thessaloniki	Development of public transport consistency in order to provide service in high density areas	2022	MP	H	Local
Thessaloniki	Organization of Municipal mobility centers	2022	MP	M	Metropolitan
Thermi	Upgrade of International Airport of Thessaloniki "Macedonia" into an international node of passenger transport	2022	MP	H	International
Thessaloniki	Upgrade of International harbor of Thessaloniki and functional	2022	MP	M	International

	unification with the urban environment of Thessaloniki				
Thessaloniki	Upgrade of passenger rail station into regional centers	2022	MP	M	Regional
Ampelokipoi-Menemeni	Upgrade of passenger bus station into regional centers	2022	MP	M	Regional
Thessaloniki	Creation of a united system for bike transport in order to help decongest the transport network and promote sustainable mobility	2022	MP	H	Metropolitan
Thessaloniki	Railway connection throughout the region	2022	GUP	M	Metropolitan
Thermaikos	Improvement of Michaniona's harbor and connection with Pieria	2022	GUP	M	Regional
Ampelokipoi-Menemeni	Creation of terminal subway stations in western Thessaloniki	2022	GUP	L	Metropolitan
Kalamaria	Creation of terminal subway station	2022	GUP	L	Metropolitan
Thermaikos	Creation of terminal subway stations in the airport area	2022	GUP	L	Metropolitan

Table 2 Transport infrastructure changes for municipalities within the hub of Thessaloniki

NAME	CHANGE	SECTOR	TARGET YEAR	PROBABILITY	MAGNITUDE
Metropolitan area of Thessaloniki	Conservation and organization of industrial area and reinforcement of competitiveness of industries and smaller craft businesses	Industry	2022	H	Regional
Delta	Displacement of Thessaloniki's international fair to the western part of the agglomeration	Business	2022	H	International
Lagkada	Promotion of spa-tourism infrastructure	Tourism	2022	H	Regional/International
Pylaia	Creation of hospitals exclusively related to oncology	Health	2022	H	International
Ampelokipoi-Menemeni	Creation of a business park in Laxanokipoi area	Business	2022	H	Regional
Eastern Thessaloniki area	Development of commercial center	Business	2022	M	Regional/International
Delta	Promotion of sports tourism and agro-tourism	Tourism	2022	H	Regional/International

Western Thessaloniki area	Development of commercial center	Business	2022	M	Regional/International
Thessaloniki	Reinforcement of Thessaloniki's role as an international node of freight transport	TI/Freight	2022	M	International
Thessaloniki	Organization of Municipal mobility centers	TI	2022	M	Metropolitan
Thermi	Upgrade of International Airport of Thessaloniki "Macedonia" into an international node of passenger transport	TI/Air	2022	H	International
Thessaloniki	Upgrade of International harbor of Thessaloniki and functional unification with the urban environment of Thessaloniki	TI/Marine	2022	M	International
Thessaloniki	Upgrade of passenger rail station into regional center	TI/Rail	2022	M	Regional
Ampelokipoi-Menemeni	Upgrade of passenger bus station into regional center	TI/Bus	2022	M	Regional
Thessaloniki	Creation of a united system for bike transport in order to help decongest the transport network and promote sustainable mobility	TI/Bike	2022	H	Metropolitan
Thessaloniki	Railway connection throughout the region	Ti/Rail	2022	M	Metropolitan
Thermaikos	Improvement of Michaniona's harbor and connection with Pieria	TI/Marine	2022	M	Regional

Table 3 Medium and highly probable changes in the hub of Thessaloniki

4.4 ANALYSIS OF TRIP GENERATING POLES – TREND ESTIMATIONS

In order to estimate future trends in passenger flows, the experts' approach described above has been used for the hub of Thessaloniki and a DELPHI approach has been adopted (Hsu, 2007). Experts were asked to assess present and future trip generating poles scenarios, based on the current status of the metropolitan area of Thessaloniki and the proposed/planned future developments.

The experts' group consisted of 4 transport engineers (freelancers), 2 researchers (employed at Hellenic Institute of Transport), 4 research associates (employed at the Hellenic Institute of Transport), 3 university professors (Aristotle University of Thessaloniki) and 2 municipal employees (civil servants) dealing with transport planning at urban level.

The experts had the following input at their disposal, in order to estimate a future passenger flow percentage change:

- Scenarios of future changes based on the probability and magnitude of each identified change;
- Numeric changes in land use, socioeconomic and transport-related changes for the hub of Thessaloniki;
- Number of trips currently conducted within the hub of Thessaloniki;
- Number of trips currently originating from outer zones and destined to the hub of Thessaloniki;
- Purpose of trips (home-based trips, work, leisure, education, other);
- Trip generation rates from previously existing traffic studies for the hub of Thessaloniki.

At the first stage of their assessment, experts estimated the percentage change from current to future number of passenger flow individually. At the second stage, results were gathered and disseminated to the group. Experts then reexamined their results, taking into consideration the ongoing economic crisis as well as other related socioeconomic conditions.

The provided scenarios of future changes in land use and transportation can be grouped in two general categories, the one being the development of new infrastructure and therefore the creation of new land uses and the other being the reinforcement or upgrade of existing land uses.

The lowest percentage change in future passenger flows according to experts will be +6% and the highest percentage change will be +9%. Moreover, the analysis revealed that in case of new infrastructure the trip generation will focus on motorized traffic. The percentage of private transport or use of public transport is highly correlated to the level of service the new land uses are expected to have as regards public transport coverage.

On the other hand, according to the respondents, upgrade of existing infrastructure can lead to generating more non-motorized traffic (cycling, walking) than motorized taking into account that the existing land uses are part of a mix land use subsystem that enhances non-motorized trips. This fact is in line with results from various other studies that elaborate on the advantages of mix land use (Cervero, 1996) and on the results from regression models (Boarnet and Crane, 2001).

5 CONCLUSIONS

This paper addresses the need to consider land use change and transportation in tandem in relation to trip generation. Land use and transportation are two intimately interdependent sectors that affect accessibility and ultimately travel behavior. Apart from accessibility, travel behavior is also affected by various other factors most of which are related to socioeconomic and socio-demographic criteria.

These criteria play an important role when it comes to identifying the impacts of land use and transport planning on transport demand. Various studies have tried to determine these impacts by developing methodologies in order to identify travelers' behavior either through questionnaire surveys or by simulating human decision making through models. However, current studies have so far been incomplete and underdeveloped especially for Greece where transport planning and land use development are two separate non-correlated processes.

Our suggestion here includes a three-step methodology that integrates the two sectors and allows planners to develop more efficient land use and transportation policies.

Through this methodology various scenarios are developed based on estimates for future changes in social, economic and demographic sectors as well as on proposals and strategic planning of areas and regions regarding future development of transportation and land use.

The results of the methodology's implementation in the case of Thessaloniki Prefecture reveals that the creation of new trip generating poles and the increase of trips' generation and distribution go hand in hand with the type of land use development and modifications as well as changes in provided transport services of an area. The estimated impacts can be determinant factors for decision making on urban or regional future

development. Therefore, the methodology laid out in this paper can be used as an evaluation tool that can help the strategic planning of future actions, measures and projects.

Our contribution undoubtedly constitutes a first step in the direction of integrated decision making at the planning process regarding land use and transportation. Nonetheless, additional research is needed in order to succeed in developing an accurate assessment of the complex interactions between land use change and transportation.

REFERENCES

- Badoe, D. A., & Miller, E. J. (2000). Transportation–land-use interaction: empirical findings in North America, and their implications for modeling. *Transportation Research Part D: Transport and Environment*, 5(4), 235-263. doi:10.1016/S1361-9209(99)00036-X.
- Cervero, R. (1996). Mixed land-uses and commuting evidence from the American Housing Survey. *Transportation Research Part A: Policy and Practice*, 30(5), 361-377. doi:10.1016/0965-8564(95)00033-X.
- Cervero, R., & Radisch, C. (1996). Travel choices in pedestrian versus automobile oriented neighborhoods. *Transport Policy*, 3(3), 127-141. doi:10.1016/0967-070X(96)00016-9.
- Cervero, R. (1998). Land-use mixing and suburban mobility. *Transportation Quarterly*, 42(1988), 429–446.
- Boarnet, M., & Crane, R. (2001). The influence of land use on travel behavior: specification and estimation strategies. *Transportation Research Part A: Policy and Practice*, 35(9), 823-845. doi:10.1016/S0965-8564(00)00019-7.
- City of Thessaloniki (2009). *Master Plan for Thessaloniki's Metropolitan Area*.
- EEA - European Environmental Agency (2010). *The European Environment — State and Outlook 2010. Urban Environment*. Available at: <http://www.eea.europa.eu/soer/europe/urban-environment>. Last accessed: March, 2015.
- ELSTAT- Hellenic Statistical Authority (2014). Census data. Last accessed: March, 2015. www.statistics.gr.
- Geurs, K. T., & van Wee, B. (2004 b). Land-use/transport interaction models as tools for sustainability impact assessment of transport investments: review and research perspectives. *European Journal of Transport and Infrastructure Research*, 4(3), 333-355.
- Geurs, K. T., & Van Wee, B. (2004). Accessibility evaluation of land-use and transport strategies: review and research directions. *Journal of Transport Geography*, 12(2), 127-140. doi:10.1016/j.jtrangeo.2003.10.005.
- Gordon, R. (1994). *New Data and Old Models in Urban Economics*. Cambridge, UK: Lincoln Institute of Land Policy.
- Giuliano, G., and S. Hanson (2004). *The Geography of Urban Transportation*. New York, NY: The Guilford Press. ISBN: 9781609180997.
- Hsu, C. C., & Sandford, B. A. (2007). The Delphi technique: making sense of consensus. *Practical Assessment, Research & Evaluation*, 12(10), 1-8. Available at: <http://pareonline.net/pdf/v12n10.pdf>.
- Hunt, J., Kriger, D. & Miller, E. (2005) Current operational urban land-use–transport modelling frameworks: A review. *Transport Reviews: A Transnational Transdisciplinary Journal*, 25(3), 329-376. doi:10.1080/0144164052000336470.
- ITE - Institution of Traffic Engineers (1976). *Traffic Engineering Handbook, Fifth Edition*. Washington, DC: ITE.
- Koppelman, F.S. and E.I. PAS (1984) Estimation of disaggregate regression models of person trip generation with multiday data. In J. Volmuller & R. Hamerslag (Eds.), *Proceedings of the 9th International Symposium on Transportation and Traffic Theory* (pp. 513-531). Utrecht, NL: VNU Science Press. ISBN: 9789067640084.
- Levinson, H.S. (1976). Urban travel characteristics. In: J.E. Baerwald (Ed.), *Transportation and Traffic Engineering Handbook* (pp. 138–206). Saddle River, NJ: Prentice Hall.
- Litman, T. (2003). *Measuring Transportation: Traffic Mobility and Accessibility*. Victoria Transport Policy Institute. Available at: www.vtip.org/tca.
- Mackett, R. (1993). Structure of linkages between transport and land use. *Transport Research Part B: Methodological*, 27B(3), 189-206. doi:10.1016/0191-2615(93)90029-A.
- Mitsakis, E., Stamos, I., Grau, J. M. S., Chrysochoou, E., Iordanopoulos, P., & Aifadopoulou, G. (2013). Urban Mobility Indicators for Thessaloniki. *Journal of Traffic and Logistics Engineering*, 1(2), 148-152. doi: 10.12720/jtle.1.2.148-152.
- Morfoulaki, M., Mitsakis, E., Chrysostomou, K., & Stamos, I. (2011). The contribution of urban mobility management to trip planning and the environmental upgrade of urban areas. *Procedia-Social and Behavioral Sciences*, 20, 162-170. doi:10.1016/j.sbspro.2011.08.021.
- Morris, J., Dumble, P., & Wigan M. (1979) Accessibility indicators for transport planning. *Transportation Research Part A: Policy and Practice*, 13(2), 91-109. doi:10.1016/0191-2607(79)90012-8.
- Ortuzar, J., & Willumsen, G. (2001). *Modeling Transport* (3rd ed.). Chichester, UK: John Wiley & Sons. ISBN: 0-471-86110-3.
- Politis, I., Papaioannou, P., Basbas, S., & Stamos, I. (2012). How do large-scale infrastructure projects contribute to environmental improvement. The case of Thessaloniki's outer ring road. *Journal of Environmental Protection and Ecology*, 13(1), 219-226.
- Preston, J. (2001). Integrating transport with socio-economic activity—a research agenda for the new millennium. *Journal of Transport Geography*, 9(1), 13-24. doi:10.1016/S0966-6923(00)00039-9
- Schlager, K. J. (1965). A land use plan design model. *Journal of the American Institute of Planners*, 31(2), 103-111. doi:10.1080/01944366508978151.

Stamos, I., Kitis, G., Basbas, S., & Tzevelekis, I. (2012). Evaluation of a High Occupancy Vehicle Lane in Central Business District Thessaloniki. *Procedia-Social and Behavioral Sciences*, 48, 1088-1096. doi:10.1016/j.sbspro.2012.06.1085.

Stamos, I., Kitis, G., Basbas, S. (2013). The implementation of a contra flow bus lane in the city of Thessaloniki: energy and environmental impacts. *Fresenius Environmental Bulletin*, 22(7b), 2191-2196.

Van Wee, B. (2002). Land use and transport: research and policy challenges. *Journal of Transport Geography*, 10(4), 259-271. doi:10.1016/S0966-6923(02)00041-8.

Webster, F. & Paulley, N. (1990). An international study on land-use and transport interaction, *Transport Review*, 10(4), 287-308. doi: 10.1080/01441649008716763.

Wilson, A. G. (1998). Land-use/transport interaction models: Past and future. *Journal of Transport Economics and Policy*, 32(1) 3-26. Available at: <http://www.jstor.org/stable/20053753>.

Wegener, M. (2004). Overview of land-use transport models. In D. A. Hensher & K. Button (Eds.), *Transport Geography and Spatial Systems. Handbook 5 of the Handbook in Transport* (pp. 127-146). Kidlington, UK: Pergamon, Elsevier Science Ltd. ISBN-13: 978-008044108.

IMAGE SOURCES

The cover image is from: <http://trendland.com>.

All other images are by Authors.

AUTHORS' PROFILES

Iraklisis Stamos is Research Associate at the Hellenic Institute of Transport.

Aifadopoulou Georgia is Vice-director of the Hellenic Institute of Transport.

Evangelos Mitsakis is Associate Researcher at the Hellenic Institute of Transport.

Maria Morfoulaki is Associate Researcher at the Hellenic Institute of Transport.

Iasonas Tamiakis is Research Associate at the Hellenic Institute of Transport.