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A methodological approach for capturing future tripgenerating poles

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Abstract

When a change in the usage of a particular urban or regional area occurs, it has an immediate effect 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. 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 optimally 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: first, the identification of future trip-generating poles within the area in question; second, the development of scenarios related to the probability of these changes occurring and their potential magnitude; finally, an estimation of possible future trends in passenger flows. This methodology is applied to the Metropolitan area of Thessaloniki, Greece. Using data obtained from developmental plans, national statistical services and research projects' and related studies findings, we develop an estimate of future trip-generation subsequent to land use change. Data is then processed and evaluated by a local experts' group, representing various key-disciplines of the area's planning stakeholders.

1 Introduction

Trip generation is a decisive parameter for all planning activities related to future investments andpolicyinterventions on a national, regional and urban level and as the literature suggests,it is a field authorities often use forecast and estimates for(Cervero, Radisch 1995; Gordon 1994; Giulianoand Hanson 2004).Trip generation istherefore an issue whose thorough and detailed investigation can justify efforts towards a certain direction or predict the future sustainability of a project (Ortuzar and Willmusen, 1978). Moreover, it is a crucial element of land-use development, as the identification of future demand for travel can help determine whethera 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 implementingthose measures

2 Methodological approach

The basic rationale for the development of the methodology, depicted in

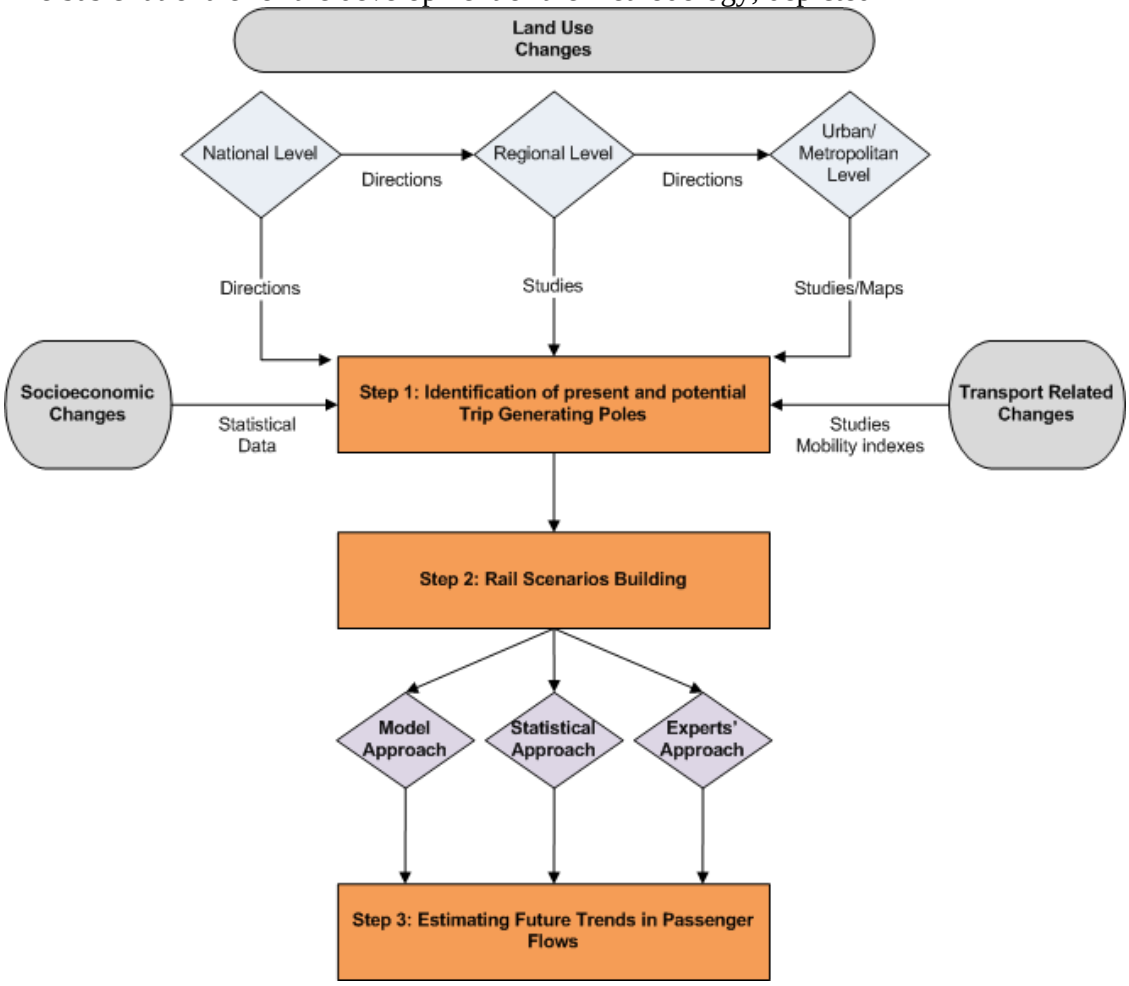

Figure1, is the combination of various parameters and sectorsrelated with trip generation (either directly or indirectly), such as land use and transport planning,

economy, industry, tourism and health. 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.

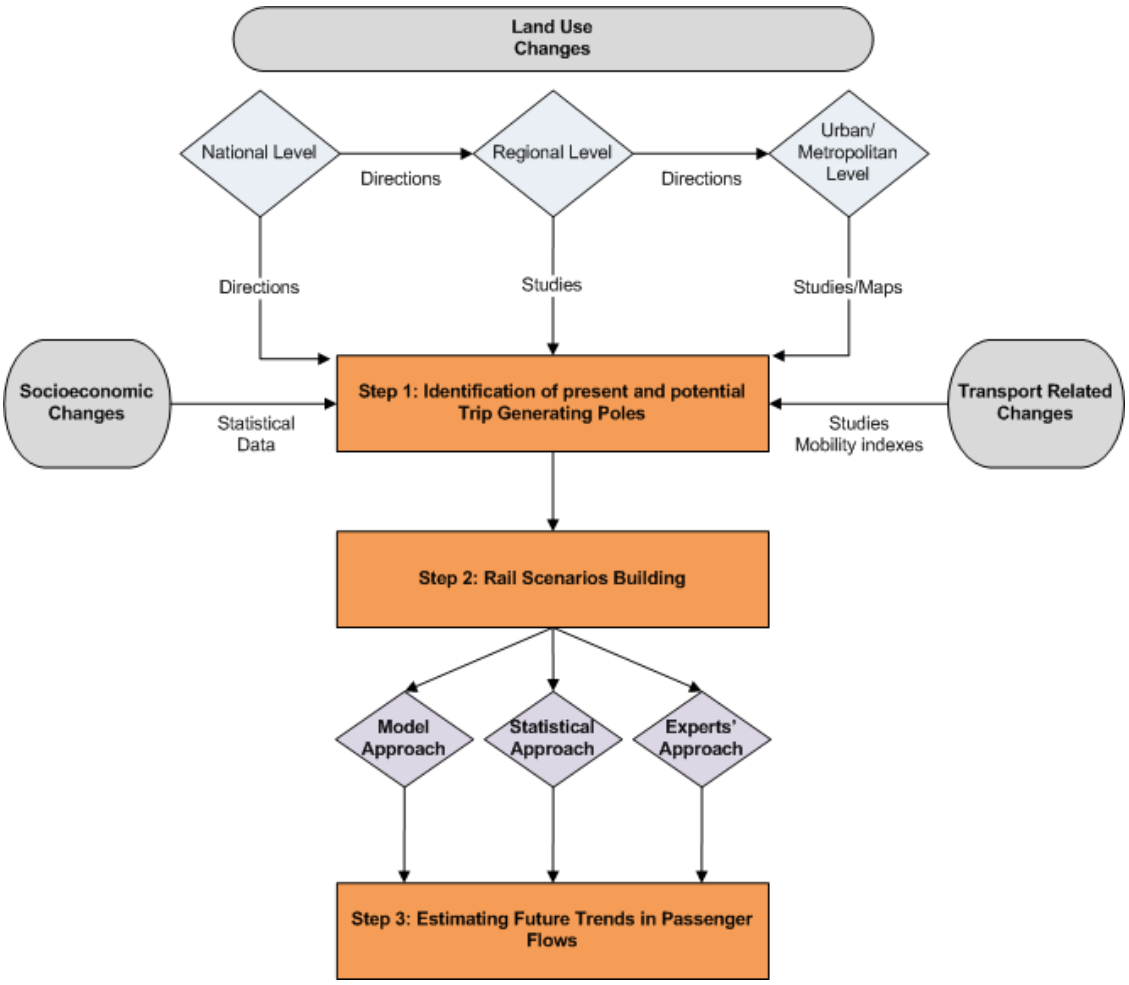

Figure1: Proposedmethodologyforidentifyingtrip-generatingpolesandestimatingfuturetrendsinpassengerflows

2.1 Step1 - Identifying existing and potential tripgenerating poles

The first step of the methodology deals with the identification of present and potential trip-generating poles. As depicted in

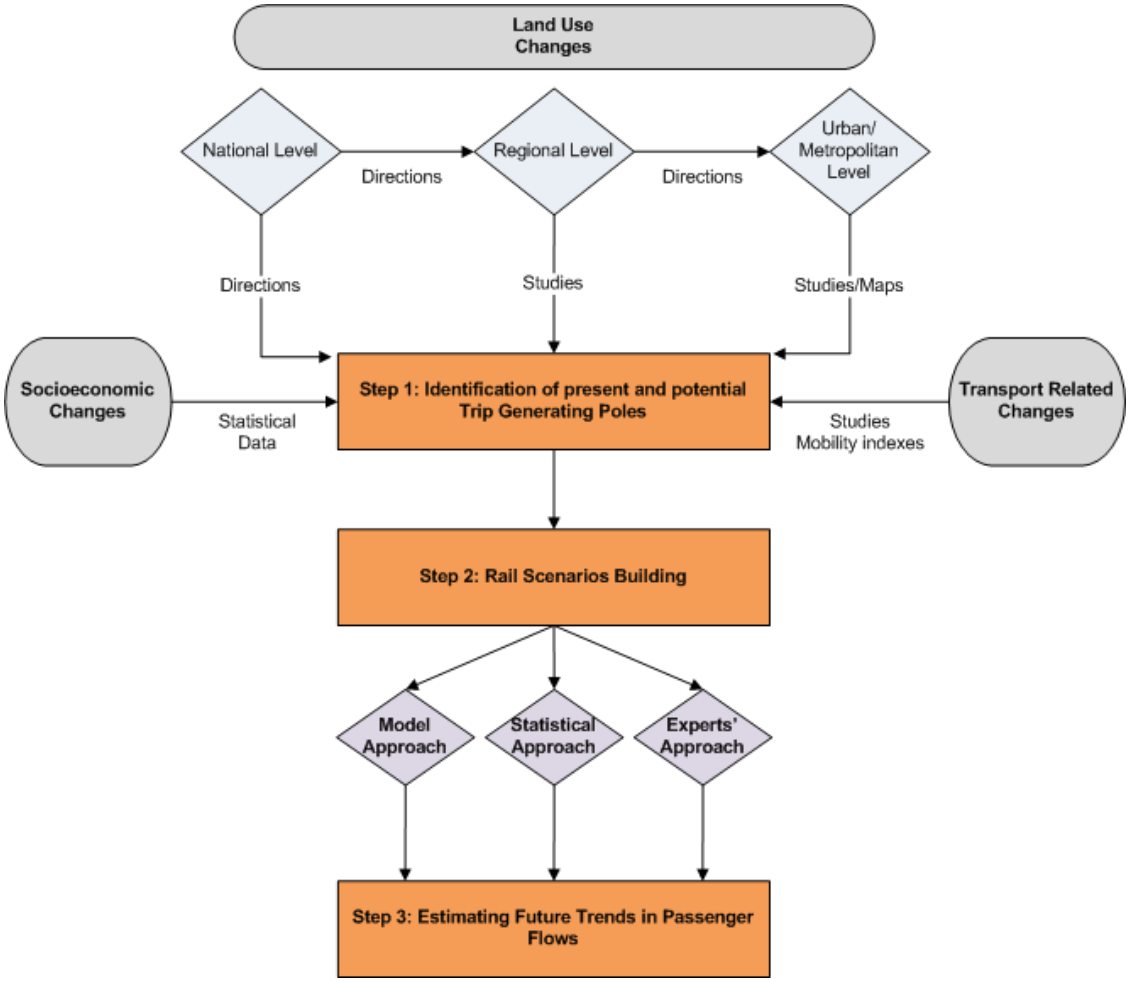

Figure1, the following areas are directly associated with trip generation:

- Land use changes
- Socioeconomic changes
- Transport-related changes

2.1.1 Land Use changes

Land use change isone of the most significant poles of tripgeneration. Land uses“affect accessibility, which can be described as the people’s ability to reach desired services and activities, which affects mobility, the amount and type of travel activity’’ (Litman 2003). Based on each land use (either existing or future), different trip generation rates are produced, and therefore an analysis of such changes is necessary. 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 relating to business, industry, education, health and leisure account for the highest trip generation rates in urban environments. It is important, moreover, to define the magnitude of each

land use change in spatial terms (international, national, regional, and urban/metropolitan).

Land use changes are often includedin national, regional and urban development plans of each country, depending on the population and extent of the area they refer to (Figure 1). 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 anational 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 tospecific 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.

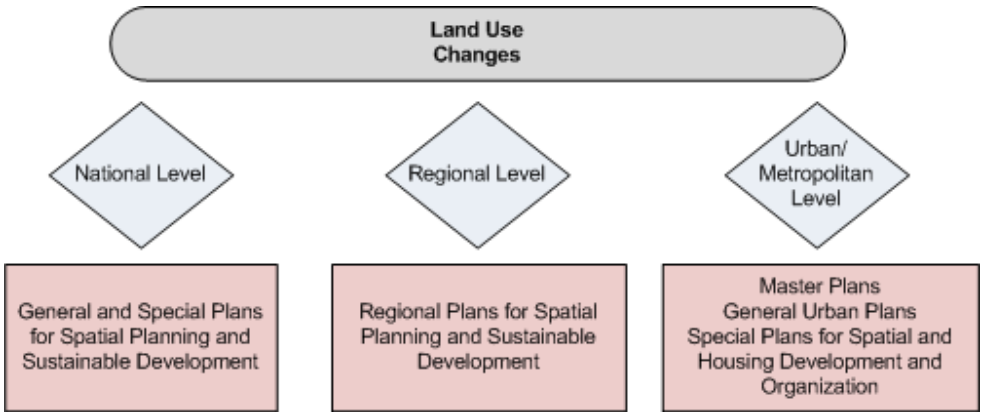

Figure 1: Identification of Land use changes at various levels

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. Alsoatregionallevel, OperationalPlansareconducted, 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) andOperational 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

Socioeconomic changes directly affect the number of trips conducted within an area(Preston 2001). To an extent, this number is determined by factors such as area population andpopulationdensity. Other socioeconomic changes include the employment rate or GDP per citizen. These changesaccount for increased/decreased mobility within an area and therefore influence the total number (and purpose) of trips conducted. Figure 2 summarizes various socioeconomic characteristics whose change would significantly influence future flows of passengers.

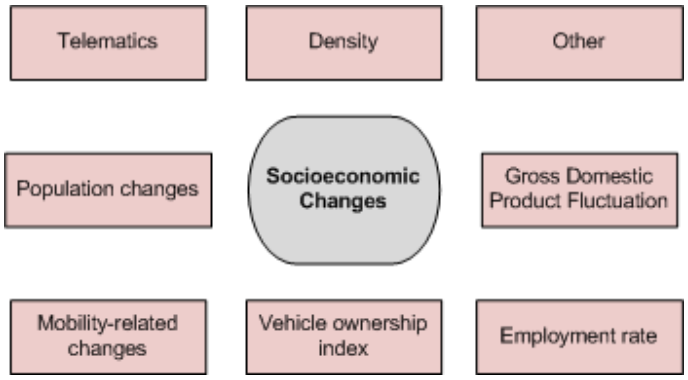

Figure 2: Identification of socioeconomic changes

Data regarding socioeconomic characteristics of areas and regions are often found within national statistical servicesor 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, businessand population changes.

2.1.3 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 3.

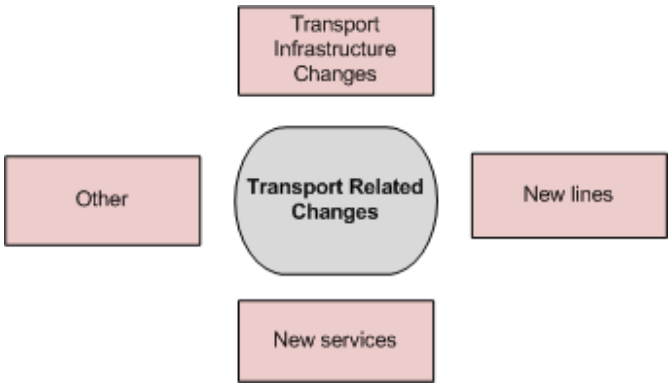

Figure 3: Identification of transport related changes

Development plans described in previous sectionsare not only limited to reporting onland 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 isolated from one another, similar sources may be drawn upon to identifytrip generating poles.

2.2 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, 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 4. The development of the probability-significance index can be an output of experts' opinion or can be stated within Development Plans as priorities for each change.

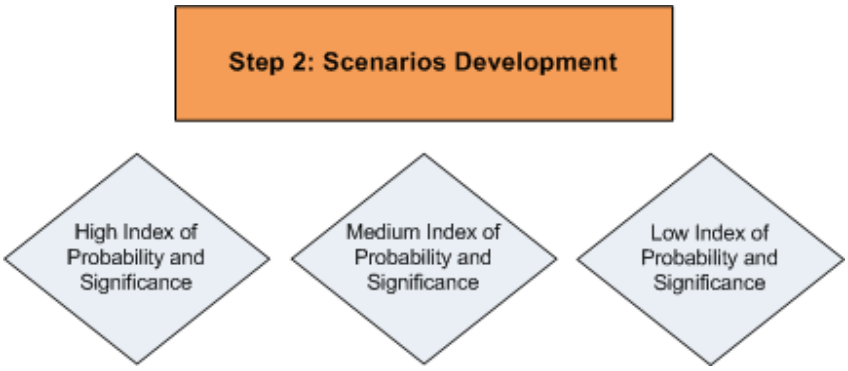

Figure 4: Scenarios classification based on Probability-Significance Index

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.

2.3 Step 3 - Estimating future trends in passenger flows

The issue of quantifying future trends in passenger flows, based on tripgenerating 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 5summarizes several approaches for estimating future trends in passenger flows.

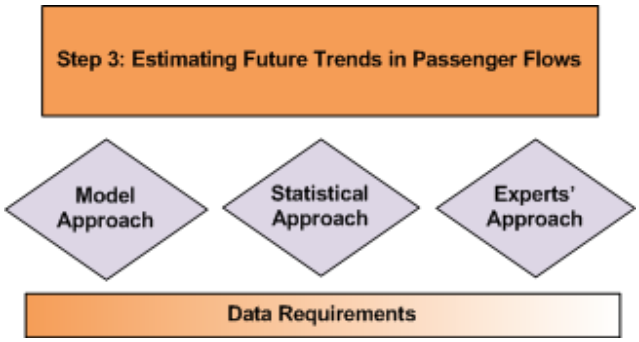

Figure 5: Approaches for estimating future trends in passenger flows

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 toquantify 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 andlabor-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%).

3 Anapplication

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

3.1 The case of Thessaloniki, Greece

Thessaloniki is the second largest city in Greece, currently accommodating 1.006.730 citizens in its greater area (ELSTAT2014). Situated in Northern Greece, Thessaloniki covers a total of 1.455,68 km2 with an average density of 16.703 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, in part as a result 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.
Figure 6 depicts the municipalities of the Greater Thessaloniki Area that are examined herein, while Table 1 summarizes their main characteristics in terms of population, size and density.

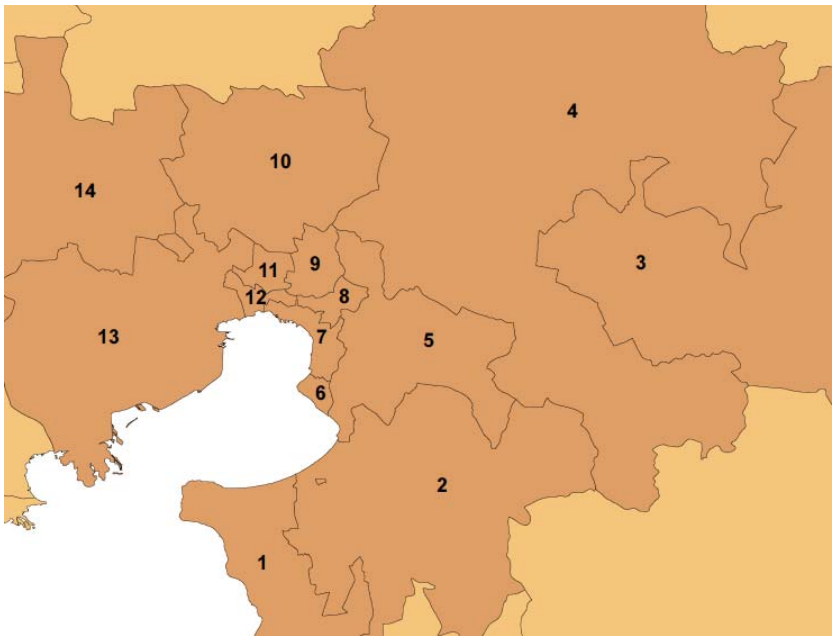

Figure 6: Municipalities within the Thessaloniki prefecture

Table 1: The municipalities of the Greater Thessaloniki Area

Municipality Name	**Population**[1]	**Area Extent (km^2)**	**Density (Citizen/km^2)**	**Map Index**
Thermaikos	37.126	133	375,5	1
Thermi	34.436	383	138,9	2
Volvi	24.454	783	29,85	3
Lagkadas	39.16	1222	33,4	4
Pylaia-Xortiatis	49.422	156	451,1	5
Kalamaria	91.279	7	14.258	6
Thessaloniki	397.156	20	16.703	7
Neapoli-Sykes	89.724	13	6.548	8
Pavlou Mela	87.587	24	4.16	9
Oraiokastro	24.962	218	175,9	10
Kordelio-Evosmos	77.174	14	7.561	11
Ampelokipoi-Menemeni	58.149	10	5.276,7	12
Delta	40.206	307	146,1	13
Chalkidona	34.299	391	85,7	14

3.2. Mapping of trip generating poles

3.2.1 Land use changes for municipalities within the Thessaloniki prefecture

With regard to the metropolitan area of the city, the Master Plan (MP) suggests the conservation of the industrial area and the reinforcement of competiveness 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(Master Plan for Thessaloniki's Metropolitan Area2009). 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 eastern part of Thessaloniki is recommended in order to provide all citizens

[1]ELSTAT 2014

with equitable access to health services, which are currently concentratedin the Western part of the city.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.

summarizes the most characteristic land use changes for municipalities within the hub of Thessaloniki and Figure 7depicts them graphically.

Table 2: 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 competiveness 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

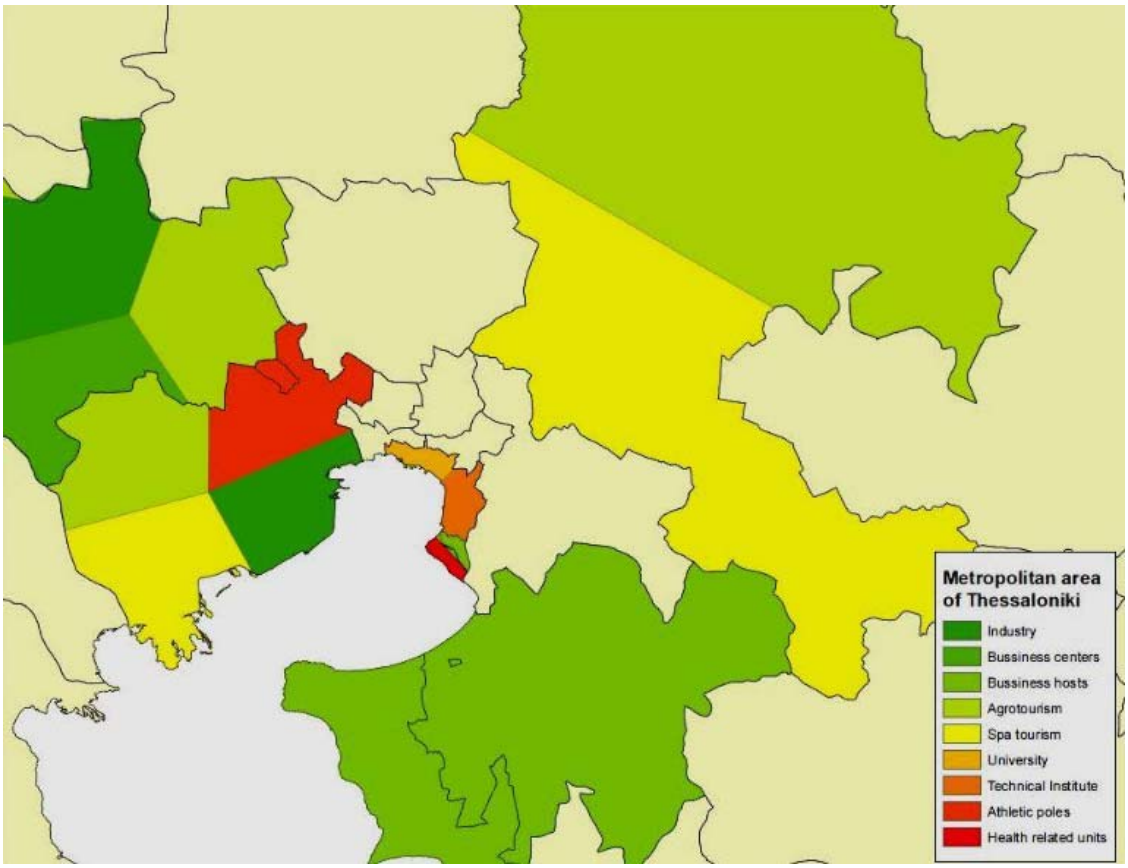

Figure 7: Land use changes in municipalities within Thessaloniki's hub

3.2.2 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 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 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. 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.
The modal split analysisreveals 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.

3.2.3 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. **Errore. L'origine riferimento non è stata trovata.** summarizes the most characteristic transport-related changes planned for municipalities within the hub of Thessaloniki.

Table 3: Transport infrastructure changes for municipalities within the hub of Thessaloniki

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 unification with the urban environment of Thessaloniki	2022	MP	M	International
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

3.3. Scenarios development

At this step, changes that are both highly probableand of regional to international magnitude are isolated, so that they can be handed over to experts for assessment.

Table 4: Medium and highly probable changes in the hub of Thessaloniki

Name	Change	Sector	Target year	Probability	Magnitude
Greater Thessaloniki area	Conservation and organization of industrial area and reinforcement of competiveness 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 centers	TI/Rail	2022	M	Regional
Ampelokipoi-Menemeni	Upgrade of passenger bus station into regional centers	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

3.4 Analysis of trip generating poles – trend estimation

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, as they were identified in sub-chapter 3.1.1 and 3.1.2. 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 lowest percentage change in future passenger flows according to experts will be +6% and the highest percentage change will be +9%.

4 Conclusions

This paper addressed the need to think about land use change and transportation in tandem. The two areas are intimately interdependent, and yet current studies have so far been incomplete and underdeveloped. Our suggestion here has been that a new tool needs to be developed which integrates the two sectors and allows planners to develop more efficient land use and transportation policies.

The methodology laid out in this paper can be used as such an evaluation tool. It can help plan 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.

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