

LAND USE TRANSPORT INTERACTION MODELS: APPLICATION PERSPECTIVES FOR THE CITY OF THESSALONIKI

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Land use patterns and transport system are considered to be the two basic components of the urban development process, and as such they have been in the core of spatial planning policies for the last 4 decades. Land use transport interaction models are computer tools that could help us understand land use changes and organization of human activities in relation to existing or planned transport infrastructure. In this context this paper examines the perspectives of applying a land use transport interaction model for the city of Thessaloniki. Obtaining, preparing and validating socioeconomic data is a crucial part of the modeling process, therefore an extensive search of the required data was performed. The quest for appropriate and suitable data concluded with a detailed recording of emerged problems. In response to the inability of finding suitable data to perform the first step of the modeling process i.e. calibration, the paper concludes with some thoughts related to data availability, organization and standardization issues. Last but not least, the paper stresses out the significance of data availability for utilization of land use transport models, so as not to remain purely academic products but tools with practical value in planning.

Key words: Land use transport interaction models, urban models, calibration, Thessaloniki.

INTRODUCTION

Land use patterns and transport system are considered to be the two basic components of urban development process, and as such they have been in the core of spatial planning policies for the last 4 decades. Therefore, urban form and land use structure were important determinants of the quality of urban space through respective urban and regional planning policies. Furthermore, in more recent years, finding the optimal spatial organization of urban functions in conjunction with a balanced transport system was the necessary condition for sustainable urban development and mobility in modern cities.

Land use transport interaction models (LUTIM) are computer tools that could help us understand land use changes, establishment of new spatial patterns and organization of human activities, in relation to existing or planned transport system. The issue of the interrelationship between land

uses and the transport system has been extensively discussed in the relevant Greek literature but mainly on the basis of its qualitative dimension (like in articles of: Pitsiava *et al.* (2013), Pitsiava & Kafkalas (2010), Basbas *et al.* (2012) and Pyrgidis *et al.* (2013)), while the quantitative dimension, as expressed through the use of LUTIM, has been neglected. Thus, although in Greece in the last thirty years there have been designed and implemented significant transport infrastructure projects (i.e. Athens Metro System, Thessaloniki Metro System, Attiki Odos in Athens, Outer Ring Road in Thessaloniki etc.), the use of such models in practice is non-existent.

In contrast, in many European countries and the US the use of LUTIM is a prerequisite to long-term and medium-term strategic plans for sustainable urban development. Relative international bibliography refers in great detail to the use and utility of LUTIM, as tools for evaluating the impacts of urban development policies (US EPA, 2000 and Spiekermann & Wegener, 2004). Actually, in the USA it was the

passage of two US federal policies in the early 1990s (Clean Air Act and Intermodal Surface Transportation Act) that brought LUTIM from academic circles to planning practice.

In Europe the issue of understanding and designing a sustainable urban transport and land use system was prevalent in the research agenda since early 1980s. Relevant reports by the European Conference of Ministers of Transport (ECMT 1995, 2002 & 2006) highlight not only the importance of developing integrated land use and transport policies, but also the importance of high quality implementation schemes and the need to gain public confidence and acceptability to support these policies. In this framework several research programs were initiated (i.e. EC Policies for Land Use and Transport for Increasing Urban Sustainability – PROPOLIS) to identify key elements for sustainable urban transport policies (Lautso *et al.*, 2004), and to create decision support tools in an effort to gain public acceptability and to engage actively key stakeholders into the planning process (Banister, 2000, Banister, 2008). Today, LUTI models are

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considered to be an essential part of urban transport policies and practices, mainly through the development of strategic plans for multimodal urban transport system, such as the Sustainable Urban Transport Plans – SUTPs (EC 2005, 2007), and the Sustainable Urban Mobility Plans – SUMP (EC, 2014). Both SUTPs and SUMP combine multi-disciplinary planning, policy analysis and decision making, where LUTI models are incorporated as tools for developing alternative scenarios and helping involved stakeholders to understand better the effects of the measures and policies discussed in the relevant plans (Bührmann *et al.*, 2011).

In this context, the paper examines the perspectives of applying a LUTIM for the city of Thessaloniki. The paper starts with the definition of LUTIMs and describes their usability and functionality within the planning context. It continues with the description of TELUM – Transportation Economic Land Use System, a LUTIM widely applied in the USA, and focuses on recording its data requirements. Following there is an attempt to collect the data necessary for the first stage of the modeling process, model calibration. The paper concludes with a description of the problems emerged during the process of data acquisition and stresses out the significance of data availability in the use of LUTIM or any urban model for that matter².

LAND USE TRANSPORT INTERACTION MODELS

Urban models and more specifically LUTIM were the way in which planners began to use the capabilities of personal computers, a tool to process large volumes of spatial data quickly, reliably, and accurately. The first generation of ITLUM occurred in the 1950s in North America, where rapid economic growth and the need for systematic study of interactions between land uses and the transport system set the conditions for creation and exploitation of the first urban models (Brail and Klosterman, 2001).

Land use transport interaction models are a class of urban models that focus primarily on population and employment location preferences in urban space, taking into account spatial interactions between different locations

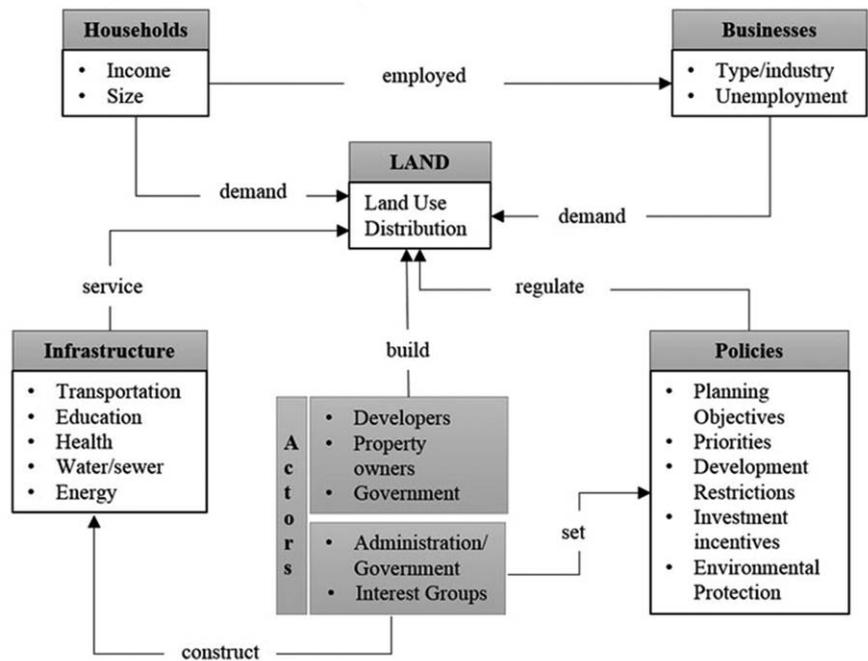


Figure 1. Interactions in a typical LUTI model

of these activities, and in relation to the transport system. Several LUTIMs have been developed, but regardless of their underlying theoretical background, their main objective is to simulate the behavior and interactions of factors and parameters that shape space, and translate their effects in a systematic way using algorithms. In this way it is possible to extrapolate the behavior of these parameters in the future, taking into account alternative development scenarios such as population growth, new infrastructure, environmental constraints, restrictions on construction, etc.

Figure 1 illustrates, in an abstract way, a typical LUTIM. The diagram represents interactions between three key players: households, businesses and government. The purpose of the diagram is not to depict in an exhaustive way the processes and interactions that might take place in such a model, but to provide a framework within which the reader can understand the process of simulation, the impacts and interdependencies for each one of these three factors.

TELUM - TRANSPORTATION ECONOMIC AND LAND USE MODEL

There are several integrated land use transport interaction models that have been applied and a few are publicly available. Current research focuses on the application of TELUM, one of the most popular LUTIMs applied in the US that is made freely available by the US Federal Highway Administration. TELUM – Transportation

Economic and Land Use Model, is a land use simulation model that can be used as a forecasting and policy analysis tool. Development of TELUM, which is part of a larger decision support system, was initiated and funded by the Federal Highway Administration (US Department of Transportation), with Rutgers University and the North Jersey Planning Authority being responsible for designing and developing the system. Funding started in 1998 with \$1 million per year, over six years period. In 2005 new funding was approved focusing on the implementation and widespread adoption of the system. Today the system is copyrighted and every metropolitan planning organization is eligible to use TELUM at no cost.

TELUM is an integrated interactive system that can be used to assist in evaluating the effects of a region’s planned transportation projects. It may also be used to make long term forecasts of a region’s spatial patterns. It uses current and prior residential, employment, and land use data to forecast future locations of each of those by employment sector, household income group, and land use type. The interrelationships between transportation and land use can be just as important, and in some cases more important, than the individual direct consequences of either. Having articulated a framework for examining, analyzing, or understanding transportation and land use interactions, it then becomes possible to consider the consequences of a wide assortment of different kinds of policies. This includes policies that attempt to achieve their

² It should be noted that the context of this paper is relying on the initial findings of an ongoing research funded by the Research Committee of the Aristotle University of Thessaloniki. The research is a cooperation between the Department of Spatial Planning and Development and the Transport Engineering Laboratory (Department of Civil Engineering) of the Aristotle University of Thessaloniki.

aims by changes on the demand side, in terms of urban planning and land use control, as well as those that attempt to achieve their aims by acting on the supply side in terms of various kinds of transportation improvement. These transportation improvements can be for highways, transit or combinations thereof, as well as in increases in utilization efficiency of existing facilities (Putman, 2005).

Model Description and Data Requirements

TELUM evolved from Putman's earlier work (Putman, 2010) and is designed to project the location of new residential and nonresidential development based upon analysis of (1) prior and existing residential and nonresidential development, (2) the location of transportation improvement(s), and (3) overall congestion in the system. TELUM forecasts the location and amount of household and employment growth for up to 30 years, information needed by an external travel demand forecasting model to estimate network flows and subsequent congestion induced changes in travel times.

Basic parts of TELUM are TELUM-RES and TELUM-EMP, a residential and an employment location model embedded with other auxiliary modules in one system. Figure 2 portrays the interrelationships between models, sub-models and their computational utilities. It also outlines the modeling process in TELUM. The chart itself is quite self-explanatory. The modeling process starts with acquiring and compiling the necessary data. It continues with calibrating the model parameters for both TELUM-EMP and TELUM-RES. TELUM-CALIB, the computational utility that performs the calibration process, uses a modified gradient search technique to calculate TELUM-RES and TELUM-EMP parameters, or coefficients, that produce the best fit for the model equations to region's data. These parameters also assure the accuracy of forecasts into future time periods. Modeling process continues with forecasting employment and household growth and calculation of the associated land demand. Based on this land demand, TELUM-LANCON estimates the change in the amount of land (per zone and locator type). If we would like to make any changes in the forecasts produced by the model, i.e. incorporate local knowledge into the system, this can be done by adjusting the attractiveness of land (TELUM-ATRMOD-attractiveness modification utility). Following is a brief description of the two most basic parts of TELUM, the employment and household allocation models, in order for the reader to understand the complexity that these models entail.

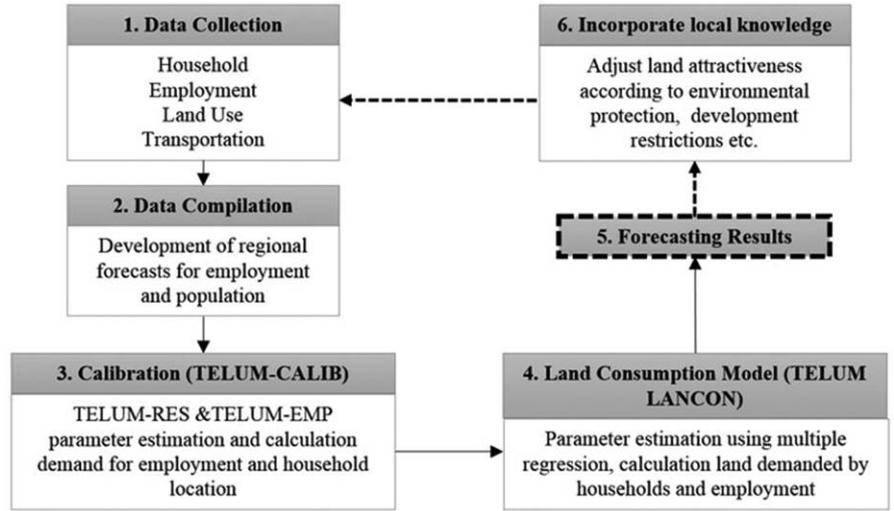


Figure 2. The modelling process in TELUM

A. TELUM-EMP-The Employment Location Model

TELUM-EMP is a modified version of the standard singly-constrained spatial interaction model. There are three modifications: 1) a multivariate, multiparametric attractiveness function is used, 2) a separate, weighted, lagged variable is included outside the spatial interaction formulation, and 3) a constraint procedure is included in the model, allowing zone and/or sector specific constraints (Putman, 1992).

TELUM-EMP model normally uses 4-8 employment sectors. Parameters λ , α , β , a and b of the equation are estimated individually for each one of the employment types through the calibration process. The equation structure used for TELUM-EMP is as follows:

$$E_{j,t}^k = \lambda^k \sum_i P_{i,t-1} A_{i,t-1}^k W_{j,t-1}^k c_{i,j,t}^{a^k} \exp(\beta^k c_{i,j,t}) + (1 - \lambda^k) E_{j,t-1}^k \quad (1)$$

where

$$W_{j,t-1}^k = (E_{j,t-1}^k)^{a^k} L_j^{b^k} \quad (2)$$

and

$$A_{i,t-1}^k = \left[\sum_l (E_{l,t-1}^k)^{a^k} L_l^{b^k} c_{l,i,t}^{a^k} \exp(\beta^k c_{l,i,t}) \right]^{-1} \quad (3)$$

where

$$E_{j,t-1}^k = \text{employment (place of work) of type } k \text{ in zone } j \text{ at time } t-1$$

$$E_{j,t}^k = \text{employment (place of work) of type } k \text{ in zone } j \text{ at time } t$$

$$L_j = \text{total area of zone } j$$

$$c_{i,j,t} = \text{impedance (travel time or cost) between } z \text{ ones } i \text{ and } j \text{ and time } t$$

$$P_{i,t-1} = \text{total number of households in zone } i \text{ at time } t-1$$

$$\lambda^k, a^k, b^k, \beta = \text{empirically derived parameters}$$

B. TELUM-RES - The Residential Location Model

TELUM-RES is also a modified version of a singly-constrained spatial interaction model. There are two major modifications: 1) a multivariate, multiparametric attractiveness function is used, 2) a consistent balanced constraint procedure is included in the model, allowing zone and/or sector specific constraints. The model normally uses 3-5 (current maximum is 8) household categories whose parameters are individually estimated (Putman, 1992 and Putman, 2010)³. The equation structure is as follows:

$$N_i^n = \sum_j Q_j^n B_j^n W_j^n c_{i,j}^{a^n} \quad (4)$$

where

$$Q_j^n = \sum_k a_{k,n} E_j^k \quad (5)$$

and

$$B_j^n = \left[\sum_l W_l^n c_{l,j}^{a^n} \right]^{-1} \quad (6)$$

and

$$W_i^n = (L_i)^{q^n} (x_i)^{r^n} (L_i)^{s^n} \prod_{n'} \left(1 + \frac{N_i^{n'}}{\sum_n N_i^n} \right)^{b_i^{n'}} \quad (7)$$

³ A more detailed description of models' structure is available in related scientific texts (Putman, 2010, 2005, 1992)

where

E_j^k = employment of type k (place of work) in zone j

N_i^n = households of type n residing in zone i

L_i^v = vacant developable land in zone i

x_i = 1.0 plus the percentage of developable land already developed in zone i

L_i^r = residential land in zone i

$a_{k,n}$ = regional coefficient of type n households per type k employee

$c_{i,j}$ = impedance (travel time or cost) between zones i and j

q^n, α^n, r^n = empirically derived parameters
 s^n, b_n^n

TELUM-RES is also capable of including additional attractiveness variables in the spatial potential term W_i , but there has been little use of this option in practice because such variables require the subsequent development of a means for their updating in forecast runs of the model.

TELUM data requirements

The success of every forecasting or analysis project is critically dependent upon the quality of its data inputs. In general, the more comprehensive and complex the proposed forecasting method is, the more extensive and expensive the required input data is.

Data requirements for TELUM can be grouped in categories depending on the different level of spatial, sectoral, and temporal detail required. It is important to distinguish between the information needed in regard to the overall modeling *region*, and the *zone-specific* information that is necessary for detailed spatial representation and analysis. *Region*, as used in TELUM, represents the total geographic area modeled. This area is defined by the researcher or agency depending on the modeling purposes. Following is a description of data requirements for TELUM along three basic dimensions for the modeling process: the geographic, the temporal and the activity/sectoral dimension.

Geographic Dimension: The level of geographic detail used in the model depends on the requirements and limitations of models employed. Also one should be aware that the greater the degree of the geographic detail (i.e.

the smaller the individual zones or analysis areas), the greater the cost of obtaining the data, the greater the required complexity of the model, and, inevitably, the lower the statistical reliability of the forecasts.

Prior applications of TELUM in the USA (Putman, 2010, Pozoukidou, 2014) have shown that the use of the US Bureau census tracts and more often aggregations of few tracts has been a satisfactory geographical level of analysis. It should be noted that most of the time analysis zones tend to be 'smaller' when they are located closer to the core of the area being modeled and progressively larger as moving away from the core. Apart from selecting the appropriate analysis zones, a quite trivial issue is defining the limits of the study area or the region modeled. There is no rigid definition imposed by the model, and a general rule would be to define the regional boundary were the amount of economic, social and other spatial interactions diminishes. Since most of the time it is not possible to define this boundary with accuracy, it is suggested that external zones are added in order to encompass the interactions outside the defined analysis zones.

Temporal Dimension: For the purpose of calibration TELUM needs data in two different time periods. The ideal would be to have base data in reference to a census year while the lag time point would be five years earlier. As far as forecasting, TELUM calculates forecasts in five-year increments i.e. if we set the current year in 2010 then forecasts will be five years beyond, starting from 2015, 2020 etc. Five-year increment is considered to be a safe choice for both calibration and forecasting, since there is little chance that sufficient data will become available in the near future to enable the use of shorter time periods. On the other hand, using larger time increments i.e. ten-year, can cause several problems. The most significant one is that too much can take place in ten years, meaning the interactions between locator types, as well as between activities and the transport system, won't be depicted in the data. However, data availability is the factor that determines the time frame of the data used, which sometimes might be less than the ideal data set.

Sectoral Dimension: TELUM models the behavior of several locator types, which can be up to eight employment and eight household types. The precise number of different locators depends on both data availability and the intended use of the model outputs. The differences in location behavior are determined from statistical analyses of the base year data for the specific region, to which the models are being applied.

Another type of data needed for calibration and forecasting purposes is transportation data. A 'description' of the transport system, which may include highway as well as transit, is taken from exogenous sources. These would be outputs of a transportation model that will provide a zone-to-zone travel time and travel cost on various modes that a user might experience. Based on the number of travel cost, as well as on the base year data regarding the initial locations of employment and households, and on a set of regional forecasts of total employment and total households, a calculation can be made that will estimate their location in the zones of the region. Often, a whole series of such forecasts will be made, at five or ten-year intervals from some base year, out to some long-term planning horizon (Putman, 2005).

Calibration Data Requirements

Model calibration is the first step of the modeling process and has to do with fitting TELUM-RES and TELUM-EMP models into the real world. This is achieved by estimating the parameters for each locator type (i.e. high income households, manufacture etc.), that will be used in models' equation. These parameters will be the ones that best fit the structure of the dataset used and will minimize the discrepancies between model results and real data. Calibration process used by TELUM CALIB module is based on the maximization of the likelihood function and employs a gradient search method (Putman, 2005).

Accuracy of the data used in the calibration process is extremely crucial, since it predefines the accuracy of the subsequent forecasting results. To perform calibration for TELUM-EMP it is necessary to have employment data by employment type and by zone for two time points five years apart. It is common practice to set a typical census year as 'current' time, such as 2011 (for Greece), and a 'lag' time point five years earlier, i.e. 2006. It should be noted that the employment data is the only data required in two time points.

For TELUM-RES it is necessary to have population data for one time point that will match TELUM-EMP 'current year'. Population data are usually households by type (4 to 8 categories of household types i.e. by income category) for each analysis zone, derived most of the times from the decennial population census. TELUM-RES allows the use of lagged household variables, which require household data for a prior time period, normally five years earlier. The use of lag household data significantly increases the accuracy of the calibration results.

Regarding land use data, it is considered to be

the most difficult data to obtain. A data set of different land use categories for each zone in 'current year' is required. The categories are shown below:

- Total zonal area
- Residential area (by household type)
- Commercial area (used for commercial and third sector employment)
- Industrial area
- Unusable area (e.g. water, environmentally sensitive lands, land with developmental constraints)
- Vacant developable area.

Despite the fact that it seems quite straightforward what type of land uses these categories may contain, questions often arise in determining where to place certain categories that may have been defined differently in the original data. Most of the time problems tend to arise in determining what constitutes vacant usable or developable land area. TELUM treats this category as developable land, or land that can be used for residential, industrial, or commercial purposes. How agricultural land, parkland, streets and highways, and wetlands are to be treated is a matter for decision by the user of the model.

APPLICATION OF TELUM IN THESSALONIKI, GREECE

Study Area Profile

Thessaloniki is the second largest city in Greece (after Athens), and one of the largest urban centers in the Balkans area. Since the early 1980s the greater area of Thessaloniki experienced tremendous changes in terms of its morphological and functional organization. Key features in these developments were urban expansion and the formation of a 'new city' that lacked defined boundaries and dominant center(s). New high speed highways (in conjunction with no investments in public transit), shopping centers, R&D facilities and companies' headquarters seem to be scattered in the peri-urban area. Suburban housing became accessible and affordable to middle and low income classes, increasing suburban housing demand and therefore becoming the main form of residential development.

Population distribution of the study area over the last 40 years comes to confirm all of the above, since the compact urban area of Thessaloniki the 'Urban Agglomeration of Thessaloniki-UATH', lost population to its surroundings (Map 1). More specifically during 1991-2001, UATH experienced only a 7% increase in population

numbers, a percentage that was not even close to the increase that the greater area of Thessaloniki experienced (32%). Dispersion of population to the outskirts of the compact center became even more obvious in the next decade (2001-2011) when UATH showed, for the first time in its urban history, a 2% decrease, while its peri-urban area (GATH) experienced a 23% increase (Yiannakou, 2012).

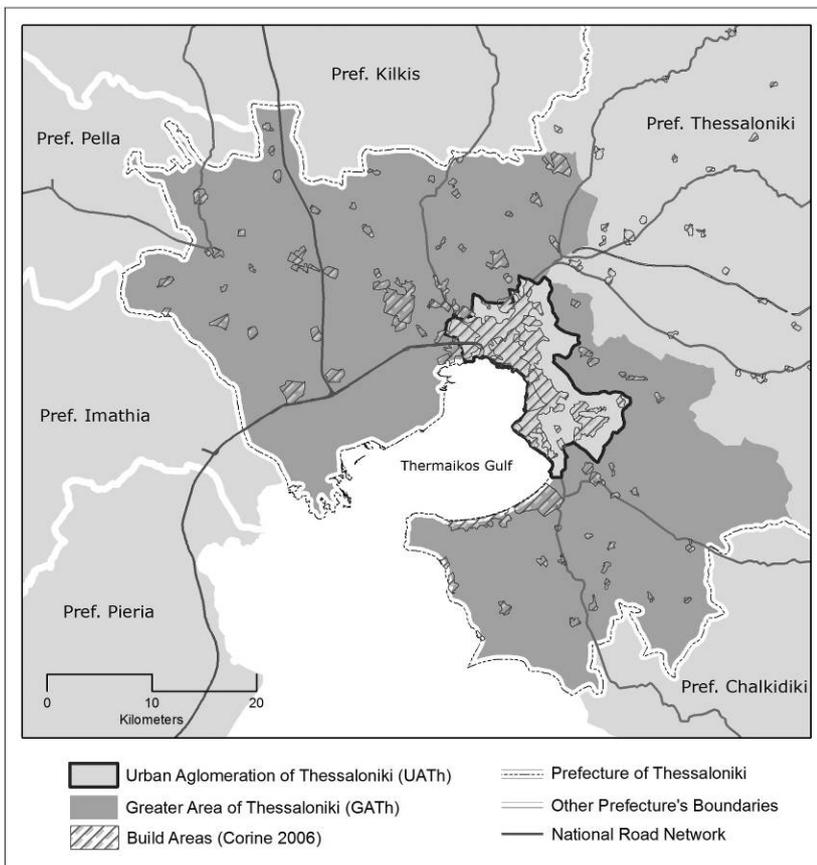
Data availability and acquisition

The most challenging issue in applying a LUTIM is acquiring the appropriate data. Data required for TELUM and for the purposes of calibrating the model(s), is presented above. The first issue that had to be addressed was the spatial analysis unit. When dealing with socio-economic data it is common that spatial unit of analysis is the census tract level (or its disaggregation), as defined by the Hellenic Census Bureau. The use of census tract as spatial analysis unit has many advantages, including the greater flexibility in defining the boundaries of our study area and the fact that we can work with actual (and not estimated) data recorded every decade (1991, 2001, 2011, etc.).

Despite the fact that census tracts might be the best spatial analysis unit, it was imperative to take into account the spatial unit for which transportation data was collected and which is available to us. It has been mentioned that in the process of modeling and mostly during forecasting procedure, it is required to have a computation of zone-to-zone travel time and travel cost on various modes. A relative search in regard to transportation data availability showed that for our study area there has been only one transportation study (TS) that was conducted back in 1997. The study defined 316 transportation analysis zones (TAZ), that most of the times were disaggregation of the corresponding census tracts. Map 2 shows the total area that transportation study covers and its relation to the UATH and GATH.

Despite the fact that the traffic study is outdated, it still remains the only source for transportation data and therefore it becomes essential that we use the same spatial analysis unit. It should be noted that definitions of TAZs were the result of an extended analysis of traffic patterns in the area of Thessaloniki. Therefore, any future efforts to update transportation data will most probably use the same zonal system.

The inevitable selection of TAZ's as TELUMS analysis zone created several spatial and temporal inconsistencies. As far as spatial inconsistencies, the first issue that arose was



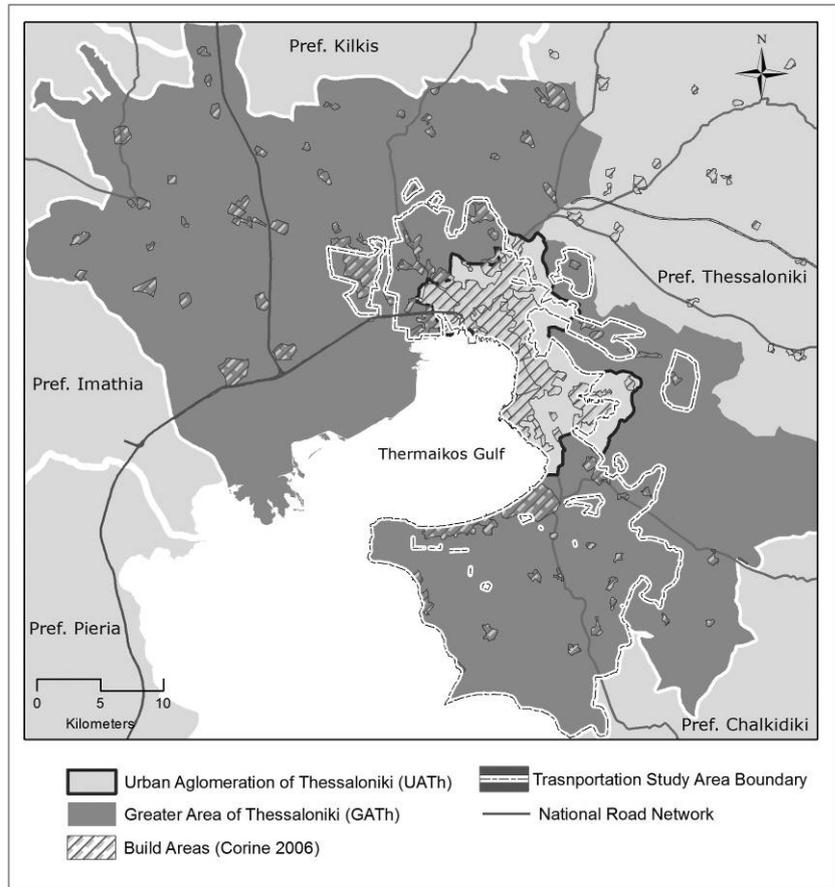
Map 1. Thessaloniki: Urban Agglomeration and Greater Area

that the study area of 316 zones as defined at the time that the transportation study was conducted (1997) includes the functional area of Thessaloniki as in 1997. Besides, as indicated in Map 2, the TS area covers mainly UATH and only a small part of GATH, when GATH, as explained earlier, experienced dramatic changes over the last decade (2001-2011). Therefore, the 1997 definition of the study area becomes obsolete for the use in TELUM. An addition of several zones that would incorporate GATH into the existing zonal system would be an appropriate solution, but the lack of past and present transportation data for these zones makes it practically useless.

Another quite trivial issue was to find appropriate land use data and to create the categories required by the model. TS provided us with some land use data, but the way it was recorded was not suitable for use by TELUM. For this reason a calculation of land use categories that were missing was conducted. In more detail, TS recorded land uses as total build area occupied by each activity (i.e. residential, commercial, etc.). Essentially, total build area is the actual land area multiplied by the corresponding floor area ratio (FAR). For instance, in a zone of 108 acres there were 267 acres build up area. A simple division will give us a FAR of 2.4, which happens to be the statutory FAR for this zone. This led us to the conclusion that there is no available 'land' for further development. If the statutory FAR was higher than 2.4, then there would have been vacant land available for development in the zone. Under the same notion we were able to calculate the acres for each one of the categories needed.

In terms of data's temporal reference, it is predetermined that since we have transportation data only for 1997, this will be set as the 'current year' for the calibration and forecasting process. Therefore, 1991, which is the immediately preceding census year, becomes the 'lag year'. This makes it a six-year increment, which is close enough to the five-year ideal time increment. Fortunately, employment, household and land use data for 1997 are available by TS itself. Table 1 summarizes data requirements and sources for the use in TELUM.

Last but not least, one cannot ignore the quite old time reference of the input data. Actually, the issue that arises here does not have to do with the time reference of the data per se, but with the fact that both employment and household 'reality' has radically changed over the last 4 years. It is well known that Greece experienced (and still does) a major economic crisis that led to financial support from the International Monetary Fund in 2010. This fact completely changed the market behavior



Map 2. Transportation Study Area Boundary

Table 1. TELUM Data Requirements and Sources

Type of Data	Spatial Reference	Temporal Reference	Source
Population Control Totals	Regional	Lag, 1991	Census
Employment Control Totals by sector	Regional	Lag, 1991	Census
Households by Income	TAZ	Current, 1997	TS
Employment by Sector	TAZ	Current, 1997	TS
Interzonal Travel Cost	TAZ	Current, 1997	TS
Land Use (Total and by type)	TAZ	Current, 1997	TS
Average number of employees by household type	TAZ	Current, 1997	Unavailable*
Households (by income) per Employees (by sector)	TAZ	Current, 1997	Unavailable*
Regional Rate of Employee Commutation	Regional	Current, 1997	TELUM default value

* We can assume uniform distribution of employees across household types

for both businesses and households due to reductions in income, unemployment and the undermining of public services and infrastructure (Thoidou, 2013). One of the most evident effects was on the housing construction sector where hundreds of new homes in the suburbs still remain unsold. The construction sector decline led to a great loss of construction jobs that were mainly occupied by immigrants. In turn, immigrants, who mostly lived in the city center, abandoned the city in order to find jobs in more prosperous countries. This created 'new' housing stock within UATH. In general, economic crisis

brought several effects that the city experienced for the first time, like high vacancy rates in commercial properties both in the city center and suburbs, reduced use of cars due to high gasoline price, and return of inhabitants in the city center due to lower rents.

The effects of economic crisis are in many ways related to the calibration of the model. As mentioned earlier calibration process adapts the model to the input data and determines the values for α , β , λ , a , b and all other related parameters. Essentially, the calculated values

for these parameters incorporate the future behavior for each locator type for employment and households. Therefore, if we calibrate the model with the 1997 data we implicitly assume that past urban development trends will continue to occur.

In a scenario where Greece did not experience economic crisis this data, even if a bit outdated, would have been appropriate for model calibration. This is because in such a scenario we assume that the development trends will continue, until full capacity of transportation and land use system occurred, or until certain governmental policies suspend or restrict market trends. When extreme and unexpected events occur (i.e. stock market crash), LUTIM, or any model for that matter, cannot automatically adapt to the new situation, unless we calibrate the model to the new 'facts'. In the case of Thessaloniki the most recent socioeconomic data available is the latest national Census (2011), which still does not capture the effects of the ongoing economic crisis. Even so, if we decided to use 2011 data inputs, the fact that there is no recent transportation data would make it impossible to calibrate the model.

It is obvious that the calibration process and the modeling process in general is a data intensive procedure. Even if the researcher decides to make certain concessions with the quality of data used, requirements can still be high enough to make its application impossible. At this point it should be noted that the choice of model(s) used here (TELUM) was not random. Actually, the option of using other LUTIMs were examined but the highly aggregated data required by TELUM in comparison to the refined data required by other models (i.e. UrbanSim) was the determinant factor in making the final decision. Nevertheless, the weakness of acquiring the appropriate data even for TELUM, has highlighted important issues related to data availability, organization and standardization.

As a result a reorientation of the course of the project was considered. The main research target from now on will be to find, organize and standardize the appropriate data. For example, land use data will most probably result from General Urban Plans that each municipality has, where existing land uses are recorded. This is not an unproblematic solution since it could be quite time consuming (GATH has 13 municipalities and several sub-municipalities each) and with several inconsistencies (General Plans have been conducted roughly from 2000 till today and have different land use codification). As far as transportation data, a

research field is required, in combination with data that could be purchased, in crude form, from the Hellenic Transport Institute. Finally, for the socioeconomic data, a research team is still on quest finding out how data that will encompass 'new' locating behavior for households and businesses, will be acquired.

CONCLUDING THOUGHTS

Implementation of LUTIMs requires access to combination, consolidation, display and exploitation of data from a variety of sources. It also requires efficient processing mechanisms that can handle large amounts of different data like topographic, cadastral, land cover and use, transportation, employment, building information, etc. (Joksic and Bajat 2004). Last but not least, they require both data at different scales to denote the functional and morphological characteristics of a city, and data over several years to identify evolution patterns.

An attempt to apply a relatively simple, in terms of its data requirements, LUTIM brings up important issues of data availability and data standardization. In a world where software vendors have implemented products tailored to the needs of specific research goals, communities and customers, standardization of data becomes a necessity in order for the interoperability of different systems to succeed (Hamilton *et al.*, 2005). There is an extended bibliography in relation to integration and interoperability strategies for urban data. There are also several conceptual urban data models developed to accommodate datasets relevant to different aspects of urban modeling and city planning in general. In an effort to underline the significance of having extensive and consistent spatial data the EU adopted the INSPIRE Directive in 2007, an infrastructure system for spatial information in the European Community. The main goal of the system was to make more and better spatial data available for the preparation and implementation of environmentally (and not only) related issues.

The final point that this paper wants to stress out is the significance of finding the appropriate data to make use of any LUTIM. It is a common misconception amongst the modeling scientific community that advancements in LUTI modeling (and urban modeling in general) has to do with two factors. The first is the refinement in the model packages, aiming to increase the percent of explained variation or, in other words, increase the predictability of the model. The second is the refinement of the spatial level of analysis, by increasing the disaggregation of the models originally developed in the 'first generation' of operational models. Indisputably,

these two factors are significant to advancement of modeling per se, but the last 15 years the usability of models has also become a major determinant of their practical value in planning. The usability of models in planning practice is determined by various factors, availability of data being a significant one (Pozoukidou, 2008, Putman, 2010). Therefore, less sophisticated models that require few data could have better utilization prospects and consequently more practical value in the planning practice.

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