# Forecasting land use changes: An empirical approach for East Thessaloniki.

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**Abstract.** Land use models are tools for predicting future urban development where mathematical models are employed to represent interactions within city environment. This paper focuses on land use transport interaction models, a certain type of urban models that represent interactions between land use development and transportation infrastructure. Given that there has not been any recorded effort of application of such models in Greece, this paper records and assess the difficulties and bottlenecks arose in the process of data acquisition, calibration and forecasting. The land use transport interaction model is applied to two municipalities in East Thessaloniki, Greece.

**Keywords:** Land use planning, land use models, urban models, applicability of models.

## 1. Introduction

McLoughlin in his book *"Urban and Regional Planning: A systems approach"* for the first-time records and extensively documents the concept of cities as urban systems that consist of a series of smaller interrelated subsystems, where human behavior and interactions are critical to their evolution (McLoughlin, 1969). Despite the fact that the legitimacy and rationality of the systemic view of cities was heavily criticized in the years to come, contemporary views of cities as highly complex environments brings back the need to find order in chaos. Geoffrey West coordinator of big projects on the new science of cities thinks that collecting and analyzing big data sets could help us discover the laws of evolution of urban phenomena (TED Global Talk, 2011). He also emphasizes that the use of advanced mathematics to understand cities does not necessarily contradict the view of cities as a set of complex semi-autonomous and interdepend actors and processes. Proponents of complexity theory and evolutionary approach argue that spatial planning should reinvent itself to serve the new challenges of an urbanized world, and new techniques of data collection, mining, management and pattern recognition should be part of it (Batty, 2012). Therefore mathematical models should be seen as a new opportunity to explore spatial relations which include new evolutionary approaches that rely on massive data, in most cases real data, that depict human behavior. In this context, this paper assess the application of a land use transport interaction model in a Greek city and records probable bottlenecks. Practical issues related to definition of study area, data availability, calibration results and forecasting procedures are explored.

## 2. The complexity of urban systems and the role of urban models.

According to Mıchael Batty in order to understand cities we must view them not simply as places in space but as systems of networks and flows (Batty 2013). Therefore in order to understand space we must comprehend how flows and networks function as one system. Critical elements that define a city system are the size of cities, their internal order, the transport routes, and finally the location of their activities. Therefore, spatial planning should be seen as a way to reshape spatial patterns and future arrangements of population, networks and activities. A wide array of simulation methods that range from simple stochastic models to bottom-up evolutionary models to aggregate land-use transportation models, have been used in order to comprehend the relation of activities, population and networks (Batty 2013). TELUM-Transportation Economic Land Use Model is a land use transport interaction model that attempts to replicate how networks, activities, population and flows are interrelated within an urban system. In specific, TELUM attempts to replicate agent interactions (households, employers, developers, and government) and to record their consequences in a systematic way. It does not explicitly model every interaction amongst those agents, but it views them from an aggregative perspective. It focuses on how employment and their location choices affect the future location of the households, and in turn, the implications on the land-use development patterns in the region. From a functional perspective, the modelling process in TELUM starts with the calibration of the model parameters for both the employment and residential allocation model (Figure 1). It continues with forecasting employment and household growth and with the calculation of the associated land demand. Based on the forecasted land demand, the system estimates the change in the amount of the different land use types (i.e. land for tertiary employment, high income households etc). If the user desires to make any changes in the forecasts produced by the model, i.e. incorporate local knowledge into the system, it can be done by adjusting the attractiveness of certain land use types (Putman, 2005).

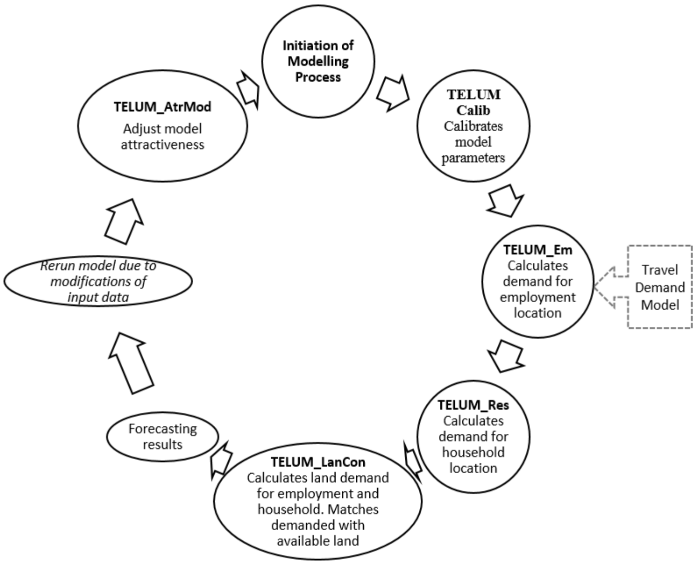


**Figure 1.** The land use modelling process in TELUM

## 3. The case study of East Thessaloniki, Greece

Greece does not have any tradition or experience in using predictive methods to perform land use planning, a practice that have been quite common for the most west European and U.S. cities since the early 1960s. Therefore there has not been an application of any kind of land use model for the city of Thessaloniki. In general it was not until 1980 for Athens and 1997 for Thessaloniki that the first transportation study was conducted, when both cities had already experienced rapid suburbanization trends. To be more specific in the case of Thessaloniki this was the first and only time that a transportation study was ever performed. Nevertheless it was a high quality study due to the extensive mobility, demographic, and land use data acquition that was realized. Located in the eastern part of Thessaloniki's greater urban agglomeration system the study area consists of two municipalities, the Municipality of Kalamaria and the Municiplaity of Pylaia (Figure 2a). The city (urban agglomeration) of Thessaloniki is the second largest city in Greece (after Athens), and one of the largest urban centers in the area of Balkans. Since the early '80s the greater area of Thessaloniki experienced tremendous changes in terms of its morphological and functional organization. Key development features were the rapid 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 housing demand and therefore becoming the main form of residential development. The two municipalities under study were part of the recorded urban expansion trend. To be more specific from 1991 to 2011 Municipality of Pylaia experienced tremendous population growth (51%) while the rest of the urban system were either experiencing decline or no significant population change. This was due to the fact that Pylaia was partially in continuation to Thessaloniki's dense urban tissue while at the same time offered an attractive environment for household relocation due to low residential density and presence of natural environment. Except form the planned, mainly residential, area Municipality of Pylaia has also an extensive area that does not have any designated land uses but still an area that practically any activity can be located there. This is a peculiarity of the Greek planning legislation system according to which any peri-urban, ex urban and rural area is potentially developable land (for residential, commercial etc. uses). Besides this was the area that most of the new shopping centers, R&D facilities and companies' headquarters were located due to the large ammount of available developable land and its proximity to the airport and city of Thessaloniki (Figure 2b). On the other hand municipality of Kalamaria has a quite different profile since it is part of the dense urban tissue of Thessaloniki. It did not experience dramatic population changes over the last decades due to the fact that this area has been under development for several decades now. It has a quite dense urban environment with almost 100% fully developed urban tissue and no developable land available. It is also primarily a residential area with the exception of certain central axis where services and recreation uses develop.

### *3.1 Data availability and acquisition*

Acquiring appropriate data for the model, is probably the most difficult, time consuming and tedious task in the modelling process. TELUM requires five types of data: population, employment, households, travel cost and land uses. Table 1 presents the type of data required to run all modelling steps, along with their spatial and temporal reference. Souce of data used to run the modelling process is also denoted. In terms of data's temporal reference, it is predetermined that since there is available transportation data only for 1997, it is inevitable to set 1997 as the "current year" for the calibration and forecasting purposes. Therefore 1991, which is the immediate preceding census year, becomes the "lag year". This makes it a six year time interval which is close enough to the five year ideal time

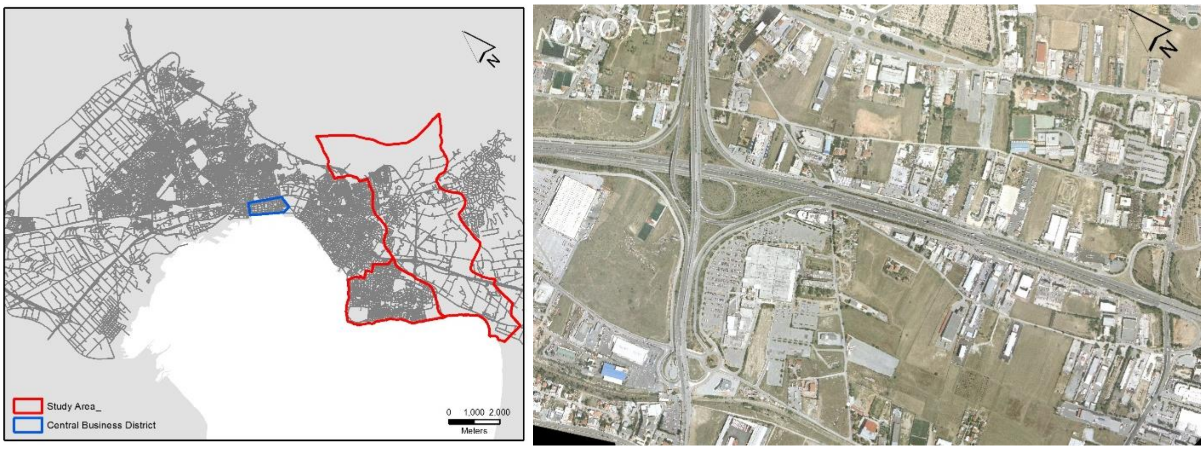


**Figure 2. (a)** Location of study area relativelly to the city of Thessaloniki **(b)** Big Box and R&D development

**Table 1.** TELUM Data Requirements

| Type of Data | Spatial Reference | Temporal Reference | Source |
|---|---|---|---|
| Population Control Totals | Regional/TAZ | Lag -1991 | Census |
| Employment Control Totals by sector | Regional/TAZ | 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

Source: Pozoukidou, 2014

interval for modeling purposes. Fortunately employment, household and land use data are available in 1997 by the transportation study (TS). In terms of spatial reference Transportation Analysis Zones (TAZ) were used for most of the required data since this was the only spatial level that transportation data was available in order to run the calibration process. It was also the only spatial level that someone could find data for employment by sector at the place-of-work and not place-of-residence (Pozoukidou, 2014). In terms of the land use data five different land use categories for each analysis zone is required. The categories are: total zonal area (study 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), and vacant developable area. Finally transportation data (zone to zone travel time, costs or composite) was also necessary. Most of the required data were available by the transportation study but extensive readjustments had to be done in order to match the available by the transportation study data to the form of data that TELUM requires (Zarov, 2016).

*3.2 The modelling Process*

In total 40 TAZ compose the study area with population of 130.000 inhabitants. The four basic employment sectors used for the modelling process were a) “Basic” that includes primary and secondary sector employment, b) “Retail services” that includes employment in retail services wholesales included, c) “Public Services” which includes public services but also private provided services such as health, education etc. and d) “Advanced Services” that includes finance, consulting, engineers, lawyers etc. All employment data were calculated at place-of-work per TAZ for 1991 and 1997. In terms of household data four income based household types were formed. These were “Low Income”, “Middle Income”, “Upper Middle Income” and “High Income” per TAZ for 1991 and 1997. In terms of land use data five land use categories, as described earlier, for each analysis zone was used. All these data along with transportation data was entered into the "Data Organization and Preparation Unit" of TELUM. In this module TELUM performs a data consistency check in order to evaluate the quality of imported data. Results indicated high correlation values between different pairs of data. In specific it seems that total current households and total lag households present a correlation of 0.997. The same applies for the four employment categories. High correlation between lag and current employment, in a specific category (i.e. in "Basic" sector), indicates little of no change in the location of that employment type. Data inconsistencies derives from the fact that both employment data for 1991 was constructed by the researches in order to fit the model requirements, since there was no suitable data by the respective Census count. In any case these type of data inconsistencies affect the validity of results and the respective variables should be replaced as more reliable data becomes available. The next step in the modelling process is calibration of the models embedded in TELUM. In specific ccalibration is the process of fitting the residential and employment models into the real world by estimating the parameters for each locator type (i.e. high income households, basic sector etc), which will be used in models' equation. These parameters will be the ones that best fit in the general model structure of the dataset and will minimize the discrepancies between the model results and real data. The measures of goodness of fit achieved from the calibration process were quite satisfactory. Table 2 shows a summary of the calibration results for employment, where three goodness-of-fit indicators are presented with their values. Best Worst LIkelhood ratio (B/W LR) for the four employment sectors are high indicating that employment data fits very well the employment model. At the same time MAPE values are quite low indicating that the estimated parameters for the household and employment model equation represent the best-fit model since the percentage of error between observed and model's current best fit estimates for each one of the locator types are within the acceptance range. For Households, B/W LR results are high indicating that household data fits quite well the household model (table 3). At the same time MAPE values are in the high end of the acceptable values indicating that the estimated parameters for the respective model equations does not represent the best-fit model since the percentage of error between observed and model's current best fit estimates for each one of the locator types are in the high end of the acceptance range. Proceeding to the calibration of the land consumption model it seems that the overall goodness of fit of the model for all household types and "Basic" employment sector is 73% and 69% respectively, indicating that the model can account for the majority of the zonal variation of change in land consumption for households and industrial land but cannot be a good predictor of it. On the contrary for retail, public services and advanced services the equation can account for most of the zonal variation (85%) of land consumption and can make reliable predictions of these type of land use. The last step of the modelling process is forecasting future spatial allocation for employment and households in the study area. In order to do forecasting it is essential to have future (forecasted) travel impedance. Since this was not possible a baseline scenario was developed.

**Table 2.** Employment Goodness of Fit

| Employment Sector | B/W LR | MAPE | MARMO |
|---|---|---|---|
| Basic | .9950 | 9% | 8% |
| Retail | .9763 | 36% | 31% |
| Public Services | .9961 | 18% | 18% |
| Advanced Services | .9334 | 23% | 23% |

**Table 3.** Household Goodness of Fit

| Household Cat. | B/W LR | MAPE | MARMO |
|---|---|---|---|
| Low Income | .9421 | 84% | 16% |
| Middle Income | .9762 | 44% | 15% |
| Upper Middle Income | .9094 | 34% | 19% |
| Upper Income | .8432 | 40% | 29% |

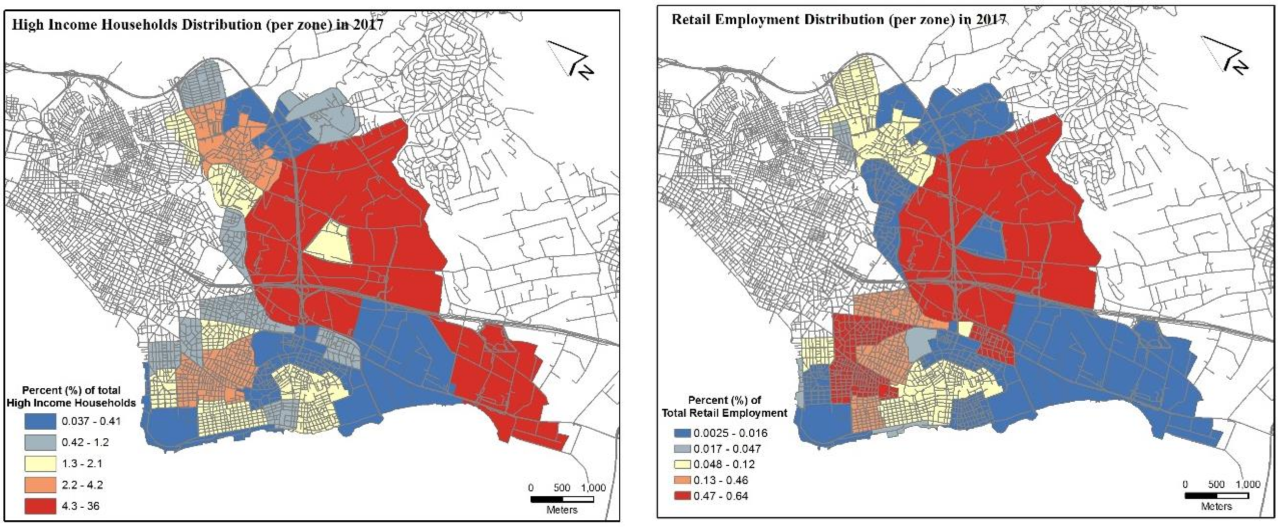


**Figure 3. Forecasting results for high income households and retail employment in 2017**

In this scenario it is assumed that there will be no change in the transportation infrastructure for the study area therefore forecasts will be based on an observed level of activity, and calibrated attractiveness variables are obtained from the current year data inputs (travel impedance). The current year for the baseline scenario is 1997 and four 5-year time intervals were set for forecasting purposes (1997-2002, 2002-2007, 2007-2012, 2012-2017). Finally forecasting was also based on the future regional employment and household projections that have been imported earlier into the system.

According to forecasting results study area presents a 24% decline for the basic employment sector while retail, public services, and advanced services presents a 25%, 4% and 4% increase respectively. In terms of households an increase of 10%-14% for all four household types have been recorded. In general as it was expected the model predicted an increase in population and household numbers as well as in the employment numbers of the tertiary sector. The spatial distribution for each locator type is not posibble to be presented here but a sample of the model outputs for 2012-2017 forecasting period are depicted in the maps below (figure3).

## 4. Discussion

The scope of this paper was to assess the application of a land use transport interaction model in a Greek city and record probable bottlenecks. Given that there has not been any recorded efforts of application of such models for Greek cities, makes the contribution of this paper critical towards the use of models in a Greek setting. Applicability assessment of the model was made for the three different modeling steps data acquisition, calibration and forecasting.

It is obvious that implementation of land use models require large amounts of different data like land use, transportation, employment, building information etc., at different scales and over several years. An attempt to apply a relative simple, in terms of its data requirements, model in the area of Thessaloniki brings up important issues of data availability and standardization. In the case of Thessaloniki available data lacked of appropriate spatial and temporal reference. The inevitable choice of TAZ's as analysis zones created several issues in acquiring appropriate, for the model, data especially data related to employment at place-of-work and land use. Despite data inconsistencies calibration results indicated that employment, household and land use allocation models can account for most of the zonal variation of each locator type and can make reliable results. In an effort to highlight the usefulness of land use models as policy evaluation and decision making tools a future development scenario was also attempted. Available dataset enabled us to predict land use changes from 1997 to 2017 in 5 years increments. Results were comparable to existing situation in 2017 indicating that the embedded models are suitable for use in Greek cities.

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