Potential contribution of LUTI models in contemporary strategic planning for urban mobility: a case study of the metropolitan area of Thessaloniki

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Abstract

The contemporary approach of strategic urban mobility planning aims at the cross-scientific analysis of the interactions between the transport system and urban structure, under the perspective of socio-economic and environmental sustainability. In this context, the European Commission currently promotes the concept of the Sustainable Urban Mobility Plan (SUMP), which can be defined as a strategic planning framework for the urban multimodal transport system combining multi-disciplinarity, policy analysis and decision making, while its objectives concise with the main pillars of sustainable urban mobility. SUMP guidelines refer to the potential use of Land Use and Transport Integrated (LUTI) models as tools for the development of strategic scenarios during the preparatory stage of the planning process. Based on the conceptual background of LUTI models, the current paper suggests that they could play an extensive role in the implementation of a SUMP. Therefore, it discusses the expected benefits and drawbacks from the implementation of a LUTI model in contemporary strategic planning for urban mobility and proposes a framework for the full integration of such a model into the SUMP cycle. An application of the proposed framework is attempted for Thessaloniki’s SUMP, recording the emerging problems and implementation issues. Finally, the paper concludes by outlying the potential added value from the full integration of a LUTI model to the SUMP cycle.

Keywords: land use transport integrated models, sustainable urban mobility.
1 Introduction

Land use refers to the allocation of a specific socio-economic activity within the boundaries of a specific location. Main land uses in the urban environment include work, education, commerce, services and recreation. The interaction of land uses within a spatial entity composes the land use system, which can be described by the following components [1, 2]: a) type, location and spatial features of various land uses, b) characteristics and distribution of demand for socio-economic activity and c) differentiation between the demand and supply of land uses. Thus, the land use system illustrates the spatial organisation of the network of socio-economic activity and describes the physical separation between them.

The overcoming of this physical separation is the overall objective from the development of the transportation system which, at the same time, leads to new mobility and accessibility conditions that may create new time-space relationship between land-uses [3]. An indicative example frequently encountered in the international literature is the concentration of specific land uses, residential and other, in the area of influence of main public transport stations and the corresponding effect on land values [4, 5]. Another aspect of the interaction between transportation and land use refers to the spatial features of transport infrastructure. In specific, transport infrastructure consumes a significant part of the available space, especially in urban areas, while it may produce fragmentation and segregation effects [6, 7].

The analysis of the interaction between the transportation system and the land use system is nowadays established as a core issue of mobility planning due to the emergence of the concept of sustainable mobility. In opposition to conventional urban transport planning, where the increasing demand in mobility is coped with the constant increase of infrastructure, sustainable urban mobility planning is a more holistic approach that aims at the maximisation of the efficiency of the transportation system and the minimisation of externalities, i.e. the negative effects on the urban development, the natural environment, the economic competitiveness and the quality of life.

The European Commission (EC) currently promotes the aforementioned sustainable planning approach for urban mobility in the framework of Sustainable Urban Mobility Plans (SUMPs) [8]. A SUMP is a strategic plan for the urban multimodal transport system that combines inter-disciplinary planning and policy analysis with decision making. Its objectives coincide with the components of sustainable mobility, i.e. accessibility for all, efficient and affordable mobility services, enhancement of safety and security, decrease of emissions and improvement of energy efficiency and upgrade of the urban environment. More specifically, it covers the whole planning process from the preparatory and goal setting stages to the elaboration and implementation stages through a series of elements that correspond to the specific objectives of the plan, each comprising a set of activities. The plan unravels in a circular pattern concluding in the setting of the basis for the conduction of the next SUMP [9].

The SUMP guidelines propose the combination of the appropriate techniques, such as quality management and benchmarking, and tools, such as indicators and
models, for the successful conduction of the activities and the fulfilment of the requirements of each element. Towards this purpose, the use of Land Use and Transport Integrated (LUTI) models is suggested during the preparatory stage of the SUMP as a tool for the analysis of strategic scenarios regarding the impact of the transportation system on locational choices [9]. Based on this suggestion, the scope of the current paper is the detailed examination of the potential contribution from the implementation of a LUTI model in the context of a SUMP’s objectives and activities and the development of a framework which fully integrates a LUTI model into the SUMP cycle. In order to achieve this scope, the first part of the paper involves the presentation of the concept and main components of a typical LUTI model, the comprehensive approach for the categorisation of LUTI models and the framework for their evaluation as tools for the support of strategic planning. The next part refers to the description of the framework for the full integration of a typical LUTI model to the SUMP cycle. The potential integration of a LUTI model in Thessaloniki’s SUMP, which is the first SUMP conducted in a Greek city, is discussed in the following part focusing on the emerging problems and implementation issues. The paper is concluded with the outline of the overall added value from the full integration of a LUTI model to the SUMP cycle. Finally, 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.

2 LUTI model components and role in strategic planning

2.1 The main components and categorisation criteria of LUTI models

A LUTI model is a tool for the support of strategic planning through the estimation of trends in locational choices and the forecast of land use patterns by combining the features of mobility, the socio-demographic characteristics, the features of the industry, the geomorphological and wider environmental factors, the availability of urban networks and the institutional and policy frameworks [10]. According to fig. 1, the available infrastructure and the physical characteristics of the wider urban space and the way these features are taken into account by the planning and policy framework create the conditions which determine the locational choices of the industry. These choices affect the locational choices of households that work in the industry according to the demographic and socio-economic features as well as to the demand and supply of the transportation system. In this way, the model is able to produce forecasts for the prediction of future land use patterns.

Various LUTI models with different approaches were developed during the late 1970s and 1980s. Indicative examples are the works of Putman [11], Lowry [12], Lee [13], Echenique [14], Anas [15] among others. However, many of the earlier models accepted criticism regarding mainly the high cost of implementation due to the high requirements for data collection and management in relation to their ability to produce valid and case-specific results. The evolution of computers and new technologies, the ability to produce and manage geo-spatial data through
Geographic Information Systems (GIS) and the emergence of innovative concepts, such as sustainability and holistic planning, are nowadays leading to the enhancement of existing and the development of new LUTI models.

![Diagram of a typical LUTI model](image)

Figure 1: Form of a typical LUTI model.

There are several methodologies for categorizing the available LUTI models in the international literature, which are based on the combined analysis of the following parameters [16–20]:

- Theoretical approach towards the correlation between the production of space and the evolution of socio-economic parameters, i.e. the theories, which derive from the economic and social sciences, and the corresponding sub-models which are implemented in order to produce quantitative relations between the socio-economic parameters and the land use or/and the transport system. The theoretical approach is the main parameter which affects the rest as explained below.
- Time dependency in the expression of the aforementioned relations, i.e. the dynamic or static features which are embedded in the LUTI model.
- Direction of the analysis, i.e. bottom-up or top-down, according to the theoretical approach and the type of data required to implement the sub-models. An evolution of socio-economic theories is observed worldwide towards the disaggregated analysis approach.

2.2 The role of LUTI models in strategic transport planning

Land use models can play a significant role in setting the framework and substance of a strategic transport plan. Relevant bibliography emphasizes the importance of
treating cities as complex and evolving systems and adopting a holistic approach in order to achieve the goals of sustainable urban mobility.

As such, LUTI models have received a renewed attention as tools and methodologies that enable city governments and citizens to design sustainable mobility policies. LUTI models can help in various stages and in various ways in the process of a strategic transport plan. First they can help achieve an understanding of the interaction and interrelationship between the transportation and land use system. This explanatory ability of the cause-effect relation represented in LUTI models, could determine decisions about sole planning investments or even the core of the proposed strategic approach.

Second, they can be used as tools for visual experimentation during the planning process. One of the main qualities of LUTI models is their predictive abilities that are built in the system. As such, they can visualize and communicate to the user the impact of new infrastructure, policies etc., enabling the creation of alternative future scenarios.

Finally, LUTI models could be very powerful communicative tools and play a significant role in a participatory planning process. More specifically in a process where different planning stakeholders are coming together to negotiate upon different interests, LUTI models could play a significant role in communicating the mutual interdependence among various perpectives, forming in that way new perceptions and values that will eventually set the ground for a collaborative decision making process.

3 Integration of a LUTI model to the SUMP cycle

3.1 Brief presentation of the SUMP cycle

The cycle of SUMP includes the following stages, i.e.: a) Preparing well, b) Rational and transparent goal setting, c) Elaborating the plan and d) Implementing the plan, covering the process of strategic planning from the preparation to the implementation and final evaluation and identifying the corresponding milestones, i.e.: a) Analysis of problems and opportunities concluded, b) Measures identified, c) SUMP document adopted and d) Final impact assessment concluded. Each stage comprises a set of elements that include a number of activities which are essential in order to overcome the corresponding milestone. In this way, the SUMP is concluded with the update and review of the implementation results and the identification of the key-features that will lead to the conduction of another SUMP cycle.

3.2 Description of the LUTI model integration framework

The proposed framework for the integration of a LUTI model to the SUMP cycle is based on the scope of maximising the potential contribution of the model to the successful conduction of the aforementioned activities. The overview of the framework is presented in fig. 2.
There are four phases which formulate the proposed LUTI integration framework corresponding to the four (4) stages of the SUMP cycle and eleven (11) actions which are connected to the appropriate activities of the eleven (11) SUMP elements. More specifically, either the outcome of an Activity of the SUMP cycle (from here after referred to as SUMP Activity) can be used as input for the corresponding action for the integration of the LUTI model (from here after referred to as LUTI Action) or a LUTI Action can provide outputs for the support of a SUMP Activity, as described in the following sub-sections.

![Diagram of LUTI model integration to the SUMP cycle](image_url)

**Figure 2:** Framework of a typical LUTI model integration to the SUMP cycle.

### 3.2.1 Phase 1. Predictive (strategy oriented)

The first phase of the proposed integration framework aims at the selection and preparation (adjustment) of the appropriate LUTI model and the development of the strategic scenarios. The results from the deployment of strategic scenarios are expected to support the analysis of problems and opportunities, according to the SUMP’s first Milestone. The first LUTI Action is the definition of the model’s scope in relation to the needs of the specific study. This action depends on the following SUMP Activities: a) 1.1, aiming at the understanding of which sustainable mobility principles will be adopted by the plan and how, b) 1.2, involving among others the analysis of the transportation and land use policy priorities which should be taken into account by the model, and c) 1.6 aiming at the definition of the network of stakeholders from different transport related...
sectors. The next action refers to the selection of the most suitable model and its adjustment to the plan’s purpose. The action depends on the aforementioned scope as well as on the SUMP Activity 1.5, i.e. the setting of the plan’s timeline, which will define the time dynamic characteristics of the model and the desired time reference of the short-term and long-term forecasts. After the selection of the most suitable model, the formulation of strategy based scenarios, i.e. a series of scenarios based on the strategic approach of the plan as suggested in SUMP Activity 3.2, takes place [9]. However, in order to formulate resilient and realistic scenarios, one should take into close consideration the analysis of problems and opportunities, conducted during SUMP Activity 3.1. The final action of this phase is the assessment of the strategy based scenarios, which are expected to lead to generic forecasts of the urban development patterns according to the examined urban mobility strategies. These forecasts can be exploited in the context of the SUMP Activities 4.1 and 5.1, which aim respectively at the identification of the strategic directions and the setting of specific priorities for sustainable urban mobility planning. Moreover, the demonstrative capabilities of the model can create a space for discussion among the stakeholders and the public (SUMP Activity 4.2).

3.2.2 Phase 2. Predictive (target oriented)
During the second phase, the LUTI model can be updated according to the quantified targets set by the second stage of the SUMP in order to provide more detailed forecasts of the way that the selected measures for the enhancement of urban mobility are expected to affect the land use system. In this way the model can contribute to the SUMP’s second milestone, i.e. the identification of the suitable measures. The SUMP Activity 5.2 has the objective of developing a series of Specific, Measurable, Achievable, Realistic and Time-bound (SMART) targets through the selection and formulation of a set of indicators. The corresponding LUTI Action aims at the model’s update according to these targets so as to be able to produce estimations of indicator values (especially the ones related to the impact of transport on land use) in different time projections. After the formulation of scenarios based on the appropriate combinations of transport related measures and interventions, the target based model can be used to estimate the impact of these measures on the land use system and support the decision making of SUMP Activity 6.1 for the identification of the most effective measures.

3.2.3 Phase 3. Evaluation
The specific phase aims at the update of the LUTI model according to the real data that derive from the regular monitoring of indicators during the stage of the SUMP’s elaboration and the provision of accurate estimations that can be used to check the progress during the stage of the SUMP’s implementation and the milestone of the adoption of the plan’s document. The SUMP Activity 8.1 refers to regular monitoring of a core set of measurable indicators for the evaluation of the plan’s elaboration. These measurements can be used as input in the LUTI Action for the update of the model. Then, the updated model can be used for the reassessment of the target based scenarios according to real data. The estimations from the reassessment can provide useful conclusions on the progress of the plan’s
implementation and the achievement of its objectives concerning mainly the goals related to urban development. Moreover, the review of the model’s assessment results during the strategic, target and real data based scenarios should be made in order to evaluate the progress of the plan towards the achievement of land use related objectives.

3.2.4 Phase 4. Validation
The objective of the phase is the overall validation of the LUTI model in order to contribute to the SUMP’s last milestone, i.e. the conclusion of the final impact assessment, and to make the necessary changes and adjustments for its implementation in the next SUMP. Towards this purpose, the results and conclusions from the SUMP Activities: a) 10.3 Check progress towards achieving the objectives, and b) 11.1 Update current plan regularly, should be embedded in the LUTI Action for the model’s validation. This process will ensure that the model will keep up with the whole SUMP cycle and be prepared for future use.

4 The case study of Thessaloniki

4.1 Spatial and transport characteristics of the study area

Thessaloniki is the second largest metropolitan area in Greece after Athens and one of the largest cities in the wider Balkan region. The regional unit of Thessaloniki has a population of approximately 880·10³ inhabitants [21]. The city’s centre accommodates a mix of land uses with the main commercial stores and services sharing the same space with dense residential uses. Moreover, there are many historical monuments within and adjacent to the city centre which is bounded by mountainous terrain from the north and the gulf of Thermaikos from the south. Nowadays, development of residential areas and commercial centres are being observed mainly at the eastern suburbs and some urban areas of the northwest, which were relatively underdeveloped until recently, while the industrial zone of the city resides at the western edge.

Currently, the only available public transport mode within the city is the public bus. Thus, the mobility conditions depend mainly on the road network while private cars and motorcycles are dominant in daily transport. Moreover, approximately 25% of the 2.3·10⁶ daily trips in the city have their origin or destination in the centre leading frequently to congestion [22]. There is an active discussion over the last years between the city’s authorities, the stakeholders and the planners on possible solutions that can decrease private car dependency in the city. Recently, a bicycle network and a public bicycle sharing system were developed while a metro system and a seaborne transport system are under development. In the meantime, there are several urban regeneration schemes which are being gradually implemented mainly within the city centre, which include traffic calming measures and the pedestrianisation of roadway segments. Moreover, other alternatives are being examined at the level of strategic planning, such as the expansion of the orbital road network and the development of surface railway systems.
4.2 Outline of Thessaloniki’s SUMP

Thessaloniki’s SUMP was initiated in 2010 by the city’s Public Transport Authority (ThePTA) in the context of the project: “ATTAC” of the European Union’s SEE Transnational Cooperation Programme [23]. The participating stakeholders comprise the public transport organisations, municipalities, institutes, technical chambers and citizens’ associations of the wider metropolitan area. The SUMP is mainly focused on the enhancement of the city’s public transport system and the counter-measures against private car dependency. The main components of the plan are the following: a) Mobility forum with the participation of the stakeholders, b) Internal evaluation procedures, c) Public information and dissemination, d) Measures for the upgrade of public and active transport and road traffic management, e) Allocation of resources for the plan’s financing requirements, f) Monitoring methods and indicators, and g) Establishment of a dedicated SUMP Unit.

The main measures included in Thessaloniki’s SUMP comprise:

- Smart and integrated ticketing and payment.
- Bus rapid transit and priority at intersections. Bus feeder lines to the metro system which is currently under construction.
- Promotion of a tramway system complementary to the metro system.
- Operation of the seaborne transport system.
- Flexible road transit including innovative taxi services.
- Congestion charging, access control and integrated parking management policy as instruments against private car dependency.
- Pedestrianization and public space regeneration. Improvement of the bicycle network and the bicycle sharing system.
- Public awareness campaigns for sustainable mobility.

4.3 Prospects for the integration of a LUTI model to Thessaloniki’s SUMP

The implementation stage of Thessaloniki’s SUMP is expected to introduce a number of measures with significant effect on the city’s mobility conditions. Moreover, these measures are also due to generate an impact on the land use patterns. Some examples from the international literature are given below [24, 25]: a) Restrictive measures for private car use combined with regeneration schemes within the city centre and other congested areas aims also at the upgrade of the urban environment, b) Promotion of active transport is expected to increase the interaction of travellers with the land uses along each trip while drivers usually interact with the land uses located at the beginning and end of each trip, and c) An intermodal public transport system is expected to affect locational choices and land rents are expected to increase within the areas of public transport stations.

The aforementioned impact on the city’s land use system depends on the city’s specific spatial features, i.e. the overall urban development trends and restraints and the land use characteristics of the central area. In the context of the contemporary holistic approach of strategic planning, the analysis of the changes in the spatial organisation and the urban environment due to the measures and
interventions for the improvement of urban mobility is an essential component of a SUMP. The use of a LUTI model is an effective tool for the estimation and assessment of the appropriate features that can support such an analysis.

In terms of the integration of a LUTI model into a SUMP, there are no functional or structural problems per se. Problems might occur due to reasons that are related to the functionality of the LUTI model itself. We briefly present the issues arose in the case of Thessaloniki’s SUMP:

a) Data acquisition issues: LUTI modelling is a quite data intensive task. Applications of such models include calibration and validation procedures that heavily rely on data quality and availability. Despite the significant progress in data acquisition processes there is still a lot of effort to be done in order to obtain appropriate urban mobility statistics and land use data. More specifically in the case of the city of Thessaloniki two data acquisition issues arose:

i. The issue of spatial analysis unit: Most of data needed for LUTI models (i.e. socioeconomic data) is available in census tract level, provided by the Hellenic Census Bureau. On the other hand transportation data is available on different spatial analysis unit, this of Transportation Analysis Zones (TAZ’s). As such a process of “spatial matching” of these two spatial units should be applied in order to achieve full spatial data compatibility.

ii. The issue of temporal reference: Despite the fact that most of the data needed to run a LUTI model is available there are serious issues when it comes to its temporal reference. In the case of Thessaloniki a transportation study was conducted in 1997 and is the only available source for detailed and appropriate transport data. As such it is predetermined that any analysis would start with data that depicts the 1997 situation of the city. Actually, the issue that arises here does not have to do with the old time reference of the data per se but with the fact that employment, household and market “reality” has radically changed over the last 4 years, due to the economic crisis. The effects of economic crisis are in many ways related to the calibration of the model. Therefore if we calibrate the model with 1997 data we implicitly assume that past urban development trends will continue to occur.

b) Usability issues: Despite that LUTI models are quite common in academia, their use in policy making and planning is scarce. This is due to the fact that potential users might not have the skills to use such models [26]. Recently there has been an effort to develop more user driven LUTI models that account for the requirements of policy makers and are integrated in the collaborative decision making process.

5 Conclusive remarks

Conclusively, this paper clearly demonstrates that integrating LUTI models in a SUMP could significantly improve its strategic and communicative aspects. This is because LUTI models can be used as testing and evaluating tools and as tools
to communicate and ensure mutual acceptance and understanding amongst involved stakeholders. The necessary conditions for this to happen are related to certain applicability aspects of LUTI models. These include (a) data availability with certain spatial and temporal specifications (b) understanding the communicative role that a LUTI model can play and finally (c) the presence of an expert (i.e. planner) that would know how to facilitate the different aspects of LUTI models (either as a strategic or a communicative tool) within the planning process.

References


