

Methods and models for analyzing the relationship between land-use and transport – A review

Extended abstract

Bjørn Gjerde Johansen, Wiljar Hansen and Aud Tennøy

Institute of Transport Economics Norway has been assigned by the Norwegian Public Roads Administration, with help from the Center for Transport Studies in Sweden, to evaluate methods and models for analyzing interaction effects between land use, infrastructure and transport demand in urban areas.

This paper will be based on findings from this project. The aim of the paper is two-fold: (1) to present an updated literature review on LUTI (Land-Use and Transport Interaction) models, with the intention of identifying recent trends in land use modeling and the capabilities of state of the art LUTI models; and (2) to contrast and compare state of the art LUTI approaches to other approaches for analyzing the relationship between land-use and transport, based on evaluation criteria meant to capture the suitability for implementation in Norway.

Background

Coordinated land use and transport planning has been an important strategy for reducing the transport needs and car dependency through several decades. This has for instance been connected to an objective of better living conditions, improved urban environments, less congestion and traffic delay, better accessibility for everyone and reduced greenhouse gas emissions. The last couple of years, this has been actualized through, amongst others, a Norwegian white paper on climate change, stated goals in the National Transport Plan, the project “Cities of the future”, initiated by the Environmental Protection Agency, and clear objectives in county and municipal master plans. It is clearly stated that the growth in transport demand should be covered by public transport, cycling and walking as opposed to a growth in car traffic. This will mainly be achieved by more concentrated land use planning, for instance by densification around public transport hubs, strengthening of the public transport systems, physical adjustments to improve the situation for cyclists and pedestrians, and use of restrictive measures towards car traffic.

However, today both baseline traffic forecasts and scenario traffic forecasts for various policies or measures are calculated by means of a four step transport model in which land use is an exogenous component. These traffic projections are again used to calculate the user benefits of various policies and measures. By excluding the feedback cycle between land use and transport, as the Norwegian transport models do, (1) all forecasts will by definition be wrong, since they don't take into account either demographics or individuals' relocation pattern, and (2) it may lead to seriously biased results in cost benefit analyses since individuals' and firms' reactions when it comes to land use in a future scenario for a policy/measure is not taken into account.

By using expert judgment for changing the land use exogenously in the models, traffic data that takes the change in land use into account may be estimated. However, it will be impossible to use the current methods for calculating user benefits, since current methods are based on traffic costs. User benefits in a situation with changed land use will not only consist of traffic benefits, but also locational benefits. A LUTI model is proposed as more realistic modeling systems for predicting

changes in the urban environment over time; however, such models are expensive and labor-intensive to develop. Therefore, we propose and compare various alternative methodologies; from a full-scale LUTI model, to a method for calculating user benefits from traffic model results where the land use has been changed exogenously based on expert judgment.

The state-of-the-art LUTI models

A literature survey has been carried out in line with that of Wegener (2004); 26 of the LUTI models considered to be most relevant for a state of the art modelling system have been thoroughly evaluated. With these models in mind, the six weaknesses observed in operational LUTI models identified a decade ago (Hunt et al., 2005) have been re-assessed. The weaknesses are

1. Excessive spatial aggregation;
2. Excessive reliance on static equilibrium assumptions (with associated assumptions of large time steps and lack of path dependencies);
3. Overly aggregate representations of households and firms, as well as a lack of representation of individuals as decision-making units separable from their households;
4. Lack of endogenous demographic processes;
5. Lack of endogenous car ownership processes; and
6. Reliance on four-stage travel demand modelling methods.

This list of weaknesses is considered to still be highly relevant, judging from the amount of references in more recent international literature. However, we conclude that the new generation of dynamic, agent-based micro-simulation models manage to address all six of Hunt et al.'s objections.

In line with Berglund (2014), we observe three trends when it comes to LUTI models:

- Trend 1: From a macro to a micro approach: The first LUTI models were static and macroscopic. However, the new LUTI models, in line with the previous paragraph, are complex, agent-based micro-simulation models on a spatial level with a high degree of disaggregation.
- Trend 2: Possibly as a reaction to trend 1, there is a parallel movement towards simpler, faster and more visually accessible land use planning tools. These planning tools are based on less data intensive and less theory rich approaches, mainly rule based and/or GIS-based. Some of these tools try to include the feedback cycle between transport and land use, while others rely on exogenous assumptions about how the land use will be affected by the transport system.
- Trend 3: There is a growing consciousness about the importance of integrated approaches for transport and land use policies in general. At the same time, we see that some planners and decision makers are skeptical towards LUTI models. It seems like a lot of planners and decision makers that have knowledge about LUTI models in line with trend 1 thinks the models are too complex to understand, while those that have knowledge about LUTI models in line with trend 2 thinks the models are too simple to capture all the urban processes.

We argue that this not should be interpreted as an argument against LUTI models, but rather as a crystallization of the inherent complexity of urban systems in general. This complexity does not make modelling the urban system less relevant, but makes it even more important to be aware of the assumptions and shortcomings behind the models that are used.

Consequently, these three trends jointly highlight what seems to be the biggest challenge for integrated land use and transport modeling; for each analysis, what is the appropriate level of model complexity? This challenge motivates the next section of the paper.

Methods for analyzing land use and transport systems, contrasted and compared

In this section, we compare five different approaches based on three main evaluation criteria. The different approaches are:

- **A – The baseline scenario – today’s four step transport models with exogenous land-use:** In this scenario, it is possible to calculate user benefits of changes in the transport system when the land use is fixed (based on transport costs). It is also possible to forecast traffic in situations where the land-use changed exogenously. However, it is not possible to calculate user benefits in situations where the land use is changed.
- **B – A methodology for calculating user benefits from exogenous changes in land use in today’s traffic models:** For calculating user benefits in situations where the land use is changed exogenously based on expert judgment, we propose a method based on Minken et al. (2003). When changing the land use, two additional sources of user benefit in addition to the change in transport cost arise; namely, a destination benefit (the user benefit from being able to change the destination choice based on the new land-use pattern) and an origin benefit (the user benefit from being able to re-locate to a new destination). The main strength of this method is to outline how destination and origin benefits can be calculated based on attraction variables that are already a part of the transport model. To be able to quantify these three sources of utility, it is necessary to implement a simple choice model in which the new land-use (based on expert judgment) is the result of individuals’ utility maximization. The complication of this method lies in deriving the necessary weights to put on the various attraction variables in the destination and origin choice models.
- **C – A simple rule-based and GIS-based planning tool:** This scenario evaluates the use of GIS-based models that based on land-use, travel and infrastructure data visualizes changes in various scenarios by use of simple and clearly defined behavioral rules. These models do not explicitly model the land-use and transport feedback cycle. However, advantages are (1) that they are quick, a wide range of land use scenarios can be run, and the results can be compared visually, and (2) that these models do not rely on expert users; it is simple to run the models, communicate the results as well as to communicate all the assumptions behind the results.
- **D – An aggregated, macroscopic LUTI model:** In this scenario, a simple land-use model is proposed, which is (1) based on representative agents in each zone, (2) can be connected to an already existing transport model, (3) have a simplistic representation of housing and land development and (4) is based on utility maximization and runs to equilibrium. This is meant as a simple, operational modelling alternative in which the land-use and transport feedback cycle is included, and where it is possible to calculate user benefits from various scenarios.
- **E – A disaggregated, microscopic LUTI model:** In this scenario, a more complex LUTI model is proposed, which is a connection between the agent based traffic model MATSim and the agent based land-use model UrbanSim. This is a dynamic micro-simulation modelling system, which has been tested in Nicolai et al. (2011). Furthermore, TØI is in the process of implementing a MATSim model in Norway (see Flügél et al. 2014). Agent based models

makes it possible to explicitly take into account the effect of congestion, which is not possible in traditional four-step traffic models. This makes it particularly relevant in urban settings.

These scenarios are ordered from simple to complex (and consequently from cheap to expensive) to implement. They are evaluated based on the main evaluation criteria below:

1. The model's adequacy for describing the interaction between transport and land use;
2. Data needs, data availability and data quality;
3. Suitability for Norwegian urban areas, including:
 - Suitability in general (what kind of policies and measures can the models assess?);
 - Modelling flexibility;
 - Required user competence;
 - Communication of results and modelling assumptions (transparency); and
 - Possibilities for using the results in cost benefit analyses and impact assessment studies.

Conclusions

The main conclusion from this analysis is that the best approach is highly dependent on user and analysis needs. While the LUTI models (D and E) are the only approaches where the feedback cycle is modelled explicitly, this is not always the most suitable method, and the costs of developing an advanced model must be weighed against the added benefits such a model can yield.

The paper is finalized by describing various conditions under which each of the above scenarios is most appropriate. From a decision maker's point of view, we show that each of the above scenarios can be considered as optimal, depending on the scopes of the analysis and implementation conditions.

Even though the original project is meant to evaluate methods for use in Norwegian conditions, we argue that the results can be generalized to most European urban contexts as well.

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