Summary:

Evaluation of models and methods for analyzing the interaction between land-use, infrastructure and traffic demand in urban areas

TØI Report 1415/2015
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Oslo 2015, 96 pages Norwegian language

Institute of Transport Economics Norway has been assigned by the Norwegian Public Roads Administration, with help from the Centre for Transport Studies in Sweden, to evaluate methods and models for analysing interaction effects between land use, infrastructure and transport demand in urban areas. The report identifies LUTI models (Land-Use and Transport Interaction) as suitable to predict the changes in urban systems over time, both because the feedback cycle between land-use and transport is taken explicitly into account in the models and because it will be possible to calculate user benefits for cost-benefit analyses based on forecasts and scenario evaluations.

The aim of this report is two-fold: (1) to present an updated literature review on LUTI models, with the intention of identifying recent trends in land use modelling 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 analysing the relationship between land-use and transport, based on evaluation criteria meant to capture the suitability for implementation in Norway. Since LUTI models are both expensive and labour intensive to develop, we propose and compare various alternative methodologies as well; 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 judgement.

Background

Coordinated land use and transport planning has been an important strategy for reducing transport demand and car dependency through 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 Ministry of Environment, 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 development, 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, 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 modelling systems for predicting changes in the urban environment over time; however, such models are expensive and labour-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 evaluated. 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 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 report.

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 it 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 Flügel 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:
    - Relevance 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.

The models are analyzed in the figure below based on the three evaluation criteria on a scale from **0** to **xxx**. To highlight the result of the analysis a color scheme is used, from bad (red) and medium (yellow) to good (light green) and very good (green). We emphasize that this is not a quantitative assessment, but rather an ordinal comparison. For more information regarding the differences between the models, the reader is referred to the full report.

Table 1. Comparative analysis of five methods and models for analysing transport and land use.

	Baseline	**Other methods and models**		**LUTI**	
Scenario:	**A**	**B**	**C**	**D**	**E**
Level of aggregation	Macro	Macro	Meso/ micro	Macro	Meso/ micro
Dynamics	Static	Static	Static	Static	Dynamic
Deterministic/ stochastic	Deter-ministic	Deter-ministic	Deter-ministic	Deter-ministic	Sto-chastic
Attraction or activity based	Attraction	Att-raction	Att-raction	Att-raction	Activity
Transport/land use interaction	**0**	**x**	**x**	**xx**	**xxx**
Data needs	**0**	**x**	**x**	**xx**	**xxx**
Suitability for Norway	**x**	**xxx**	**xx**	**xx**	**xx**
User expert level	*Medium*	*Medium*	*Low*	*High*	*High*
Suitability for cost-benefit analyses	*No*	*Yes*	*No*	*Yes*	*Yes*

Recommendations

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. Therefore, our main recommendation is that an objective study is conducted, in which the analysis needs as well as the budget is properly assessed:

- To analyse measures where no large land use changes are expected, today's transport models may be used (scenario A). In this case, the analysis should be supplemented by a qualitative analysis where potential land use changes (and how these would affect the results) are discussed. If the future land use can be predicted based on expert judgement, the transport models can be run with the new land use added exogenously. This will produce new traffic flows. However, it will not be possible to use this as a basis for predicting user benefits.

- The cheapest and fastest way proposed to calculate user benefits of measures from which the new land use pattern can be predicted based on expert judgement, is presented in scenario B. This solution is well adapted for cost benefit analyses if a LUTI model is not available. However, if this method is going to be used it is recommended that some case studies are conducted first, considering that this method has not yet been tested in real-life scenarios.
- If the purpose is that multiple planners should be able to test effects of various land use measures, without needing to calculate user benefits, and without needing complementarity with existing transport models, the ATP model is recommended (scenario C). This is cheap to use, simple, fast and visually accessible. It is easy to both change and communicate the assumptions behind the model. The ATP model is also suitable as a supplement to other methods and models.
- LUTI models (scenarios D and E) will be more expensive and complex than the previous alternatives; however, such models will explicitly take into account the feedback cycle between transport and land use. These models are recommended for analysing complex scenarios in which it is difficult to know what the results will be in advance. The choice of LUTI-model will be highly dependent on the choice of (and requirements to) the transport model of the modelling system. If a working agent-based micro simulation traffic model is developed, scenario E is recommended. However, if today's macroscopic four step transport models are considered appropriate, scenario D is recommended. See Flügel et al. (2014) for more information regarding the difference between these models.

If it is decided to develop a LUTI model for Norwegian urban areas, we recommend that some preparatory work is carried out first. This is in particular two preliminary studies that are vital for a successful LUTI model, as well as interesting by their own merits.

- Firstly, a project should be conducted to map, collect and format the relevant land use data that is available in Norway. It is difficult to predict how labour intensive this process will be. The main challenges are related to right formatting of the data, including geographical components, meaningful and consistent business categories and avoiding "the central office effect", namely that for some registers all sales and production is located at the geographical location of the central office. Such a project will be useful independent of a potential LUTI model, as it will lay the ground for other empirical land use analyses as well.
- Secondly, a project should be conducted to identify the most suitable accessibility indicators for Norwegian conditions. These accessibility indicators are important for connecting the transport part and the land use part of a LUTI model. It is important that the modelling system is designed

in such a way that accessibility indicators can be calculated based on the transport part of the modelling system. It will be beneficial independent of a potential LUTI model to gain additional insights as to how the land use is affected by such indicators, as it will yield additional knowledge and insights to the connection between transport and land use in Norway in general.