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Viewpoint: Toward a new generation of land use transport interaction models

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Abstract: Land use transport interaction (LUTI) models are often developed to model the interaction between the land use and transport systems for relatively large-scale spatial developments, like new residential or office areas, new main roads, or railway lines. In this paper I argue that we need a next generation of LUTI models that model trends such as peak car; decline in population, shops, services, etc.; impact of information and communications technology (ICT) on activity patterns and travel; and cycling policies. The current generation of LUTI models cannot adequately answer the policy questions raised by these trends. However, a major problem is that the future of these trends is uncertain, and we lack empirical research into the dynamics between these trends and their wider impact on land use and transport systems. Nevertheless, LUTI models can, by utilizing what-if calculations, help explore future trends and their implications. Other challenges for LUTI models include the calculation of a wider set of accessibility indicators, the inclusion of interactions between key actors in the transport and land-use system—serious gaming may prove a useful way to explore these interactions—and the development of dynamic visualizations.

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1 Introduction

The traditional four-step transport models have been in use for several decades, providing insights into the expected travel behavior and traffic flows of candidate transport policy options, examples being new roads or rail lines, as well as options for land-use changes such as the building of new residential areas or office locations (e.g., Ortuzar and Willumsen 2011). In these models the transport system does not have an impact on land use, which is often in contrast to reality, as expressed in the saying: In the long term, every light rail line is located correctly. That is, the new light rail line, and in particular its stations, will fuel land-use changes in the vicinity of stations. In addition, the land-use system does not impact transport—both are considered exogenous. To deal with such impacts, mainly the impact of the transport system on land use, so called land use transport interaction (LUTI) models were developed more than two decades ago (e.g., Wegener and Fürst 1999; Hunt, Kriger, and Miller 2005; Wegener 2011). These models were mainly developed to provide answers to policy-relevant questions related to

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relatively large-scale spatial developments, for example, land-use changes due to new motorways, other main roads, or new railway lines. Related land-use changes are mainly the conversion of low-density use (e.g., agricultural land) to urban areas (residential, commercial, and employment areas). LUTI models have not been widely applied, although there are some examples in the academic literature. For example, Schoemakers and van der d (2004) describe four applications of the Dutch TIGRIS model, all related to urban and transport extensions. Devereu, Ying, and Elston (2004) used a LUTI model to explore policy options for the London to Ipswich corridor. Waddell et al. (2007) describe the application of a LUTI model to explore the impacts of transport plans for the Greater Wasatch Front area of Utah.

In this paper, I argue that a paradigm shift is needed: The development of a next generation of LUTI models is required to provide answers to a new generation of policy questions related to (1) the dynamics within urban areas, rather than the conversion of agricultural land to urban areas, and (2) explicitly modeling the changes related to a decrease (rather than increase) in the value of indicators related to land use and the transport system, such as the number of inhabitants or households, shops, bus stops, railway stations, etc., and (3) the changing behavior of homogeneous groups of people. The need for a new generation of LUTI models was also emphasized by Wegener (2011), but the reasons for this need come from an important external factor—climate change and the need to reduce greenhouse gas emission—rather than from factors that more directly link to the transport and land-use system.

The paper focuses on LUTI models, but several of the messages also apply to conventional transport models and activity-based models. In addition, the paper is limited to western countries that face the trends discussed in Section 2, including saturation of car use, a decrease in population growth, or even a decline, and an aging society. The paper is also limited to passenger transport and does not include goods transport. It is not the aim of the paper to explain the state of the art of LUTI modeling, the suitability of current models to answer the policy questions raised so far or to discuss the assumptions and algorithms of current LUTI models.

Section 2 gives an overview of some trends in western countries that are not well covered by the current generation of LUTI models. Section 3 presents related policy questions, followed by Section 4, which gives an overview of related research questions. Section 5 discusses the implications for LUTI models. Section 6 finally finishes with some concluding remarks.

2 Trends in society

This section discusses a selection of trends in society that have implications for policy questions relevant for LUTI models.

2.1 Peak car, peak travel

A first trend is that in western countries car ownership and car use seem to have saturated earlier than expected, a phenomenon that is sometimes labeled as “peak car” or “peak travel”—see a recent special issue in Transport Reviews (Goodwin and van Dender 2013). It is likely that the worldwide crisis that started in 2008-09 has had an impact on these trends, but it cannot fully explain them, partly because the trend started before the crisis, in around 2005. Explanations that can be found in the literature include an increasing focus on information and communications technology (ICT) and the wish to be continuously electronically accessible (which is difficult while driving a car), changing attitudes within homogeneous groups of (young) people (see below) and a decrease in the status of the car among young people. See, for example, Delbosc and Currie (2013) for an overview of the literature related to youth ownership of driver’s licenses.

If these trends continue, the impact of the road system on land use may decrease. For example, if

the train becomes more popular, the impact of the rail system on land use could increase. Some papers provide indications that young adults increasingly tend to live in urban areas, and that this trend to some extent contributes to the peak car effect (e.g., Van der Waard et al. 2013).

2.2 Changing attitudes/peoples' preferences

Partly related to the previous topic is the phenomenon that the attitudes and preferences of young people might be changing. In the literature on peak car, this is often emphasized as one of the explanations for decreasing car ownership and use levels, with the reduced status (see above) being one of the results. In addition to young people, changes in attitudes and preferences of the elderly might become relevant. For many years the elderly have become increasingly mobile and car oriented, with higher car ownership levels, although this trend can at least to a large extent be explained by increases in income, education level, and ownership of a driver's license. The question is whether their attitudes and preferences change, or to put it more generally, whether homogeneous groups of older people are changing their behavior. The fact that people are getting older and staying relatively healthy for a longer time could lead to changes within groups that models assume to be homogeneous.

2.3 Demography: less growth, decline

The era of great population growth, a decrease in household size, and consequently strong growth in the number of dwellings has passed, at least in some countries, such as Japan and Germany. In addition, if there is demographic growth at the national level, this generally is not the case for all regions within a country. Some remote regions in France, for example, have faced a declining population for more than three decades, fuelling the debate on social exclusion. Shops, schools, post offices, and employment disappeared, making the villages less attractive for those who stayed and forcing others to leave, etc., all in all creating a downward spiral. See for example a special issue in Transport Policy (Stanley and Lucas 2009). The overall pattern of less or no population growth or even a decline, at the national and certainly regional level, is expected in many western countries.

LUTI models can deal with demographic variables, such as the population size of a zone. But to the best of my knowledge they do not model a decline in population size because houses are left or even demolished. For the impact of the transport system on land use the questions need to shift from "Where will we build?" to "Which dynamics within urban areas can we expect?" How do the transport and the land-use system interact when a decline takes place? A declining population could result in the closure of bus stops or railway stations, making the surrounding areas less attractive for people who favor public transport. It is not clear whether current LUTI models are able to model decline. Researchers found that, in some areas, the parameters change when decline rather than growth occurs. For example, Dargay (2001) found that the effect of income on car ownership is asymmetric.

2.4 The impact of ICT on activity patterns (working, changing shopping behavior, e-learning)

ICT has an increasing impact on activity patterns. Especially office work can to some extent be done at home. Online shopping is an increasing share of overall shopping (Rotem-Mindali and Weltevreden 2013). E-learning can substitute classroom teaching. Van Wee, Chorus, and Geurs (2013) argued that researchers should increasingly include the impact of ICT on accessibility. But how can this be done? It is unlikely that ICT will have a uniform impact on all types of activities, and consequently the importance of having physical access to related opportunities remains. So we need to understand both the complementarity and substitution role of ICT for all kinds of activities and activity patterns. Although

in the past the net effect of substitution and complementarity on travel behavior has been shown to be around zero (see Van Wee, Chorus, and Geurs 2013 for an overview of the literature), it is not certain whether this will remain so in the future. Maybe the quality of ICT will increase to a level that people will increasingly substitute some activities with electronic equivalents. E-shopping will probably become the standard for some categories of products. Shops may adapt and convert from selling products to providing paid advice on products that would then be bought online.

The relevance of ICT for the impact of the transport system on land use is very difficult to assess, but it is likely to be more than marginal. It is also possible that a dichotomy will occur: For social activities, proximity and access by travel modes other than the car will become increasingly important, whereas for utilitarian trips (work, business trips) using electronic (ICT-based) alternatives will dominate, or at least become more important. Maybe the number of shops will decrease, but not equally for all shop types, and spatial patterns in shops and shopping may occur. For example, inner city areas may increasingly become the areas where consumers look and try products and ask for (paid) advice, which they then order electronically. It is also possible that people will be less inclined to substitute e-shopping for shopping for clothes, compared to products with less emotional attachment, such as laptops or cameras. The relevance of the accessibility of shops and consequently the impact of the transport system on shop location choice might therefore change in the future. It is probably too early to model these potential changes in LUTI models. So is it better to wait and see? The counter question is: When will it be too late in terms of such models being able to inform policy decisions? We cannot wait for the substantial amount of research needed to understand the changes in society before being confident to model those changes that will have already taken place. A better option is probably to formulate what-if assumptions, and test their impact via LUTI models—see Section 4.

2.5 Electric mobility

E-bikes are becoming increasingly important, although only in a selection of countries (e.g., Germany, the Netherlands, China). If a trend toward e-bikes occurs, this could increase the range of cyclists making e-bikes an increasingly feasible alternative to cars and public transport. The impact of accessibility by car or public transport on land use could decrease, and the impact of accessibility by e-bike could increase. We expect this trend to be relevant for specific areas, activities, and population groups. For example, access to urban work locations up to a distance of 15 kilometers by middle-aged people could become more important.

Electric cars have a limited range and may need to recharge at the destination side of a trip, therefore having an impact on travel patterns. Access to designated parking places could become more important in the future. If, for example, an office area has privileged parking spaces enabling an electric car to be charged, such an area may become more important. On the other hand, if this were the case, we could expect such parking places to become the standard at many office locations, reducing their potential impact on spatial developments.

2.6 The revival of the bike

Over recent years the bicycle has become increasingly popular in several cities and regions, both as a means of transport and from a policy perspective, examples being Paris, London, and New York (Pucher and Bueler 2013). If this trend continues, it could increase the importance of proximity and access by bike relative to car or public transport based accessibility. If policymakers designated road infrastructure increasingly to the bike, this could also affect accessibility by car, which could result in changes in the relative accessibility of urban areas. The bike is relatively attractive for shorter trips, say up to 5-10 kilo-

meters. This implies that spatial impacts will be scale-dependent, and probably more important at the urban level than at higher spatial scales. We continue by discussing some trends that have been present for a longer period of time

2.7 Scale changes in health and education services

Health services and education have increasingly become large-scale services, harvesting scale effects and the benefits of specialization. This trend may continue, and the long-distance accessibility of those services may become increasingly important, as opposed to short-distance accessibility. LUTI models can include those trends, and explore the impact via "what-if" scenarios (see below).

2.8 Aging

Western societies are aging. The aging population is more mobile than equally old generations in the past, due to the fact that older people are now more healthy, have higher incomes (better pensions), are more likely to have a driving license and own more cars. This is a well-known trend. Due to the longer life expectancy and increased pressure on the pension systems, it is possible that the retirement age may increase. Consequently the impact of the transport system on job locations could remain important for workers for a longer period because of working longer.

2.9 Interactions between trends

Several of the trends discussed above may interact. For example, increased use of the e-bike may support a trend for inner city areas to become places where people ask for advice about consumer products and try them but not buy them. The combination of a shift to cycling together with a decline in population size and office working will decrease the number of people using public transport, and this decline will increasingly make some areas less attractive for people who prefer to travel by public transport.

3 Policy relevance

What do these trends mean for policymaking? In general terms the question is: What is the relevance of these trends for the transport and land-use system? Limiting this question to the added value of LUTI-models (compared to the conventional four-step transport models) the policy question is: What is the relevance of these trends for the impact of the transport system on land use? Note that the relevance for the impact of land use on the transport system is addressed by conventional four-step transport models. Another relevant question is: Which policy options in the domain of the transport system will have what effect on the land-use system and what is the impact on policy-relevant indicators for accessibility, the environment, and safety? We expect the impacts on accessibility and the environment to be of primary importance.

In addition to these general questions, I discuss below the importance of the trends for some specific policy areas.

3.1 Redevelopment of urban areas

Urban renewal is not a new phenomenon. Municipalities have developed urban renewal policies on a larger scale since the 1970s mainly as a response to the poor quality of housing and residential areas. The impact on travel behavior and accessibility could be estimated relatively easily using the traditional four-step model, assuming that land-use change had an effect on travel behavior, and ignoring the inter-

actions between the transport system and land use. What often changed was the number of dwellings in a specific urban renewal area (densities often decreased due to urban renewal), with other locations or new residential areas compensating for a loss of dwellings in case of decreasing densities.

However, I argue that the interaction between the transport and land-use system is relevant for the redevelopment of urban areas. This was probably also true in the past, but in the future the dynamics in existing urban areas might become more complex. In periods of decline, the level of public transport service may deteriorate and congestion may decrease, improving the competitive position of the car. In addition, the relative attractiveness of areas for residents, shops, services, companies, etc. may change due to mode-specific accessibility changes, which may have an impact on the numbers, locations, and characteristics of shops and services, the distribution of population groups over residential areas (partly fuelled by residential self-selection effects, see for example Cao, Mokhtarian, and Handy 2009), etc. These land-use changes will then have an impact on the transport system, etc. The same applies for the redevelopment of office areas. If teleworking, combined with a shrinking workforce resulted in many empty offices, redevelopment of the area may be an option, or at least considering the transformation of office buildings into apartments in general, or for designated groups of people, e.g. students.

3.2 Shrinking population

An important question, in the case of a declining population (at several spatial scales), is whether policymakers should intervene or whether the free market would do its job adequately. Even if one supported the latter position, knowing what developments can be expected could be interesting, for example, for planning public services. On the other hand, one could also support the position that policymakers should intervene, for example, to select the most viable areas and support those, e.g., via (public) transport policies. In both cases it is important to know how the land-use system and transport system interact.

3.3 Equity, social exclusion

Due to the dynamics within urban areas, one can expect people without access to a car to become worse off, raising several questions regarding equity and maybe even social exclusion. An important question then becomes: Should policymakers try to reduce such negative effects, and if so how? Are public transport policies an option? Or would it be better to implement cycling policies? Or could ICT be an alternative for travel, for example, providing options to e-shop? For a discussion on transport-related equity issues, see Thomopoulos, Grant-Muller, and Tight (2009). For a method to evaluate social exclusion effects using accessibility indicators and ethical theories see Lucas et al. (2015). I argue that it could be of added value if LUTI models explicitly provided output allowing the researcher to draw conclusions on levels of social exclusion. The question then becomes: Will next generation models be capable of providing such outputs with any degree of confidence? What is probably needed is output in terms of access from dwellings to destinations that fulfill basic needs (for example, grocery shops, basic medical services, and schools) by other modes than the car (slow modes, public transport). The evaluation of social exclusion effects is beyond the scope of LUTI models and necessitates the development of dedicated methodologies (Lucas et al. 2015).

3.4 Revival of cycling questions

Several cities and regions have (re)discovered the bicycle (Pucher and Buehler 2012). Cycling policies may be an answer to deteriorating public transport services, but they could also contribute to the decline

in these services. An important question is: What would be the wider impact of introducing cycling facilities and other measures to increase cycling levels? It could well be that accessibility by bike will become more important in some regions, a phenomenon that is not included in LUTI models.

4 Research questions

Before LUTI models that are useful in answering a new generation of policy questions and addressing the trends as described above can be developed, a lot of research is needed, helping modelers to understand the mutual interactions between the land-use and transport systems. One problem, however, is that researchers are uncertain about many future developments, the case of peak car described above being a good example (Goodwin and van Dender 2013). Will car ownership and use increase once the crisis is over? Will the trend in the decrease of car ownership levels for some specific socioeconomic-demographic groups (homogeneous groups of people) continue, or will these levels at the disaggregate level become stable? Will there be a cohort effect: Will people in their 20s also be less car oriented once they are in their 30s and 40s (or even the rest of their lives), or will they only postpone car ownership and use? As long as we do not know, LUTI models cannot adequately model these trends. They can, however, make "what-if" calculations: What if the parameters for homogeneous groups of people remain stable? What if the trends continue? What if there is a cohort effect?

There is also a lack of knowledge about the implications of decline, in general, and the related mutual interactions between land use and transport. The same applies to the impacts of ICT, electric mobility, cycling, and several other trends societies have not faced in the past.

Another relevant question is whether people, in addition to self-selecting residential areas, also self-select in other areas, such as work locations, or other destination types (see Van Wee 2009 for an overview of options for self-selection other than residential self-selection). We simply do not know, but if they do, these phenomena could be relevant for understanding the relationships between land use and transport, and related policies.

Next, I think the link between parking and travel behavior, but also the impact of parking options (availability, locations, price) on land use is poorly understood. On the one hand, increasing options for free or cheap parking can make destinations more attractive, while on the other hand, the related car use can make areas with abundant parking less attractive.

Finally, chaining of activities and multi-modality are relatively poorly understood (and modeled in LUTI models). This will become increasingly problematic with further synchronization of the transport and land-use system (Nagurney 2003).

5 Implications for LUTI models

The previous section has already addressed some of the challenges for the next generation of LUTI models. This section adds to those. I do not intend to give a full overview, but rather to fuel the debate on a selection of challenges.

5.1 Accessibility indicators

Another challenge is that they need to model a wider spectrum of accessibility indicators (See Geurs and Van Wee 2004 for an overview of such indicators). Depending on the policy question there may be a need for:

- Potential accessibility of several destination types (working, shops, medical and other services, education, etc.), preferably also including ICT (Van Wee, Chorus, and Geurs 2013).

- Accessibility indicators explaining the possibilities for activity patterns and therefore time-space person (or household) accessibility measures (e.g., Neutens et al. 2008; Kwan 1999).
- Disaggregations of accessibility levels to find out if specific (groups of) people or areas will face social exclusion, or to explore whether "unfair" distributions of accessibility levels may occur (see Lucas et al. 2015).
- Logsum-based measures (De Jong et al. 2007) to be able to value accessibility in monetary terms, for example, because policies are to be evaluated via a cost-benefit analysis (CBA).

5.2 The role of key actors, serious gaming

A next challenge is the explicit role of key actors in the dynamics related to land use and transport interaction. What, for example, will public transport service providers do under specific conditions of decline? What would companies do (relocate or not) as a result of changes in the transport system and neighborhood characteristics? Which options are available for planners and policymakers, for example, in the area of cycling facilities, subsidizing public transport, or transit-oriented development, and what would be the wider effects on the land-use and transport system and also society? I argue that serious gaming could be an attractive option to explore the interactions between actors, especially when there is a lack of empirical data showing real-world interactions (see Meijer et al. 2012 for an example of serious gaming in the transport area). Serious gaming has been applied to the area of planning and other complex multi-actor public policymaking (Mayer 2009) and can provide insights into how actors interact, insights that would be difficult to understand via alternative methods. According to Mayer (2009, 851-852), "Gaming (…) remedies some of the weaknesses felt in modeling and simulation—for instance, by opening up the black box and enhancing policy-oriented learning."

5.3 Combining LUTI models and expert judgments

As long as a lack of knowledge limits the development of comprehensive LUTI models, researchers could consider hybrid methodologies combining LUTI models with expert judgments. See for example Geurs and Van Wee (2006) for an example of combining a LUTI model and expert judgments to ex-post analyze the impact of land-use policies.

5.4 Output, visualizations

In addition, I think LUTI modelers should reconsider the way they communicate their output. My recommendation would be for dynamic visualizations, in addition to tables providing data for key indicators, as a helpful way to communicate what may happen under specific cases.

6 Concluding remarks

Discussing the need for a next generation of LUTI models is relatively easy compared to carrying out all the research needed to develop such models and the model development itself. I realize that developing LUTI models is very complex—most current models have several shortcomings (Hunt, Kriger, and Miller 2005; Wegener 2011) and are not perfect, and I think the modelers are well aware of this. I am not at all sure if this next generation of LUTI models will be developed at all. For decades researchers have discussed the added value of LUTI models (and the same applies to activity-based models), but real-world applications are relatively limited. The conventional four-step model still dominates practice. So we should not be overly optimistic about the possibility of implementing the suggestions discussed in this paper.

Nevertheless, I think a more general paradigm shift in transport research, especially in the area of travel behavior, is needed. A new generation of policy questions needs to be answered, and these are different from past questions, which were often related to new urban developments, extending the transport system and congestion reduction (and less commonly accidents and environmental impacts). Examples of policy questions included: Where to build new residential areas? Where to plan new commercial and industrial areas? What land-use change can be expected due to building new motorways and railway lines, stations and motorway exits? What land-use changes can be expected if congestion is strongly reduced by increasing the capacity of motorways? In addition, we might face a shift from questions related to solving capacity problems and congestion to other and wider impacts of the transport and land-use system, putting topics on the agenda such as climate change and reduction in greenhouse gasses, well-being and health, social exclusion and other accessibility indicators, livable cities, increasing interaction between ICT and activity patterns, etc. Examples of new policy questions include: To what extent will a decline in population size and public transport have mutual impacts? How can cities remain attractive in the face of population decline and electronic shopping? How can we reduce the levels of social exclusion of those who have no access to a car and public transport services decline? Where can we reallocate space from main urban roads to slow modes or attractive (green) public space, without restricting accessibility by car? Which land use and transport system options make us less car dependent? If we do not study these topics, and use the results for LUTI and other models to help us answer important policy questions, future generations will be highly surprised.

A final remark: This paper is only "a" view and is one that could be contested. On several of the topics discussed alternative interpretations could be offered. For instance, as an anonymous reviewer remarked, it is not necessarily certain that the increasing use of ICT will reduce the impact of the road system on land use—increasing use of ICTs could lead to dispersed locations of homes and businesses (i.e., promotion of further sprawl).

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