The development of the TIGRIS XL model: a bottom-up approach to transport, land-use and the economy

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Abstract:
The project appraisal method in the Netherlands distinguishes direct effects, indirect distribution effects and indirect generative effects. In general transport models are available for calculating the benefits of transport projects to travellers as part of the direct effects. The TIGRIS XL model, a Land-Use and Transport Interaction model, adds indirect distribution effects for the housing and labour market, by modelling changes in the spatial distribution of jobs and residents. This paper describes the current TIGRIS XL model and how it can be applied in the evaluation of transport projects. It also discusses ideas on how to extend the TIGRIS XL model to address indirect generative effects as well.

The current TIGRIS XL model, its integration with the National Model System (standard tool for the Dutch government to analyze the effects on passenger transport) and basic design principles are the starting point of such an exploration. These design principles include:
• an emphasis on detail, both spatial as well as in socio-economic segments, to account for differences in the availability of choice alternatives and in choice behaviour, and to provide impacts by region and socio-economic group;
• the requirement that the relationships used rest on an empirical foundation.

In this paper a post-processing module is proposed, which transforms changes in travel times and land-use into agglomeration effects. The so-called agglomeration effects combine several of the generative effects; like scale advantages, increasing variety of products, labour market matches and knowledge spill-over. The effects on productivity of changes in the agglomeration indicator can be estimated on existing data sources as is demonstrated in the UK (Graham 2005).

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1. Introduction

In the Netherlands the TIGRIS XL model has been developed by a consortium of RAND Europe, Bureau Louter and Spiekermann & Wegener for the Transport Research Centre to help the Ministry of Transport and its regional directorates deal with policy questions related to land-use and transport. The model aims to support the Ministry on a wide set of issues:

- effects of transport policies, including infrastructure as well as pricing policies, on a national and regional scale;
- effects of long-term national socio-economic scenarios on transport and land-use;
- effects of alternative land-use policies, including various degrees of market regulation, on land-use and transport.

The focus in this paper is on the function of supporting the evaluation of transport policies. To provide some background, the paper will give a brief description of the TIGRIS XL model and the standardised method for transport project appraisal in the Netherlands. The full project appraisal method, as originally developed for large infrastructure projects, needs as input: direct effects, external effects (e.g. environmental) and so-called indirect effects. Please note that the external effects are outside the scope of this paper.

In the Netherlands the direct effects are generated by applying transport models (together with external values of time) for calculating the benefits of the transport project to the travellers. This is the most traditional part of the analysis. The National Model System (LMS) is used regularly as the standard tool to analyse the transport effects of infrastructure projects. For the indirect effects, consisting of distributive and generative or additional welfare effects, less standardised tools are available. The TIGRIS XL model is such a tool and it adds distribution effects between regions by modelling the effects of infrastructure measures on the spatial distribution of residents and employment. In this paper we shall explore how the current TIGRIS XL model can be extended to address further, additional or generative, economic effects.

The current TIGRIS XL model, its integration with the LMS and basic design principles are the starting point of such an exploration. These design principles include:

- an emphasis on detail, both spatial as well as in socio-economic segments, to account for differences in the availability of choice alternatives and in choice behaviour, and to provide impacts by region and socio-economic group;
- the requirement that the relationships used rest on an empirical foundation.

In this paper we shall focus in particular on an approach to address agglomeration effects and additional welfare effects on the housing market.
2. The TIGRIS XL model: an introduction

RAND Europe, and its partners Bureau Louter and Spiekermann & Wegener, have developed a new Land-use and Transport Interaction model (TIGRIS XL) for the Transport Research Centre of the Ministry of Transport, Public Works and Water Management in the Netherlands. The TIGRIS XL model is a system of sub-models that includes dynamic interactions between the sub-models. Its land-use model uses time steps of one year, which enables the user to analyse how the system evolves over time. The land-use model is fully integrated with the National Transport Model (NMS) of the Netherlands and the two models, land-use and transport, interact every five years.

TIGRIS XL is a linkage module model and it consists of five modules addressing specific markets. The advantage is that each module can be developed in a flexible way to address its specific characteristics, local policies and data availability. Core modules in TIGRIS XL are the housing market and labour market module; these modules include the effect of changes in transport on residential or firm location behaviour and in this way link changes in the transport system to changes in land-use. A land and real estate module simulates supply constraints arising from the amount of available land, land-use policies and construction. The module defines different levels of government influence, ranging from completely regulated towards free market, and various feedback loops between demand and supply are available. A demographic module is included to simulate demographic developments at the local level. At the regional or national level the model output is consistent with existing socio-economic forecasts.

Figure 1 presents an overview of the model and the main relationships between the modules, for a more extensive description we refer to RAND Europe (2003). In Figure 1, two spatial scale levels are distinguished, namely the regional level (COROP, 40 regions in the Netherlands) and local transport zones of the National Model System (NMS sub-zones, 1308 sub-zones covering the Netherlands).
Figure 2: functional design of the prototype TIGRIS XL model

Labour market module (regional and local dimension)
Demography
Land market and real estate market
Housing market
Transport market

**Demography**
The demographic module addresses the transition processes of the population and households. It deals with persons by category (gender, age) as well as households by category (size, income, etc.). The demographic module operates at the local zone level and processes, besides the transitions (e.g. ageing), the migration flows calculated in the housing market module. The
demography module ensures consistency between households and persons categories for all the zones.

**Land and real estate market**
The land and real estate market module processes the changes in land-use and buildings, office space and houses, and addresses both brown field and green field developments. The land and real estate market interacts with the housing market and labour market module. The modelling of the changes in land-use depends on the setting for the level of market regulation. This can vary from a regulated land-use planning system to a free market. In a regulated market, all supply changes are planned by the government. In a free market supply changes are based on the preferences of the actors and only restricted by the availability of land.

**Housing market module**
The aim of the housing market module is to simulate the annual moves (if any) of households. The module interacts with the demographic, land and real estate, labour and transport market module to account, for example, for demographic changes and changes in the supply of houses. The housing market module simulates two choices, namely the choice to move or stay and the residential location choice, conditional on a move. The residential location choice has a nested logit structure and contains a regional and local scale level: there is a choice of region and a choice of location within the region. At each level a wide set of explanatory variables have been tested in the model estimation to address differences in household characteristics, local amenities, prices and accessibility. Another important variable is the distance (travel time) related impedance, that was included to reflect the geographical dimension of the moves. The parameters of the move/stay and residential location choice function, for each household type, have been estimated on a large four-annual housing market survey in the Netherlands with over 100,000 households (the so-called WBO of 2002).

**Labour market module**
The labour market module in TIGRIS XL models the changes in number of jobs by sector and changes in workforce at a regional and zone level. Specific models have been estimated for seven economic sectors to account for the differences in location behaviour between sectors. For each sector the influence of accessibility on the spatial distribution has been modelled in combination with a set of other explanatory variables. The parameters have been estimated on a historical data set (1986 – 2000) including employment figures by sector at a local level. The labour market module interacts with the demographic, land and real estate, housing market and transport modules.

**Transport market**
The transport module calculates the changes in transport demand and accessibility. The National Transport Model is integrated for this purpose within the TIGRIS XL framework. The land-use markets for the TIGRIS XL model generate socio-economic input data for the transport module and the transport module calculates accessibility indicators based on the changes in socio-economic data and/or transport policy measures. These accessibility indicators are input for the residential and firm location choice modules. The transport module interacts with the land-use
modules every five years. The selection and statistical testing of accessibility indicators is crucial for the responsiveness and reliability of a LUTI-model.

A wide range of accessibility measures does exist and a detailed overview of accessibility indicators can be found in Hilbers and Verroen (1993) or in Geurs and Ritsema van Eck (2001). The latter authors categorise accessibility measures into three groups following different perspectives:

- Infrastructure-based accessibility measures. These measures are used to analyse the (observed or simulated) performance of transport infrastructure;
- Activity-based accessibility measures. These measures are used to analyse the range of available opportunities with respect to their distribution in space and the travel impedance between origins and destinations. Activity-based measures can be further subdivided into geographical (or potential) and time-space measures;
- Utility-based accessibility measures. These measures are used to analyse the benefits individuals derive from the land-use transport system.

The utility-based accessibility measures are selected by the TIGRIS XL team as preferred accessibility measure. Reasons for this choice are:

- The utility-based accessibility measures have a strong theoretical foundation in economic theory;
- The utility-based accessibility measures include personal characteristics and preferences besides characteristics of the transport and land use system. Including the individual component of accessibility means that more realistic accessibility indicators, resembling the individual activity pattern more closely, can be included as explanatory variable in residential or firm location choices;
- Potential use of changes in utility as benefit measure in project evaluation.

The utility-based accessibility measures for TIGRIS XL have been derived from the National Transport Model (LMS). The LMS consist of a set of discrete choice models for various choices in transport that can be based on micro-economic utility theory. This model can generate the “logsum” value, expressing the utility for a traveller from a set of available choice alternatives. Well-known references for such type of models and the logsum variable are McFadden (1981), Ben-Akiva and Lerman (1985) and Daly and Zachary (1976).

Residential location choice decision are made at a household level and therefore, the person type specific logsum indicators, needed to be transformed into household type specific logsum indicators. Similar “logsum” accessibility measures have been generated as explanatory variables for the labour market module. These variables describe the accessibility of a firm for its employees and the accessibility of other economic activities for trips departing from a firm (business purpose).

Another relationship between transport and the housing market is that the performance of the transport system affects the size of urban/regional housing markets. The size of the market that households consider varies with changes in the transport system, and a travel time indicator was included in the residential location choice module to represent the impedance between the old and new location.
3. Project appraisal method in the Netherlands

In the Netherlands the societal effects of large infrastructure projects have been subject of intensive debate over the last decades. In 1998 the Ministry of Economic Affairs and Ministry of Transport, Public Works and Water Management started the so-called OEEI (now OEI) initiative (research program on economic effects of infrastructure measures). This project resulted in an officially approved standard methodology for the evaluation of large-scale infrastructure projects in The Netherlands. The applied methodology follows a cost-benefit philosophy. This standardisation and regulation of the project appraisal method in the Netherlands is in line with the current practice in many of the other EU-countries. For example, in Germany, UK and France the CBA-method is the primary evaluation method and regulations exist about how it should be applied. The CBA-method in the Netherlands differs from many others because of its wider perspective on the economic effects.

This wider perspective, including indirect effects (effects on other markets than transport, such a housing or labour) is at least prescribed for the evaluation of large infrastructure projects. For smaller projects a less comprehensive method can be used. The OEI methodology states that a broad perspective on welfare economics is needed to evaluate large infrastructure projects. It further states that cost-benefit analysis is the most adequate method for evaluating investment in infrastructure. A cost-benefit analysis can be included in several stages of the policy making process. Early in the process an approximate cost-benefit analysis can be used to select promising alternatives and a thorough cost-benefit analysis can be carried out to support the final decision-making.

The OEI-method extends the traditional cost-benefit approach by also presenting non-monetary effects in the project overview sheets. It is finally up to the politician to weigh the monetary and non-monetary effects. The OEI guideline (CPB, NEI, 2000) describes the main elements of the cost-benefit analysis and presents an outline of the way such analysis needs to be made. In this paper we only point at some elements, for a more in-depth description of the elements we refer to the guideline. The main elements are:

- Provide a clear description of alternatives and careful formulation of the reference alternative (the situation without the project);
- Use scenarios to take into account uncertain external factors;
- Account for all project costs, including planning costs, construction costs, operating expenses during the life time of the project and the costs of dismantling the infrastructure at the end;
- Commence the evaluation with a careful market and competition analysis; this phase should identify the effects for operators and users and the effects on other means of transport (including network effects). The product of this step in the evaluation is a partial cost-benefit analysis addressing direct effects;
- Estimate the external effects, defined as non-market effects of the infrastructure project (e.g. air pollution);
- Estimate the indirect effects, defined as effects on other markets. This analysis includes an estimation of indirect distribution effects and generative effects at the national level;
• Pay specific attention to the risks and flexibility of the project, including an analysis of phasing and delay in the project.

The OEI method has now been in use for several years and issues have been raised about the approach and the application in practice. In general it should be noted that OEI has contributed to a more transparent and systematic discussion on the evaluation of large infrastructure projects. The issues highlighted below are of particular interest for the rest of this paper and consist of some general observations/comments:

• A cost-benefit analysis can lead to an unbalanced focus on the monetary effects. Although the OEI guideline emphasizes the importance of a PM item for distribution effects, in practice a cost-benefit approach can easily lead to less attention for these types of effects. This seems especially to be the case for social distribution effects. From the point of view of policy coherence between policies in field of transport and other fields of policy making it can be argued that in practice a large share of all policies and projects focus on distribution effects. The nature of transport measures is such that in general a measure results in winners and losers. A general cost-benefit analysis only calculating the overall societal costs or benefits is therefore not enough. Policy makers need to know who the winners and losers are, the effects need to be consistent with policies in other fields and without this knowledge it is not possible to address policy coherence.

• All experts involved in an OEI review meeting estimated that the indirect effects would be significantly smaller than the direct effects. Some suggest that the indirect effects are in a range between 10-30% of the direct effects. (Workshop “Twee jaar ervaring met OEEI: de discussie over indirecte effecten, CPB 2003). A report of SACTRA in the UK suggests that the indirect effects are maximally 60% of the direct effects (SACTRA, 1999). All recognize the large uncertainties, and that indirect effects strongly differ between projects. The dominant role of the indirect welfare effects in the discussions seems to be mostly related to the uncertainty in estimating them. Direct effects, regional distribution and social distribution effects might deserve a more prominent role in the discussions, given their importance. We belief that in the short/medium term there are good prospects for improving the estimation of the direct and distribution effects. A satisfactory and widely accepted comprehensive estimation of the indirect effects, both from a theoretical and empirical point of view, seems to be more a long-term ambition. In the meanwhile we suggest to follow a stepwise approach and explore how we can move beyond current practice of generally ignoring indirect effects, by empirically estimating the most important indirect effects (see ch. 5);

• The OEI-definition of indirect effects is rather complex and therefore difficult to implement in practice. In principle, indirect effects only occur in case of imperfect markets. It is therefore necessary to make an assessment of the various markets (e.g. land, labour, and housing). The chosen way forward to this issue is to assume and implement a certain market condition (monopolistic competition) which allows addressing additional effects. Empirical evidence on the type of market situation and the indirect effects of transport measures under these conditions seems to be largely missing. We belief that a more pragmatic and empirically oriented approach could enrich the ongoing discussion.
4. TIGRIS XL and project appraisal

As stated before the TIGRIS XL model aims to support, among other purposes, the appraisal of transport policies and transport infrastructure projects. The TIGRIS XL model focuses on infrastructure projects at regional as well as a national scale level. The scope of the evaluation can differ between regional projects and large-scale national projects. And the effects might also be viewed differently by regional or national authorities. Below we try to position the TIGRIS XL output within the context of the standardized evaluation method.

Direct effects
The direct effects basically remain unchanged in TIGRIS XL and consistent with the current use of the NMS (together with external values of time) for calculating the benefits of the transport project to the travellers. Research projects have been carried out to investigate whether this could be replaced by logsum changes directly from the NMS (De Jong et al, 2005). The TIGRIS XL model can add second-order transport effects. The second-order effect addresses the additional transport benefits resulting from the changes in land-use. The land-use effects of a transport measures might in the long run generate additional users of the infrastructure.

Distribution effects
The TIGRIS XL model addresses distribution effects of transport measures both at the inter-regional and intra-regional level. For example, for a new interregional railway connection, the model can both assess the shift in employment and residents between regions and the shift within a region between cities with a connection and cities without.

The change in the number of jobs at the regional level resulting from a transport project is a generative effect for the region. This effect is probably the largest generative effect for a region and results from firms moving into the region to take advantage of the more attractive business locations due to an improved accessibility. The generative effect in TIGRIS XL does not include efficiency gains, and at the national level GDP and total employment are unchanged.

For many regional transport projects the expected generative national effects, e.g. by solving market imperfections like labour market imbalances or changing the level of competition, will be extremely small and addressing the distribution effects might be sufficient for the project appraisal. However, for large-scale infrastructure measures the generative effects at the national might be of importance for the project evaluation. These effects are at least part of the discussion and analytical instruments are needed to quantify these effects.

Generative effects at the national level
The main omission in TIGRIS XL is the lack of a way to calculate generative effects at the national level. The next section will explore an enhancement of the model to include these
effects in an approximate fashion. However we would like to stay as close as possible to the basic design principles of the TIGRIS XL framework. These design principles include:

- an emphasis on detail, both spatial as well as in socio-economic segments, to account for differences in the availability of choice alternatives and in choice behaviour, and to provide impacts by region and socio-economic group;
- the requirement that the relationships used rest on an empirical foundation.

5. **A possible extension of TIGRIS XL to include additional or generative welfare effects**

As stated above for large scale infrastructure projects generative welfare effects play an important role in the policy discussion and such discussion would benefit from “reliable” quantitative input. The generative effects can be different in nature and the most important generative effects of transport measures at a national level, from a theoretical perspective, are by market (RUG/SEO 2004):

- product market, generative effects can result from imperfect competition, scale advantages and product differentiation;
- labour market, scale of the labour market, and imperfect match between demand and supply at a regional level;
- knowledge spill-over effects;
- International effects, mainly consisting of relocation effects;
- Housing and land market restrictions and regional imbalances.

A modelling approach calculating all of these generative effects based on empirically founded relationships is non-existing and not foreseen in the near future. Each of the existing models is missing certain markets and in most models the modelled relationships lack an empirical foundation. The TIGRIS XL model describes the housing market and elements of the land and labour market. However, the model does not describe the product market, knowledge spill-over and international effects. An extension of the model with all these elements seems to be infeasible, certainly if the empirical and practical character of the model needs to be preserved.

An alternative way is to combine several effects in a single outcome indicator and estimate the effect of transport and land-use changes on this outcome indicator. The so-called agglomeration effect seems to combine several of the generative effects; like scale advantages, increasing variety of products, labour market matches and knowledge spill-over. An estimation of this agglomeration or urbanization economies effect seems to be feasible where an individual estimation of each of the effects seems to be infeasible based on currently available data sources. The TIGRIS XL model is capable of generating agglomeration variables, since the model simulates the land-use changes and transport times affecting the size and density of urban areas.
Furthermore we think that the TIGRIS XL model with its detailed modelling of the housing market and land changes can be a useful instrument to address the additional welfare effects on these markets. A post-processing module is needed to transform current TIGRIS XL output into additional welfare effects. Below we explore such a transformation process.

**Agglomeration effects**

The basic principle of agglomeration for firms is proximity in multiple dimensions and these include:

- Backward linkages to suppliers and employees
- Forward linkages to clients
- Horizontal linkages to other firms in the same sector, knowledge spill-over etc.

The linkages for an individual firm depend on the characteristics of the firm, the spatial distribution of socio-economic activities and the performance of the transport system. The performance of a firm depends on how good/efficient it can realize these linkages and the proximity of relevant activities in agglomerations might result in a positive relationship between city size and productivity. There is substantial literature quantifying the relationship between city size and productivity.

This productivity relationship between degree of agglomeration, resulting from the different linkages, and productivity (GDP per employee) forms the foundation for our approach. This relationship can be quantified by a variable addressing the degree of agglomeration and an elasticity of productivity with respect to this degree of agglomeration. An example of how such an effect can be quantified can be found in the Department for Transport note on “Transport, wider Economic benefits, and impacts on GDP” (DFT, 2005) and a more detailed description can be found in Graham (2005). It should be mentioned that the method used and the results are specific for the UK situation and rely on local data sources. However we believe that the concept is of value for the Dutch situation as well.

The basic element of the concept is a two step approach in which transport affects the degree of agglomeration and agglomeration has an effect on productivity. In this way the causality problems of directly estimating the effects of transport infrastructure on productivity can be avoided. Furthermore the effects are project specific and, for example, the specific location of a project does matter. The work of Graham (2005) applies this method and presents an empirical foundation for an economic sector specific relationship between agglomeration, expressed in a density variable, and additional productivity.

Of specific value, in our opinion, is to apply this approach in combination with the TIGRIS XL model addressing the changes in degree of agglomeration. The impact of transport measures on the agglomeration variable, e.g. density of residents or jobs, can be addressed at a detailed level by the TIGRIS XL model including congestion and spatial distribution effects. The value of an
agglomeration variable can be a gravity type of variable and, for example, depending on
generalized travel cost from zone x to all jobs in all other zones. The variables can be sector
specific and have different values at a zone or regional level, regional level variables can be
aggregated from the lower zone level. An important advantage of using a detailed modelling is
that the use of abstract administrative boundaries can be avoided.

It would be preferable to estimate the parameters for the effect of agglomeration on productivity
at the level of individual firms and aggregate bottom-up. Micro-level data enable to estimate
agglomeration effects in combination with firm internal effects of increasing returns to scale.
However micro-level estimation sets high demands on data sources and requires information for
individual firms on production, labour and capital input, which me be unavailable for reasons of
confidentiality. A second-best option, if available data sources would not support a micro-level
analysis, is estimating the effect of agglomeration on productivity by sector at a regional level.
At this level it will not be possible to separate internal scale advantages, relating to size of firms,
and external scale advantages like product differentiation or labour market matches.

In the work of Graham (2005) a micro database, called Financial Analysis Made Easy, has been
use to estimate the coefficients by economic sector. The coefficients, describing the relationship
between productivity and effective density (agglomeration variable), vary widely between
economic sectors and the average elasticity of productivity with respect to effective density is
0.04 for manufacturing and 0.12 for services. The report emphasizes that more work on this
subject is needed and in our view the first results are certainly encouraging to progress and
refine this approach.

Welfare effects on the housing and land market

In the Dutch context both the housing and land-market are partly regulated and both markets
face imperfections and externalities like regional imbalances in land and housing demand and
supply, market regulations to protect scarce natural land resources or social housing
programmes.

The most important land market imperfection in the Netherlands is that physical planning
restrictions are imposed on a large scale to protect natural land or open spaces. The price effect
on development sites is large; land prices for development sites can be tenfold or more of land
prices for agricultural land. The net welfare effects at a national level do not automatically
increase if the market regulation would become less strict (this means lower land prices for
developments sites), because the welfare effects depend on the right societal price setting for
open space and/or natural land. A second issue, potentially resulting in additional welfare effects,
is that the pressure on land and therefore the welfare contribution of open spaces and natural
land is not equal in all regions. A transport project can result in a better match in population or
labour distribution between regions with scarce land resources and regions with ample land
resources. Such an effect can be described as an indirect external welfare effect and will vary strongly by location and type of transport project. In this section we will not explore this type of effect any further, but it is clear that a land-use model like TIGRIS XL can deliver valuable information for calculating such an effect.

At the housing market a transport measure can have an effect on the housing utility for residents living in a region affected by the transport measure. In a perfectly functioning housing market this effect will be passed on to the immobile factor namely the house/land owner via changes in the housing price. In TIGRIS XL a change in accessibility will result in a change in utility in the move/stay module, as accessibility is a significant explanatory variable in the move/stay choice function. For a large part of the housing market in the Netherlands, namely the private ownership market, the outcome is likely to be a passing on of the transport effect into the housing price as the market can be described as being largely a free market and the household residing in and owning the building are one. For the rental market the transport effects are not directly passed on into the price, since rent increases are to a large extent controlled by the government. In this case the transport effects will be passed on to the households residing in the affected houses at the rental market. In principle we suggest to ignore the additional welfare effects on households staying at their location, as transport changes do not solve imperfections at the housing market such as imbalances between supply and demand for land and houses.

A second effect is that a transport measure results in the relocation of households. The housing market module of the TIGRIS XL model simulates residential location choices through a discrete choice type of modelling. The model operates at a spatial detailed level of 1308 zones and the utility functions are household type specific. Six different types of households are distinguished to account for differences in residential location behaviour. The discrete choice modelling of the housing market makes TIGRIS XL capable of addressing the increase in utility at the housing market resulting from a transport project by comparing a project situation to the reference situation. For each case the household type specific utility needs to be calculated and then the results from individual households are aggregated to the zone level. At a national level the change in utility between project variants and the reference situation can be calculated for each household type. The changes in utility by household type need to be transformed into monetary values for each household type. For the household types with a significant coefficient for the housing price, this information can be used to transform utility changes into monetary effects.

Once the utility changes have been converted into monetary values, the question again is whether these increases in welfare are an additional effect or just a passing on of the transport effect. As long as the indirect network effects or long-term transport effects are not included in the evaluation it seems straightforward and the effect can be included as an additional welfare effect. However, once the second order transport effects are correctly included in the evaluation there is a risk of double counting. Simply ignoring the effect under these circumstances does not seem to be correct as well, since the transport measure does not only increase the accessibility of
location but it also widens the size of the housing markets. However it seems to be a sound assumption that, if these effects can be proven, that they will remain small. Several test applications with TIGRIS XL show that the number of people relocating as a response on transport measures is rather small.

More important is the question if current methods to monetise transport effects account for increased housing utility. Following the idea that transport is a derived demand, and under assumption of a perfect housing market, the demand function for transport should include changes in housing utility as well. In a perfect housing market the change in housing utility or housing price, resulting from a transport measure, cannot be more than the calculated direct transport benefits. Our suggestion is to perform an ex-post analysis to check the consistency between the direct transport benefits and changes in the housing prices. A significant change in the infrastructure and time series data on housing prices will be needed to analyse this. The analysis should be restricted to the private ownership segment of the housing market as the assumption of a perfect market conforms best with reality for this segment of the housing market.

6. CONCLUSIONS AND RECOMMENDATIONS

The TIGRIS XL model is well capable of addressing the direct and indirect distribution effects of transport infrastructure measure. For many regional transport projects the expected generative effects at a national level will be extremely small and addressing the distribution effects seems to be sufficient for project appraisal. However, for large-scale infrastructure measures the generative effects at the national might be of importance for the project evaluation. These effects are at least part of the discussion and analytical instruments are needed to quantify these effects.

In this paper we have explored if and how TIGRIS XL could contribute to calculate these generative effects by staying as close as possible to its design principles of sufficient spatial detail and of an empirical foundation for the key relationships. Agglomeration effects, welfare effects on the housing market and external effects on the land market are potentially indirect effects where TIGRIS XL can strengthen the current policy making practice. However for each of these effects additional research will be needed to develop an approach in sufficient detail and the model needs to be expanded with specific post-processing modules.
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