Accessibility appraisal of integrated land-use/transport policy strategies:  
It’s not just adding up travel time savings

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1. INTRODUCTION

The concept of accessibility plays an important role in transport appraisal and policy-making. The outcome of cost-benefit analysis (CBA) often plays a crucial role in the political decision making process of infrastructure investments in the Netherlands. Accessibility appraisal forms an important part of a CBA of transport investments; the size of the accessibility benefits accruing to transport users strongly affect the outcome of economic appraisals, thus decisions on whether or not to build new transport infrastructures. However, finding an operational and theoretically sound concept of accessibility is quite difficult and complex, as seen in the review of Geurs and Van Wee (2004). Conventional approaches to accessibility measurement estimating congestion levels, travel times and/or costs, often represent the standard output of transport models and are used as input to the well-known rule-of-half measure of consumer surplus typically applied in transport project appraisal. However, this conventional approach has important shortcomings for accessibility evaluation and economic appraisal of land-use, transport and integrated land-use/transport policy strategies, as a result of the exclusion of the land-use component of accessibility. Firstly, the impact of land-use changes arising from transport investments is ignored, for example, the impact of improved travelling speed on urban sprawl. Secondly, the conventional approaches to measuring accessibility benefits do not correctly measure accessibility impacts of land-use strategies that affect the spatial distribution of activities. Although the indirect impact of land-use changes via speed
in the road network (e.g. more congestion) may be included and expressed in these measures, generally speaking and far more important, the direct effect (changes in the attractiveness and distribution of activities) is not. The rule-of-half measure of consumer surplus assumes that all accessibility benefits accruing to economic agents can be attributed to generalised cost changes within the transport system. This is a convenient argument with a practical outcome, since it is easier to identify and estimate the benefits/disbenefits accruing directly to travellers rather search for their more elusive manifestations further along the chains of reaction in other markets (SACTRA, 1999). Under the assumption of perfect competition in all the sectors of the economy (using transport), the transportation consumers’ surplus is shown to summarise the welfare effects of transport changes for consumers and producers from both markets (see e.g. Jara-Diaz, 1986). However, in the literature it has been pointed out repeatedly that the rule-of-half gives incorrectly measured welfare effects of land-use policy plans (e.g., Neuburger, 1971) and transport strategies where land uses are forecasted to change as a result of the strategy (Bates, 2006; Geurs et al., 2006; Simmonds, 2004). The problem is that the rule-of-half measure does not correctly measure total accessibility benefits (and thus welfare changes) when changes are introduced that are not attributable to generalised cost changes. In general, accessibility may change as a result of either a transport (generalised cost) change or a land-use change, but the rule-of-half measure only estimates benefits for the origin-destination combinations where (generalised) costs change. Hence, the measure does not account for changes in the relative attractiveness of locations due to land-use changes and related changes in trip distribution taking place for reasons other than transport cost changes. This omission thus affects the measurement of the impacts of transport policies as land-use effects from such policies are not valued, but is particularly problematic when assessing the accessibility impacts of land-use or integrated land-use/transport policy strategies – the topic of this paper. Some authors have suggested adapting the rule-of-half in evaluations of land-use/transport planning to obtain a more complete evaluation of net user benefits by adding user benefits that occur from changes in attraction of location and changes in location (Bates, 2006; Simmonds, 2004). In this paper, we examine an alternative and more comprehensive approach to measure the total accessibility benefits, the logsum measure of accessibility.

The purpose of this paper is to examine the logsum as a measure of accessibility and transport user benefit in integrated land-use/transport policy appraisal. The paper firstly describes the theoretical basis for the logsum accessibility measure and applications in practice (Section 2). Secondly, the TIGRIS XL land-use/transport modelling framework is presented that has been applied to calculate the accessibility effects of integrated land-use and transport strategies (Section 3). Thirdly, the paper describes the application of the logsum accessibility measure within a large-scale land-use policy evaluation study for the Netherlands (Section 4).
2. LOGSUM ACCESSIBILITY AS AN EVALUATION MEASURE

2.1 Theory

In this section we provide an introduction to the concept of the logsum as measure of accessibility and welfare changes. One of the earliest references to the logsum as an accessibility measure is from (Ben-Akiva and Lerman, 1979). An introduction can be found in the textbooks on discrete choice models (e.g., Train, 2003). This section is based on De Jong et al. (2007; 2005), who present an contemporary literature review on the theoretical and applied literature on the logsum as an evaluation measure.

The utility that decision maker \( n \) obtains from alternative \( j \) is decomposed into an observed and an unobserved (random) component:

\[
U_{nj} = V_{nj} + \epsilon_{nj}
\]  

Where:

- \( U_{nj} \) is the utility that decision maker \( n \) obtains from alternative \( j \) (\( n = 1, \ldots, N ; j = 1, \ldots, J \)),
- \( V_{nj} \) = “representative utility”;
- \( \epsilon_{nj} \) captures the factors that affect utility, but are not observable by the researcher.

In a standard multinomial logit (MNL) model, with \( \epsilon_{nj} \) i.i.d. extreme value with standard variance (\( \pi^2/6 \)), the choice probabilities are given by:

\[
P_{nj} = \frac{e^{V_{nj}}}{\sum_j e^{V_{nj}}}.
\]

The “logsum” now is the log of the denominator of this logit choice probability. It gives the expected utility from a choice (from a set of alternatives), and is also used to link different choices (as in nested logit models, e.g. of mode and destination choice).

The logsum can also be used in project evaluation in an expression for the consumer benefits.

In the field of policy analysis, the researcher is mostly interested in measuring a change in consumer surplus that results from a particular policy. By definition, a person’s consumer surplus is the utility (also taking account of the disutility of travel time and costs), in money terms, that a person receives in the choice situation. The decision-maker \( n \) chooses the alternative that provides the greatest utility, so that, provided that utility is linear in income, the consumer surplus (\( CS_n \)) can be calculated in money terms as:

\[
CS_n = \frac{1}{\alpha_n} U_n = \frac{1}{\alpha_n} \max_j (U_{nj} \forall j)
\]

where

\( \alpha_n \) is the marginal utility of income and equal to \( dU_n/dY_n \) if \( j \) is chosen,
\( Y_n \) is the income of person \( n \), and 
\( U_n \) the overall utility for the person \( n \)
Note that the division by \( \alpha_n \) in the consumer surplus formula, translates utility into 
money units (e.g. dollars, euros) since \( 1/\alpha_n = dY_n/dU_{nj} \).

If the model is MNL and utility is linear in income (that is \( \alpha_n \) is constant with respect to income), then expected consumer surplus becomes:

\[
E(\text{CS}_n) = \left( \frac{1}{\alpha_n} \right) \ln \left( \sum_{j=1}^J e^{v_{nj}} \right) + C \tag{4}
\]

where \( C \) is an unknown constant that represents the fact that the absolute value of 
utility can never be measured. Aside from the division and addition of constants, 
expected consumer surplus in a standard logit model is simply the logsum. Under the 
usual interpretation of distribution of errors, \( E(\text{CS}_n) \) is the average consumer surplus 
in the subpopulation of people who have the same representative utilities as person \( n \). 
Total consumer surplus in the population can be calculated as the weighted sum of 
\( E(\text{CS}_n) \) over a sample of decision-makers, with the weights reflecting the number of 
people in the population who face the same representative utilities as the sampled 
person.

The change in consumer surplus for decision-maker \( n \) is calculated as the difference 
between the calculation of \( E(\text{CS}_n) \) under the conditions before the change and the 
calculation of \( E(\text{CS}_n) \) after the change (e.g. introduction of policy):

\[
\Delta E(\text{CS}_n) = \left( \frac{1}{\alpha_n} \right) \left[ \ln \left( \sum_{j=1}^{J_1} e^{v_{nj}} \right) - \ln \left( \sum_{j=1}^{J_0} e^{v_{nj}} \right) \right] \tag{5}
\]

where superscript 0 and 1 refer to before and after the change.

Since the unknown constant \( C \) appears in the expected consumer surplus both before 
and after change, it drops out in calculating the changes in the consumer surplus. 
However, to calculate this change in consumer surplus, the researcher must know (or 
have estimated) the marginal utility in income \( \alpha_n \). Usually a price or cost variable 
enters the representative utility and, in case that happens in a linear additive fashion, 
the negative of its coefficient is \( \alpha_n \) by definition. The above equations for calculating 
the expected consumer surplus depend critically on the assumption that the marginal 
utility of income is constant with respect to income. If this is not the case, a far more 
complex formula is needed. However, for policy analysis absolute levels are not 
required, rather only changes in consumer surplus are relevant, and the formula for 
calculating the expected consumer surplus can be used if the marginal utility of 
income is constant over the range of implicit changes that are considered by the 
policy. So, for policy changes that change the consumer surplus by small amounts per 
person relative to their income, the formula can be used even though in reality the 
marginal utility of income varies with income.

2.2 Applications of the logsum measure in practice

De Jong et al. (2007; 2005) give an overview of academic literature on logsums as a 
measure of consumer surplus in transport appraisal. It is concluded that although the 
theory on the use of the logsum change as a measure of the change in the consumer
surplus was published in the late seventies and early eighties, the application of this theory in practical appraisals of transport projects has been fairly limited. De Jong et al. found seven studies, all published after the year 2000, describing applications of the logsum in transport appraisal. National disaggregate transport models are in use in Scandinavia, the Netherlands and Italy and regional and urban models using these concepts can be found in the same countries, France, the United Kingdom, Australia, Israel and especially the United States. It is therefore not surprising that the logsum applications in evaluation took place in the USA (e.g., Gupta et al., 2006), Scandinavia and The Netherlands (e.g., Koopmans and Kroes, 2003).

All applications use transport models that include mode choice. Some logsum applications in project evaluation also use models for destination choice and/or departure time choice. A common segmentation for the logsum calculations and outputs is by travel purpose. Most applications use one or more cost coefficients to get outcomes in monetary terms, but some do not convert the (dimensionless) logsum change to time in minutes (e.g., Koopmans and Kroes, 2003). The applications of the logsum concept in transport project appraisal all use the relatively simple formulation with constant marginal utility of money.

In theory, when a transport investment is not assumed to affect the spatial distribution of activities (land use is fixed), an accessibility benefit approximation using the rule-of-half will only slightly differ from the more exact logsum measure when computed at the same level of aggregation. This is because the rule of half method assumes a linear demand curve while the logsum method uses an non-linear demand curve (e.g., see for a comparison, Bates, 2006). However, in practical applications, both methods may estimate very different results depending on the operationalisation, e.g. assumptions on the type of travel costs and time components included and the aggregation level at which the in the rule-of-half measure is computed. This is illustrated in recent case studies for the Netherlands (de Jong et al., 2007) and the UK (Kohli and Daly, 2006), where accessibility benefits of public transport and road investments schemes are examined using the logsum and rule-of-half method. De Jong et al. conclude that an advantage of the rule-of-half approach is that it is more transparent (but only in simple situations) and more intuitive and therefore easier to explain to non-experts. However, the rule-of-a-half calculations can get very complicated when one wants to take account all possible changes in travel behaviour resulting from a transport project, e.g. changes in route choice, time of day, destination and/or transport modes.

There are few applications in the academic literature of the logsum method in transport appraisal, but even less examples of applications of the logsum method to measure accessibility and welfare changes in land use policy appraisal. In many operational integrated land-use/transport interaction models (e.g., TIGRIS XL – see below) or land-use models 'connected' to stand alone transport models (e.g., Urbansim - Waddell et al., 2007), logsum values are taken from the (mode-destination) logit models used in the travel demand model are input to the land-use model, e.g. as variables in residential and/or business location choice models (see Hunt et al., 2005, for an overview). However, surprisingly, these logsum values are seldomly converted to monetary terms and used as an evaluation measure in land-use policy appraisal. Niemeier (1997) probably presented one of the very few applications in academic literature so far. She examined consumer welfare changes of land use and
transport changes by constructing a series of hypothetical policy scenarios (elimination of travel destinations or transport modes). Logsum accessibility changes were taken from a mode-destination logit model for home-to-work trips in Washington State.

3. USING TIGRIS XL TO EVALUATE LAND-USE AND TRANSPORT POLICIES

3.1 Overview of TIGRIS XL

Governmental policies towards land-use and transport both affect the accessibility for firms and residents. A land-use and transport interaction model is capable of calculating accessibility changes, resulting from land-use and transport strategies. Such calculation includes the mutual interactions between land-use and transport over time and the outcome is different from the sum of the two measures if taken individually. In this study the changes in accessibility are calculated by the TIGRIS XL model; an integrated land use and transport model that has been developed for the Transport Research Centre in the Netherlands (RAND Europe, 2006; Zondag, 2007).

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 (LMS) 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. Figure 1 presents an overview of the model and the main relationships between the modules. In Figure 1, two spatial scale levels are distinguished: the regional level (COROP, 40 regions in the Netherlands) and local transport zones of the National Model System (LMS sub-zones, 1308 sub-zones covering the Netherlands).

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.

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 handles, besides the transitions (e.g. ageing), the migration flows calculated in the housing market module.
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 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 non-regulated market. In a regulated market, all supply changes are planned by the government. In a non-regulated market supply changes are based on the preferences of the actors and only restricted by the availability of land.

The aim of the housing market module is to simulate the annual moves (if any) of households. 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. Choices depend on household characteristics, local amenities, prices, accessibility and distance (travel time) of relocations. 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 labour market module in TIGRIS XL models the changes in number of jobs by seven economic sectors and changes in workforce at a regional and zone level. 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.
The transport module calculates the changes in transport demand and accessibility. The TIGRIS XL model is integrated with the National Transport Model (LMS). The LMS consist of a set of discrete choice models for various choices in transport (including tour frequency, mode and destination choice and departure time choice) that can be based on micro-economic utility theory, enabling the derivation of utility-based accessibility measures.

TIGRIS XL calculates a wide range of accessibility indicators, ranging from ‘infrastructure-based’ accessibility measures (e.g., travel times, vehicle hours lost in congestion), ‘location-based’ accessibility measures (e.g., number of jobs or population which can be accessed within 45 or 60 minutes travel time by car or public transport) to ‘utility-based’ accessibility measures. This paper focuses on the utility-based accessibility measures – the logsum measure of accessibility (see Section 3.2). The main advantages of this approach are as follows (see Geurs and van Wee, 2004, for a discussion):

- 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 used as explanatory variable in residential or firm location choices;
- Potential use of changes in utility as benefit measure in project evaluation.

### 3.2 The logsum measure using TIGRIS XL

The logsums in the TIGRIS XL model are derived from the National Transport Model (LMS). The logsums from the LMS are computed for tours (round trips) at the individual level and expresses a traveller’s utility of a choice set with travel alternatives. This choice set contains all travel alternatives to all 1308 possible destinations, across all five modes. For each origin zone \( z \) in the TIGRIS XL model, the logsum is computed from the travel alternatives to all destination and mode combinations \( j \) for each person type \( i \), and travel purpose \( p \):

\[
L_{pic} = \log \left( \sum_j \exp \left( \mu_p V_{p ij} \right) \right)
\]

with \( \mu_p \) as the scale parameter for travel purpose \( p \).

V, the representative utility (the deterministic or observed utility component) in the mode-destination choice models of the LMS is in a simplified form specified as

---

1 The LMS distinguishes 490 person types segmented to 5 household income classes, 2 gender classes, and 49 age classes.

2 The actual models are nested logit and have many explanatory variables but are presented here in a somewhat simplified form for ease of understanding.
\[ V_{zijp} = \beta_p T_{zj} + \chi_{ph} \ln(C_{zj}) + \delta_p D_{pj} + \ldots \] 

where \( T \) is travel time (comprising various components with their own coefficients), \( C \) the travel cost, \( D \) a variable representing the attractiveness of the destination zone (destination utility) for a specific activity (e.g. population, employment, retail employment, number of students at schools and universities). The costs coefficients \( \chi \) differ between travel purposes, but also between income groups \( h \) within each travel purpose). The cost variable enters in logarithmic form.

Equation 6 expresses logsums in utils, and these need to be translated into monetary terms. Because the costs are in logarithmic form, we can’t simply use the costs coefficients as marginal utility of income (use the \( \chi \)s for the \( \alpha \)s). In de Jong (2007), a method is described to derive approximate marginal utility of income from the coefficients for logarithmic cost, which does no require external values of time. In this application however, we avoid this complication, by using the time coefficients (the \( \beta \)s) first. First, the logsums are translated into travel times by time coefficients \( \beta \) and next into costs by value of times, \( VoT \). The travel time coefficients are purpose specific and are available from the LMS. The value of time \( VoT_{ph} \) by travel purpose \( p \) and household income category \( h \), in equation (7), is used to convert the logsum accessibility changes into monetary benefits. We use VoTs here from Stated Preference research, that are prescribed in the transport appraisal guidance in the Netherlands. The monetary value of the accessibility of zone \( z \) for a person of type \( i \), that belongs to household income group \( h \), is computed as:

\[ CS_{piz}^L = VoT_{ph} \cdot \frac{1}{\beta_p} \cdot L_{piz} \]  

(8)

Please note that this term does not represent the absolute value of utility for it does not include constant \( C \), see equation (4). By definition, this constant is unknown and can never be measured.

The monetary value of accessibility in equation 8 represents the accessibility value for a tour. For accessibility evaluation, the accessibility benefits are computed over all actors in the transport model, by multiplying the accessibility value with the number of people \( A_{piz} \) in that population segment \( i \) that make a tour for that purpose \( p \) from that zone \( z \) (or more exactly: the number of tours in this population segment for this purpose from this origin).

\[ \Delta E(CS_{piz}) = (1/\alpha_n) \left[ A_{piz}^1 \ln \left( \sum_{j=1}^{j_1} e^{V_{zj}} \right) - A_{piz}^0 \ln \left( \sum_{j=1}^{j_0} e^{V_{zj}^0} \right) \right] \]  

(9)

Where the superscript 1 refers to the situation with the policy to be evaluated and the superscript 0 to the situation without the policy (reference).
3.3. Logsum measure by transport mode

In the National Model System, logsums are computed in a mode/destination model which simulates all destination and mode choices simultaneously in a nested structure. Unlike results for different population segments (e.g. income classes), logsum results by travel mode can not easily be calculated, since mode is not a segmentation variable, but an endogenous (choice) variable. An approximation method was developed and is applied here to distinguish the contribution of changes in transport modes in the logsum. The approximation is based on the mode choice probabilities, and the sum of utilities over all alternatives within a transport mode.

Changes in land use and the transport infrastructure influence the destination and mode choices in the transport model, and the associated accessibility benefits, in three ways:

1. Origin effect: accessibility changes or land use policies lead to a different spatial distribution of population. In the model this is represented by a different expansion of the logsums per tour (differences between $A^1$ and $A^0$ in equation 9). This effect could therefore also be called the ‘expansion’ effect.

2. Transport cost effect: benefits from changes in transport costs (and times) lead to utility changes for specific transport modes and destinations (through the $C$ and $T$ terms in equation 7);

3. Destination utility effect: the redistribution of population and employment leads to differences in the attractiveness of the destinations in the choice model (through the $D$ terms in equation 7).

The origin effect in a specific scenario influences the number of tours that are made from a location. The influence of this effect is calculated with the change of tours that are made compared to the reference scenario, and the share of tours that are made with this transport mode. First the share of each transport mode is specified with the probability that a specific transport mode is chosen. This is calculated as the sum over all individual alternatives with that transport mode.

$$P_{pizm} = \sum_{j,m} P_{piz} = \frac{\sum_{j,m} \exp[V_{piz}]}{\sum_{j} \exp[V_{piz}]} \quad (10)$$

The logsum benefits from the origin effect, $\Delta LR$, is computed as:

$$\Delta LR_{pizm}^{Scen} = (AT_{piz}^{Scen} - AT_{piz}^{Ref}) \cdot P_{pizm}^{Ref} \cdot L_{pizm}^{Ref} \quad (11)$$

The second and third effect, the cost and destination effect is calculated in one step because the mode and destinations choices are modelled simultaneously. The share of the mode changes on the total logsum is proportional to the utility change of all mode alternatives, described with mode fractions:
The cost/destination effect of accessibility changes, $\Delta LV$, is computed with these fractions:

$$\Delta LV_{\text{scen}} = AT_{\text{scen}} \cdot frac_{\text{scen}} \cdot \left( L_{\text{scen}} - L_{\text{ref}} \right)$$

4. CASE STUDY: ACCESSIBILITY BENEFITS OF INTEGRATED LAND-USE/TRANSPORT POLICY SCENARIOS FOR THE NETHERLANDS

4.1 Case study description

The Netherlands Environmental Assessment Agency recently conducted a major land use policy evaluation study titled ‘The Nederlands in the Future’ (MNP, 2007). In this study, land-use trend scenarios, showing the continuation of land use trends and existing policies, and several quite extreme alternative land-use and transport policy scenarios were constructed for the entire territory of the Netherlands for the period 2000-2040, using the Land Use Scanner, a GIS-based land-use model (Hilferink and Rietveld, 1999). The trend and alternative land-use scenarios have been examined within the context of two different socio-economic scenarios for the period 2002-2040;

- Global Economy (GE) scenario; a scenario with a relative high economic growth (2.6% yearly GDP growth), a high population growth (from about 16 million to 20 million inhabitants in 2040), and a high demand for housing locations (housing stock increases by 1% per year) and employment locations (number of workers increases by 0.4% per year);
- Transatlantic Market (TM) scenario, a scenario with a modest economic growth (1.9% yearly GDP growth), modest population growth (up to 17 million inhabitants) and modest demand for housing (housing stock increases by 0.5% per year) and employment locations (stabilisation of number of workers).

In this paper we focus on one of the land use projections which were developed, the Compact Urban Development scenario. Compact urban development has been a basic principle of spatial planning in the Netherlands for the past fifty years. Current policy, as formulated in the Dutch National Spatial Strategy (Ministry of Housing Spatial Planning and the Environment, 2006), endeavours to concentrate urbanisation and economic activities within designated concentration areas, where possible within the existing built-up area, or in new-build designated clusters outside that area. The Government wants to make optimum use of the little space available and of the investment in infrastructure, and also to support the cities in their function as an economic and cultural engine. The National Spatial Strategy gives two policy objectives for concentration. First, it gives an operational target for concentration: the ratio between the number of houses and jobs within the designated concentration areas and outside these areas must remain at least the same. Second, it gives an
‘ambition’ to build 40% of the total expansion programme for housing and jobs within in the built-up area that existed in 2000. The Trend Scenario, which we use a baseline, assumes a continuation of historical trends and assumes the objective for urbanisation within designated concentration areas is achieved but the (ambitious) target for building within the existing built-up area is not. It is assumed that 13% of net national house building in 2002-2030 is in the existing built-up area, the majority of it being completed by 2010.

In the Compact Urban Development scenario, a high degree of concentration of urbanisation is assumed, combined with various investment programmes for road and public transport infrastructure and for road pricing. The basic assumptions are as follows:

1. Urbanisation within the existing built-up area: half of the demand for new dwellings in the Transatlantic Market scenario for the period 2011-2040 (about 500,000 dwellings) is realised in the built-up area that existed in 2000. In the Global Economy scenario, the same absolute number of dwellings is located in the built-up area. In relative terms this means that about 40% of total demand for dwellings is located within the existing built-up area; a figure consistent with the ambition formulated in the Dutch National Spatial Strategy. In total, about 6% to 8% of the total housing stock and population in 2040 is relocated compared to the Trend scenario.

2. Urbanisation within designated concentration areas: in provinces where concentration areas have been designated by the National Spatial Strategy, urban expansion locations (residual claim, after taking account of 1) fall entirely within the concentration areas. Urban expansion locations in the concentration areas are positioned 1200 metres from existing or planned railway stations. If there is insufficient space in those areas to allocate the spatial claim, building can take place elsewhere (but still within the concentration areas).

3. Infrastructure investments: existing investment plans for road and public transport and an additional road investment package of about 14.5 billion Euros as described in the Dutch Mobility Policy Document (Ministry of Transport Public Works and Water Management, 2006) are assumed to have been realized. The infrastructure package is also assumed in the Trend Scenario.

In addition, four alternative transport policy variants were examined:

– Variant 1: Planned road investments. Planned road investments for the period up to 2010-2015 are assumed to be realised. The additional road investment package as described in the Mobility Policy Document is not assumed to be realised.

– Variant 2: Road pricing. A national road pricing scheme, based on a car kilometre charge differentiated by time, place and vehicle characteristics and a congestion charge for all road traffic. The design of the scheme is in line with the basic principles outlined in the Mobility Policy Document. The scheme is designed to be cost neutral for car owners; car ownership taxes are abolished and car purchase tax is reduced by 25% when the scheme is introduced.

– Variant 3: Road pricing and better quality public transport: This variant includes an improvement in the quality of public transport along with road pricing. The package of measures concerns improvements to the existing road and rail networks and not the construction of entirely new connections. It involves (compared with the Trend Scenario) (a) a doubling in the frequency of existing train services within and between the designated concentration areas, the opening of some new...
railway stations, shorter waiting, changing and journey times for buses, trams and metro. The investment costs have not been estimated in detail but probably lie within a range of 3 to 8 billion Euros (MNP, 2007).

– **Variant 4: Road pricing and additional road investments from the Mobility Policy Document.** This variant includes the car kilometre charge (included in variant 2) and the additional road investment programme included in the *Trend Scenario*.

The detailed land-use projections from the Land Use Scanner for the period 2010-2040 were used as input for the TIGRIS XL model to calculate the impacts on population distribution, employment distribution, transport and accessibility of the various land-use and transport strategies. This paper focuses on the accessibility effects and more specifically on the logsum accessibility effects. The changes in accessibility result from changes in the transport system, land-use and/or the interactions between transport and land-use. Within the TIGRIS XL model, transport and land-use influence each other dynamically; for example, a land-use policy influences the distribution of residents which has an impact on transport flows and congestion and subsequently these changes in travel time influence the settlement pattern of residents and firms.

### 4.2 Results

Table 1 presents the logsum accessibility benefits of the Compact Urban development scenario for both socio-economic scenarios for 2040.

Table 1: Logsum accessibility benefits for the Compact Urban Development land-use policy scenario compared to the Transatlantic Market and Global Economy trend scenarios.

<table>
<thead>
<tr>
<th>By transport mode</th>
<th>Origin effect</th>
<th>Transport cost and destination effect</th>
<th>Total effect</th>
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<tbody>
<tr>
<td></td>
<td>Transatlantic Market 2040</td>
<td>Global Economy 2040</td>
<td>Transatlantic Market 2040</td>
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<tr>
<td></td>
<td>1176</td>
<td>2073</td>
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Table 1 shows significant accessibility benefits for the *Compact Urban Development* scenario amounting to 1.7 to 3.3 billion Euro per year in 2040. The accessibility benefits are much higher than for the road and public transport infrastructure investment programmes examined in this study, which result in accessibility benefits of about 0.2 to 0.3 billion Euro per year (see Table 2). This difference is related to the scale of investments. As an illustration, the total investment cost of the public transport and road infrastructure programmes examined here are estimated at 18-23 billion Euro (0.1-0.5 billion per year over a 30 year period), respectively, whereas the
additional transition costs of urbanisation for the Compact Urban Development scenario are estimated at 0.8 to 1.3 billion Euro during a 30-year period (MNP, 2007).

In the Transatlantic Market scenario, a high share of new housing is directed towards locations in the existing built-up area near railway stations. This improves accessibility (origin effect) for train users and, quite strongly, for slow modes but reduces accessibility by car. In the Global Economy scenario, dwellings and firms are more concentrated in Greenfield locations at close proximity to existing towns which improves accessibility for all modes. Car users also profit from a compact urban development strategy; it reduces congestion on the main motorway network and reduces average trip distances and thus travel costs (transport cost and destination effect).

Table 1 also shows that the overall benefits are significantly higher for the Global Economy scenario than for the Transatlantic Market scenario. This is mainly due to the higher land use demand and thus stronger land use variation as the result of the compact urbanisation strategy for the period 2000-2040. As an illustration, the yearly transition cost of urbanisation for the Global Economy scenario are estimated at about 10 billion and 19 billion Euro for the Transatlantic Market and Global Economy trend scenario, respectively (MNP, 2007). Also, average household incomes are higher in the Global Economy scenario which results in higher values of time and accessibility benefits.

Table 2 shows the logsum accessibility changes of the transport policy variants compared to the Compact Urban Developments base scenario. The table shows that Planned Road Investments variant, which includes a road construction package of 14.5 billion Euros, leads to 250 to 300 million Euros accessibility benefits a year in 2040, depending on the socio-economic scenario. The logsum accessibility changes for public transport users and slow modes are the result of land-use changes (relocation of people and jobs). All road pricing variants have negative accessibility impacts. However, the road pricing scheme yields substantially higher accessibility benefits than road and public transport investments when taking account that road taxes and 25% of the car purchase tax are to be abolished when the kilometre charge is introduced. Revenues of the ownership and purchase taxes, forecasted at 3.9 billion Euro for the Transatlantic Market scenario for 2020 and 2040 and 4.2 and 4.6 for the Global Economy scenario for 2020 and 2040, respectively, are recycled to car owners.

The accessibility benefits of the Road pricing and road investment variant and Road pricing and public transport investment variants are higher than for the Road pricing variant due to additional accessibility benefits resulting from road or public transport investments. In addition to the planned road investments and introduction of a national road pricing scheme, the accessibility benefits of the public transport investment are similar in size to those of the road investment package. Different population segments benefit from the investments. Mainly (existing) public transport users profit from the public transport investments, and car drivers profit from road investments; mode shifts are marginal.
Table 2: Logsum accessibility changes (million Euro) by transport mode (car, train, bus/tram/metro, slow modes) for the transport policy variants, compared to the Compact Urban Development base Scenario

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<th>Total</th>
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<td>Car</td>
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<td>milion Euro/year</td>
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**Transatlantic Market scenario 2020**
Var 1: planned road investments: 258, 274, -1, 7, -21
Var 2: road pricing: -2,407 (1,493), -2,447 (1,453), 6, -16, 49
Var 3: road pricing and PT: -2,165 (1,735), -2,458 (1,442), 86, 111, 95
Var 4: road pricing and road inv.: -2,211 (1,689), -2,331 (1,569), 5, 4, 112

**Transatlantic Market scenario 2040**
Var 1: planned road investments: 254, 190, -6, 9, 61
Var 2: road pricing: -2,794 (1,106), -2,938 (962), 12, -5, 135
Var 3: road pricing and PT: -2,596 (1,304), -2,901 (999), 154, 66, 86
Var 4: road pricing and road inv.: -2,521 (1,379), -2,689 (1,211), 22, 11, 136

**Global Economy scenario 2020**
Var 1: planned road investments: 263, 278, 1, -1, -15
Var 2: road pricing: -2,639 (1,561), -2,673 (1,527), -56, -38, 128
Var 3: road pricing and PT: -2,382 (1,818), -2,726 (1,474), 222, 191, -69
Var 4: road pricing and road inv.: -2,390 (1,810), -2,537 (1,663), -17, -7, 172

**Global Economy scenario 2040**
Var 1: planned road investments: 316, 627, 4, 15, -330
Var 2: road pricing: -3,113 (1,487), -3,332 (1,268), 23, 9, 188
Var 3: road pricing and PT: -2,816 (1,784), -3,396 (1,204), 274, 153, 152
Var 4: road pricing and road inv.: -2,754 (1,846), -3,023 (1,577), 38, 41, 190

*Figures between brackets are accessibility benefits for car users taking into account that road taxes and 25% of the car purchase tax are abolished when the kilometre charge is introduced. Total revenues are forecasted at 3.9 billion Euro for the Transatlantic Market scenario for 2020 and 2040 and 4.2 and 4.6 for the Global Economy scenario for 2020 and 2040, respectively.*

5. CONCLUSIONS AND DISCUSSION

In this paper a comprehensive appraisal framework was developed and applied to assess the accessibility impacts and benefits, expressed in monetary terms, of integrated land-use/transport policies. It comprised:

- The use of land-use/transport interaction model to incorporate second order changes, i.e. land use reacting to changes in transport times and costs, transport reacting in turn, etc.;
- The use of the logsum measure instead of the conventional rule-of-half method to capture changes in destination utility, as well as changes in generalised travel costs.

Logsum values were taken from the disaggregate logit choice models of the Dutch National Transport Model within the TIGRIS XL land-use/transport interaction modelling framework. In addition a methodology was developed to split up logsum
accessibility benefits by transport mode. The methodology was applied and tested in a large scale scenario study for the Netherlands.

The case study for the Netherlands clearly shows that land use policy strategies may significantly impact the accessibility benefits. The size of the changes in accessibility benefits of land-use policies compared to benefits from infrastructure investments shows it is it important to include these effects in standard evaluation practices. In standard accessibility evaluation with the rule-of-half method these accessibility benefits are not measured and would need to be measured in the land-use system. In practice, it is quite difficult to identify and measure these benefits within the land-use system. In theory, land-use benefits can be measured as changes in land or housing values using hedonic pricing methods or changes in location benefits using willingness-to-pay functions of appropriate location models. The problem, however, is that the assumption of perfectly competitive economic markets, where consumers and firms compete for land and land lots or houses are sold to the highest bidder, is typically violated in practice, due to market imperfections and heavy market interventions, particularly in the heavily regulated Dutch housing market. Martínez and Araya (1998) for example found empirical evidence that only a fraction of transport benefits are transferred into the land-use system and percolate down into land rents. This paper shows that the logsum accessibility measure provides an elegant and convenient solution to measure these benefits when a travel demand model (using discrete choice models) is available that already produces logsums. This approach may form an important step to go improve the current (Dutch) standard practice of accessibility appraisal. The logsum measure is able to incorporate land use effects of transport investments and allows an appraisal of integrated land-use/transport policy strategies. Additional applications will however be necessary to show the added value of the logsum accessibility method in transport project appraisal.

The logsum measure of accessibility presented is a comprehensive measure of accessibility, but a partial measure of location benefits. Accessibility is an important but one of the many variables determining location quality and value; e.g. dwelling attributes, availability of green areas, environmental quality are important too. A strategy of compact urban development may thus provide accessibility benefits, but generate overall losses in property values and location value as it does not match residential and firm location preferences (which are better satisfied in the land use trend scenario). Within a land-use/transport framework such as the TIGRIS XL model used in this study, the overall land use welfare changes, could be derived in principle from the residential and firm location models where the logsum accessibility measure is used as input variable. Few studies have been conducted in this direction (e.g., see Srour and Kockelman, 2001) but it is certainly an area that deserves more research.

Some authors have recommend the use of the rule-of-half method as a complementary analysis tool along with the logsum method for some cases, as it would ensure consistency and add to the scheme impact analysis (e.g., Kohli and Daly, 2006). In the Netherlands it is not uncommon to use quite simple and aggregate rule-of-half measurements in transport infrastructure appraisal. This is obviously has the advantage of the ease of calculation and interpretation, but does not result in accurate user benefit computations. Although it is practically infeasible to estimate rule-of-half measures at the same level of segmentation and thus accuracy as the logsum measure, it seems worthwhile to examine the level of segmentation and type of transport
projects at which the rule-of-half measures are sufficiently accurate and can still be applied in practical transport appraisal.

REFERENCES
Koopmans, Carl, Kroes, Eric, 2003, Estimation of congestion costs in the Netherlands. Universiteit van Amsterdam
RAND Europe, Amsterdam/Leiden.


