SUSTAINABILITY IMPACT ASSESSMENT OF PUBLIC ACTIONS AND INNOVATIONS FOR TRANSPORT ISSUES

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ABSTRACT

Since the early 1990s, the concept of sustainable development has been broadly used in many areas. In the field of mobility, sustainability goes together with new environmentally friendly services and products, behavioral changes and incentive plans coming from the public policies. Because of these multiple aspects, “sustainable mobility” is known as a fairly wide issue, and impact assessments in this field are complex.
The paper proposes an integrated impact and sensitivity analysis which merges sustainability aspects of transport (economic, environmental and social aspects) under several scales of consideration. A model has been developed that can be used to assess the sustainability of innovations or/and public actions. The setting-up is initiated with the adaptation of an existing model, the TILT model (Transport Issue in the Long Term) and with the completion of a set of sustainability indicators.
Throughout the methodological development of the model, a case study has been considered to test the potential of the impact assessment: Public transport users developed ideas in the field “sustainable mobility” using their daily experience with transportation in the city regions of Munich and Frankfurt in Germany. Beyond the evaluation of ideas that are coming from the case study, the sustainability evaluation system could be used in the future as decision-making assistance by policy makers to encourage sustainable urban mobility, by firms to assess the impacts of their products on CO_2 emissions and the acceptability of the user, or by the users themselves to evaluate the impacts of products and services they want to use on the environment and on their own concerns.

Keywords: Innovations, public action, model, sustainability indicators, sustainable mobility

INTRODUCTION

Following in the footsteps of sustainable development, the concept of sustainable transportation is gaining in importance on the one hand in the city planning decision process, on the other hand directly in the user behavior. For example, cell phone ticketing in subway and buses aims at influencing the population behavior thanks to a more attractive and flexible public transportation. Such a measure theoretically implies a reduction of emissions of greenhouse gases since the use of private vehicles should decline. In practice, it is, however, difficult to assess the entire and precise sustainability impacts (social, environmental and economic impacts) of a measure that modifies urban mobility. We see indeed a chain reaction with multiple influencing factors: First of all, the measure has direct impacts through its construction. Then, if it is accepted by the user, the measure implies behavioral changes, which themselves imply on the one hand, direct impacts according to the use, on the other hand, implicit effects linked to a new modal-share distribution. Finally, the demand concerning the infrastructure is increasing, which implies new impacts concerning the construction and use, as well as a new modal-share distribution.

To assess the complete sustainability impacts of a measure (innovation or public action), the challenge is therefore to find the equilibrium in the system by merging the calculation of direct impacts and implicit impacts linked to the modal share distribution. The presented paper takes up the challenge and proposes a flexible assessment model with back-and-forth adjustment, which is focused on innovations and public actions for transportation issues in Western European cities for the next 15 years.

In order to provide practical use for the developed model, a case study has been considered throughout the conception phase. Thanks to surveys realized in the city regions of Munich and Frankfurt in Germany, public transport users have been asked to develop ideas in the field “sustainable mobility” using their daily experience with transportation. Therefore, the model must perform a screening of the diverse application levels of the ideas; in other words, it must permit a concise assessment, because the screening should be usable for companies or users in the future, but nevertheless represent an exhaustive evaluation for assuring the reliability of the results.

STRUCTURE OF THE ASSESSMENT MODEL

The model, which evaluates the impacts of innovation or public actions in mobility, rests on several modules (Figure 1) that need to be at equilibrium in order to obtain the expected sustainability assessment.

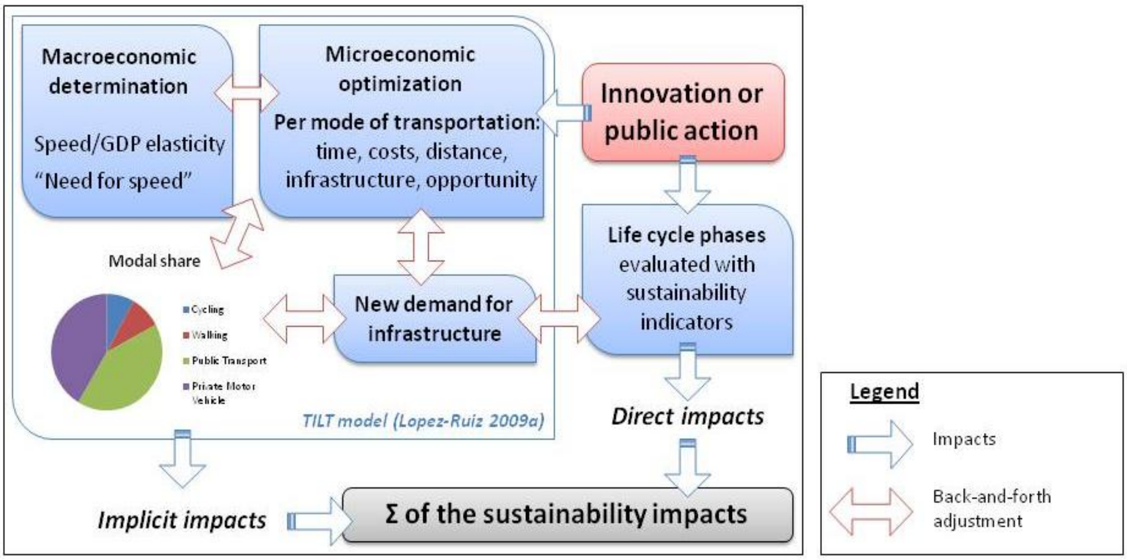

Figure 1: Structure of the suggested assessment model

For the calculation of direct impacts, a set of sustainability indicators is established and enables a fast, tangible and accurate screening of the measures (section 2.1). For the calculation of implicit impacts, the assessment of modal share distribution is based on an existing model: The TILT model (Transport Issue in the Long Term) (Lopez-Ruiz 2009a). The basis of the TILT approach lies in a twofold structure composed of a macro- and a microeconomic part, which are both recovered on the presented model (section 2.2).

Assessment of the direct impacts with sustainability indicators

The word "indicators" comes from Latin "indicare", which can be translated as "to describe", "to evaluate". Therefore, indicators can be understood as parameters for the description and the evaluation of complex issues (OECD 2003). The sustainability of mobility is largely considered under Agenda 21-processes (EEA 2000). In this case, mainly social and ecological indicators are taken into account, for example energy consumption, emissions, security and quality of public spaces. In order to establish the set of indicators, criteria for the choice of indicators are taken into account: i) the relevance to sustainability (Reul 2003), ii) the comprehensibility (Reul 2003) since our study has to be understood by the public, iii) the data availability and data quality (LfU 2006) since we need available data having sufficient quality to ensure the reproducibility and reliability of the results.
Key factors for successful diffusion of an innovation in field mobility have been identified by the help of scenario-oriented expert interviews and surveys (Beck et al. 2009). These key

factors are used in our model as social indicators, to reflect the acceptance of an innovation or a public action by the public (Table 1).

Table 1: Key factors and their intrinsic characteristics for the field mobility (Beck et al. 2009, modified)

Convenience	**Information**	**Social Appreciation**	**Safety**
Independence Privacy Transportation of luggage, etc. Time spent, waiting time Frequency of transition Convenience of transport Parking Force deployment Navigation Fun Journey can be alternatively used	Planning (routes, timetables) Can be combined (networked mobility) Special offers Navigation Availability, timeliness and comprehensibility of Information	Mobility as status symbols Mobility as an attitude question Prestige Positive sanctions Lifestyle Group membership Claims in the social environment Sustainability awareness	Lack of familiarity Inadvertent social proximity Lack of location knowledge Cost transparency Safety of transport (security) Safety in transport

The work with sustainability indicators and the assessment of direct impacts can be compared with a life cycle assessment, which is, however, in our case simplified. In particular, the methodology as described in the standard ISO14040 (2006) is recovered. One of the important steps in a life cycle assessment is the definition of assumptions in order to describe the system precisely. For our model, these assumptions are the following:

- The most relevant life cycle phases are considered depending on the innovation;
- The geographical boundary for the assessment is the urban area and catchment (the city of Munich and, respectively, Frankfurt in Germany according to our case study);
- Functional units have to be defined for each innovation and public action in order to enable comparison between two innovations or between the actual status and the forecast.

Once the set of indicators is established and the system is described, the direct impacts have to be calculated. For this aim, the data acquisition is conducted via literature and database analysis (for example, the ecoinvent database (ECOINVENT 2007)), as well as interviews with experts in sustainable mobility.

Modal-share calculation

The modal-share is calculated using the TILT model (Transport Issues in the Long Term), designed to be a long-term equilibrium transport model by combining a macroeconomic and microeconomic structure in a backcasting approach. Because sustainable development is a highly complex problem area (Dreborg 1996, Geurs et al. 2004) - which will probably call for major changes of industrialized societies and long-term strategic planning - the choice of method was very important and a backcasting model for scenario building seemed to be the most appropriate way of proceeding. Backcasting scenario building typically aims at providing policy makers (and an interested general public) with images of the future as a background for opinion-forming and decision-making (Clement 1995).

The TILT approach (Lopez-Ruiz 2009a) is based on a twofold structure composed of a macro- and a microeconomic part (see Figure 2). This structure serves as the core transport model that will provide input to additional modules, which determine the total energy use, CO_2 emissions, the public policy sensitivity and the economic impact for any specified scenario.

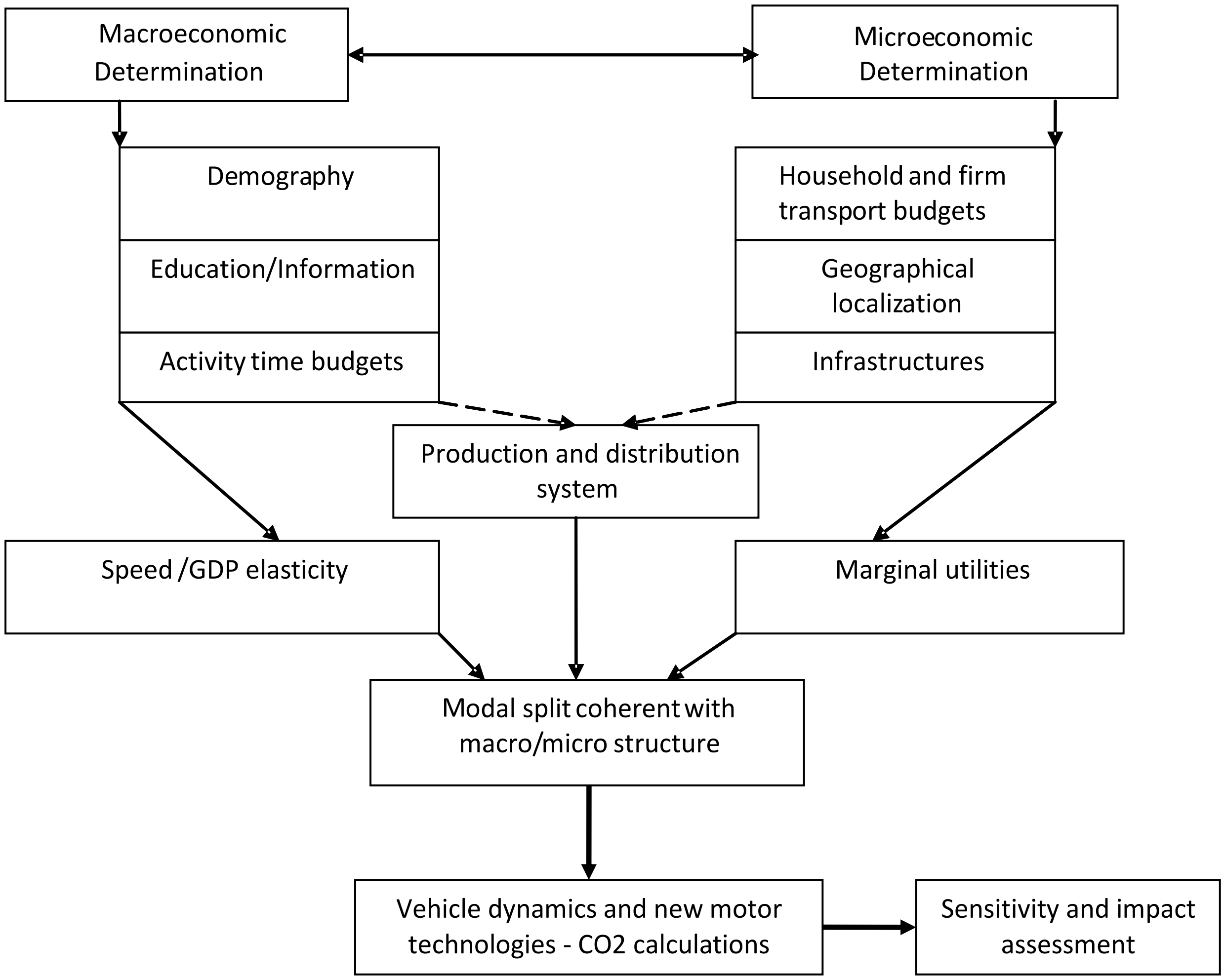

Figure 2: TILT Model Structure (Lopez-Ruiz 2009a)

The core transport model is composed by a macroeconomic determination and a microeconomic optimization that need to be at equilibrium in order to obtain a coherent modal split as a result. Thus, scenario building using a backcasting methodology with the TILT model requires first, the specification of the desired future and second, a "back-and-forth" movement where there is an interaction between the macro- and the microeconomic modules in order to identify the different possible equilibriums that allow the attainment of the specified future.

The macroeconomic determination of the TILT model

The macroeconomic component of the TILT model relies on a structure where population growth (determined by exogenous birth/death rates) and the evolution of population education levels (user determined) influence productivity in the different defined age classes. These changes in productivity, joined to demographic evolution, determine the GDP as well as consumption levels and time use (work, sleep, self accomplishment, leisure and transport). From the calculation of time used in transport activities, the macroeconomic determination is established through the use of average modal speeds that are based on a speed/GDP elasticity, which, in the case of France, has proven to be fairly stable over time (LET-ENERDATA 2008). This implies different modal split possibilities, given that the "need for speed" is sensitive to the affluence and freight value (Schafer et al. 2000). Consequently, transport modal saturation rhythms can be varied in the macroeconomic model through public policies affecting speed/GDP elasticities.

The microeconomic optimization of the TILT model

In order to have a more precise view of the effects of public policies on each scenario, a microeconomic component was developed within the TILT framework (Lopez-Ruiz 2009b). This component allows further analysis of demand determinants behind each scenario's modal split.

The microeconomic component of the TILT model is based on a representative agent's optimization of decisions based on the opportunities inherent to household/firm locations on an aggregated level, transport costs (ventilated into different categories referring to household/firm transport monetary budgets) and infrastructure availability (based on a lateness index) (Lomax et al. 1997).

The microeconomic component is largely inspired by developments done on ant algorithms (Lopez-Ruiz 2009a & Dorigo et al. 1999) and relies on the idea of a representative agent that optimizes his transport choices by taking into account opportunity and cost in respect to a certain level of service on infrastructure. Thus, the results stemming from the macroeconomic determination will influence the representative agent's choices. In turn, these choices must be coherent with the overall transport structure in order to be validated and represented in the decision table where the value assigned to each choice is calculated.

The TILT model considers opportunities as the sum of the consumption in goods and services in a certain period of time (Linder 1970) and that the lateness index is defined by the difference existing between normal transit time and the real transit time. This last indicator is useful in factoring in speed, distance and time into the calculation and has the convenience of being comparable between modes.

CASE STUDY

Supported by our industrial partners Rhein-Main-Verkehrsverbund (RMV), which is the public transport network around Frankfurt am Main, and Münchner Verkehrs- und Tarifverbund (MVV), which is the public transport network of Munich, workshops have been carried out with public transport users. With an ideas competition in the Internet, the fifteen most creative participants have been determined and invited to a one and a half day workshop. In these workshops, they have been asked to develop concepts to reach a sustainable urban mobility, with the possible inclusion of public transport and new technologies. A selection of concepts, which the participants developed, is used to test our model (Table 2).

Table 2: Concepts of sustainable mobility developed by users of public transport (selection)

Selection of developed concepts	Workshop
Tangential ring buses, faster than standard buses (shuttle between suburban train stations)	RMV, MVV
Mobile communication supply in tunnels (for subway and suburban train)	MVV
Displays in connecting stations for bus drivers with the time arrival of subway/suburban train	MVV
Video surveillance in the stations and in the train	RMV
Cell phone ticket with bar code or prepaid system with electronic ticket for people without cell phones (with protection of data privacy)	RMV, MVV
Report about the CO_2 emissions saved by using public transport instead of individual means of transport per SMS	MVV

The participants of the survey had no knowledge in particular about sustainability. For this reason, many of the resulting ideas are not obviously sustainable and may have side-effects which could decrease the sustainability. Moreover, as the field “sustainable mobility” is fairly wide, the participants were free to propose ideas for many application levels. For these reasons, the resulting ideas were a good basis for development of the presented model.
The model enables on the one hand the assessment of the modal-share implied by the innovation through the existing model TILT (section 3.1), on the other hand to enhance the assessment of TILT thanks to the calculation of the direct impacts with the help of sustainability indicators (section 3.2).

Modal-share and implicit impacts

As it has been shown in the presentation of the TILT model’s structure, modal share calculations are completely dependent on three variables: cost, speed and opportunities. In this manner, we are capable of assessing changes brought on by new situations in the modeled configuration. Furthermore, the TILT “insight modules” enable the model to take into account new motor technologies and to facilitate sensitivity and economic assessments on different geographical scales. The insight modules are the:

- Vehicle fleet dynamic and technology evolution module that analyzes technological impact based on market penetration probabilities and vehicles' survival rates for different motor technologies and different transport services (road, rail, sea, air, inland waterways).
- Public policy module that joins a sensitivity analysis (for policy categories) and multicriteria analysis (for specific public policies) in order to offer a detailed impact assessment of public action on CO_2 emissions.
- Economic assessment module (based on an input-output equilibrium analysis) that details impacts on employment and production by economic sector.

With these insight modules, the TILT model is capable of offering information to decision makers concerning public action and motor innovations. This leaves out other innovations that are not taken into account through the technology evolution module.

Focused on the objective of this project to offer a detailed assessment of changes concerning innovations (technological and/or organizational), a methodology has been developed in order to classify innovative concepts as per the influence they might have on the system's variables and how this influence will have an overall impact on the system and on other concepts.

In this manner, we are able to assess direct, indirect and induced effects of an innovation change alongside other public policies and how this will impact modal shares in a modeled situation, for example: if an innovation concerning a change in averages speed for cars where to be put in place, this will imply a modal shift towards public transport through changes in the main variables. This will, in turn, have an impact on other concepts (indirect effects) that will in turn bring about induced effects on the system.

The quantification of each impact through the change in one (or more) of the variables will lead to the quantification of the effect of each concept in the system. This assessment can be achieved by reasoning on a capacity basis. Some of the categorized concepts have a direct relationship to system use. In this sense, if a modal shift leads to an increase/decrease in the system's use, new trade-offs will appear in the system.

The TILT model is a powerful tool for delivering a clear assessment of public policy sensitivity and infrastructure needs. However, TILT is oriented for public policies and does not enable the impact assessment of innovations that are not linked to new motor technologies. Furthermore, it does not explore in detail the user acceptance through indicators such as convenience or safety, which are important within our study for the assessment of social aspects. This is why, in order to enable a comprehensive sustainability evaluation of the concepts, TILT has to be completed with some sustainability indicators, in particular social indicators, which will provide the direct impact assessment.

Direct impacts calculation with sustainability indicators

Parallel to the macro and micro structures of TILT and the assessment of modal share distribution, which leads to the assessment of implicit effects, the set of sustainability indicators was established to perform the direct impact assessment of the concepts (Table 3).

Table 3: Set of sustainability indicators

	Name of the indicator	**Description**	**Unit**
Environmental indicators	Greenhouse gases emissions	Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O)	kg CO_2 e/year
	Material consumption	Main materials that constitute the product (e.g. metal, glass, plastic, etc.)	kg/year
	Land use	Consumption of surface area	ha/year
	Pollutant emissions	Sulfur dioxide (SO_2), nitrogen oxide (NO_x) and particulates	kg/year
Economic indicators	Return on investment for the public authorities	Potential profit for the public authorities linked to the implementation of the concept	€/year
	Return on investment for the company	Potential profit for the company linked to the implementation of the concept	€/year
Social indicators	Costs	Travel costs for the user	€/year
	Time	Travel time for the user	h/day
	Convenience	Independence, Privacy, Transportation of luggage, Convenience of transport, Force deployment, Fun, Journey can be alternatively used	*Qualitative (low - high)*
	Information	Planning (routes, timetables), Special offers, Availability, Timeliness, Comprehensibility of Information	*Qualitative (low - high)*
	Social appreciation	Mobility as status symbols, Lifestyle, Group membership, Claims in the social environment, Sustainability awareness	*Qualitative (low - high)*
	Safety	Lack of familiarity, Inadvertent social proximity, Lack of location knowledge, Safety of transport (security), Safety in transport	*Qualitative (low - high)*

The measurement of the sustainability indicators is provided for the different life cycle phases of each developed concept. For the environmental and economic indicators, databanks like the ECOINVENT database (2007) are used as well as experts' interviews for the identification of unintended effects. The indicators "Costs" and "Time" are already taken into account in TILT and are emphasized in the final presentation of the results. The other social indicators "Convenience", "Information", "Social appreciation" and "Safety" are assessed in a qualitative way through workshops, surveys and interviews and evaluated on a scale between low and high.

Once the direct and the implicit impacts are calculated, the results are merged to provide a conclusion about the sustainability impacts for each innovation.

CONCLUSIONS AND OUTLOOK

In the light of the current environmental situation, it is necessary, more than ever, to take into account the important role played by transport activities in greenhouse gas emissions. The presented study offers in this context an integrated method for a sustainability evaluation of transportation issues. Based on a scientific approach, the method combines ecological and socio-economic aspects into a model to enable a comprehensive sustainability impact assessment for innovations and public actions in field mobility. On the one hand, the model recovers the methodology of the TILT model, which proposes a clear line, based on simple economic relationships and straightforward macro/micro equilibrium. On the other hand, a set of sustainability indicators enhances the model and enables a more precise assessment of innovations, in particular, for urban areas. Thus, the interest of the model lies not only in its accuracy for the scientific community, but also in its capacity to allow a fast screening of innovations for companies and to be tangible and transparent for the users.

In consideration of a case study which integrates users to concept generation in field mobility, the present model makes available an impact assessment for the cities of Munich and Frankfurt. Nevertheless, the model is developed in such a way that it can easily be generalized and implemented in other territories or countries. This assures that the further development of the model will be flexible for application in cities of Western Europe. It will in addition lead to the development of a tool which will be able to assess in part automatically sustainability impacts of innovations and public actions. A scaled system, such as a "traffic light" system (German Council for Sustainable Development 2008) or a point-based system can be established to help comparison between the innovations and the public actions, and to enable better communication with businesses, politics, and the public.

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