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How can activity-based approaches contribute to air quality research?

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1. INTRODUCTION

An efficient transport system is a vital requirement for economic development and provides personal mobility for activities such as work, education and leisure that are key ingredients of modern life. But transport also contributes significantly to several environmental and health problems, like climate change, acidification and local air pollution. The last decades, transportation control measures (TCMs) have been defined to manage both emissions and exposure associated with vehicular transport. Unfortunately, the total vehicle miles travelled and the number of trips made increased drastically, substantially offsetting the emission reduction through advances in technology. Due to this fact one should consider the use of alternative emission reduction policies, focusing at the driving forces of the problem, to limit the consequences of vehicular transport. However, because of the limited data available to predict the travel effects of combined (or even individual) TCM strategies and the inadequacy to forecast changes in travel behavior, the value of these TCMs is currently unknown.

Questions that involve the linkages between a set of travel decisions and activities can not be examined through a traditional four-step transportation model. The lacking of the interactions among individual and household travel decisions in response to TCMs lay at the heart of the failings of these conventional trip-based models to provide adequate measures of their potential impact (Recker and Parimi, 1999). This kind of model focuses on individual trips where the spatial and temporal interrelationships between all trips are ignored. The inability of the four-step trip-based models to evaluate responses to TCMs has prompted the development of an new approach to travel analysis: the activity-based approach.

The major idea behind activity-based models is that travel demand is derived from the activities that individuals and households need or wish to perform, with travel decisions forming part of the broader activity of scheduling decisions (Ettema and Timmermans, 1997). Travel is merely seen as just one of the attributes. Moreover, decisions with respect to travel are driven by a collection of activities that form an agenda for participation. Travel should therefore be modelled within the context of the entire agenda, or in other words, as a component of an activity scheduling decision. Activity-based approaches aim at predicting *which* activities are conducted, *where*, *when*, for *how long*, *with whom* and the *transport mode* involved.

2. ADVANTAGES FOR AIR QUALITY RESEARCH

This section describes in what way activity-based models can be used in air quality research and how the assessment of important variables for air-quality analysis can be improved by this approach. Furthermore this section presents the advantages of using an activity-based approach for policymakers aiming at a reduction of traffic air pollution.

2.1 Development of an integrated assessment framework

The activity-based modelling approach perfectly fits within the integrated assessment framework known as the DPSIR framework, with DPSIR standing for Driving forces, Pressure, State, Impact and Response. The DPSIR framework was built on a model from the Organisation for Economic Co-operation and Development (OECD, 1993), and a few years later adopted by the European Environmental Agency for environmental reporting purposes (EEA, 1999). This model structures the description of the environmental problems by formalising the relationships between various sectors of human activity and the environment as causal chains (figure 1). The DPSIR approach takes into account the connections between the causes of environmental problems, their impacts, and the societal responses to which they give rise.

In order to structure the problem of human exposure to traffic air pollution an adapted DPSIR framework was developed. Figure 1 illustrates the DPSIR framework for human exposure to traffic air pollution. Figure 1 can be explained as follows: the *driving forces* related to the problem of traffic air pollution are the underlying activities that people want or have to perform. People go to work or to school, they go shopping, have an active social life… In order to perform all these activities, travel is a necessary consequence. The activity-based models provide predictions of the travel demand through an analysis of activities. The environmental *pressures* resulting from these driving forces consist of the emissions caused by the different transport modes. Vehicle exhaust emissions contain carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x) and particulate matter (PM), and are determined by the use of emission models. Next, dispersion models calculate the ambient concentration of traffic air pollutants, leading to a degraded *state* of the environment. Finally, the exposure of people to these concentrations has an *impact* on human health (via concentration-response functions). Through valuation rules this approach will allow for monetization of environmental damage costs (*external costs*) from traffic air pollution for human exposure (Int Panis *et al*, 2004). These consequences make the society carry out a *response* through various actions or measures on different levels of the DPSIR framework.

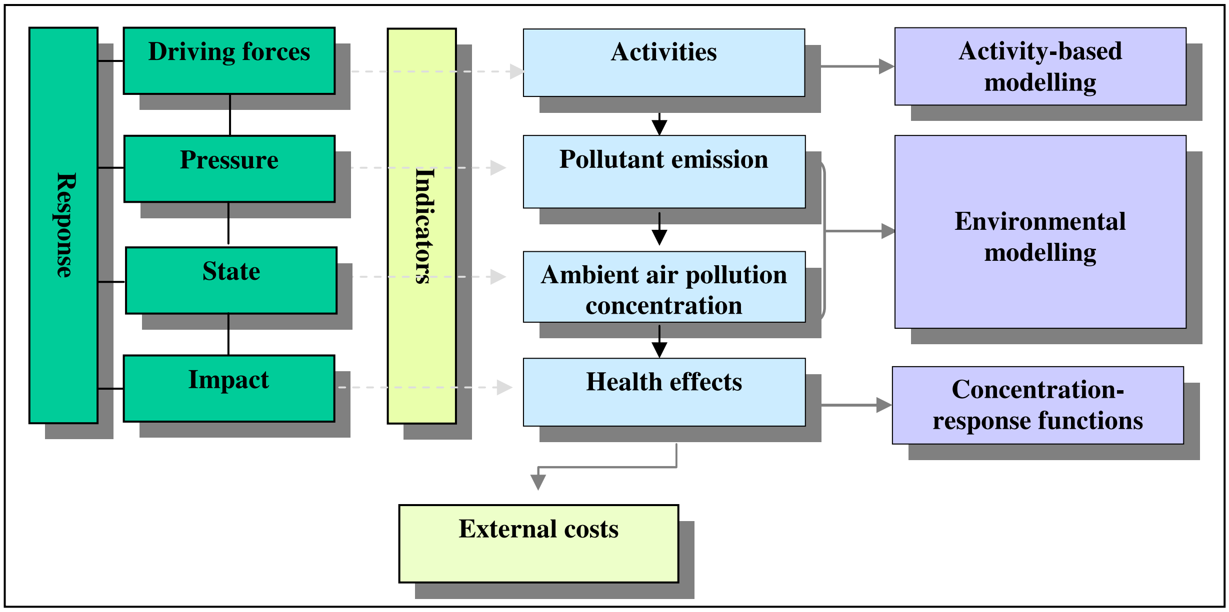

FIGURE 1. DPSIR framework for the human exposure to traffic air pollution

The use of the activity-based approach in this framework allows for the application of source-related measures, intervening on people's travel behaviour, instead of end-of-pipe measures focusing on the end of the problem chain.

2.2 Improvement of transportation and emission assessments

There are many transportation variables that affect emissions of traffic air pollutants. Cambridge Systematics (1997) provides a table prioritizing the transportation data desired for emission modelling. The following variables have been identified as the most important for this type of analysis:

- vehicle miles of travel (VMT);
- travel by mode and occupancy rates for auto modes;
- percentage of cold/hot starts;
- speed/acceleration/driving profile;
- travel by time of day and time/location of starts;
- travel by vehicle class and model;
- travel by facility type.

Due to the richer set of concepts which are involved in activity-based transportation models the estimate of important transportation variables listed above can be improved by using an activity-based approach (Shiftan, 2000). Vehicle energy use and emissions depend not only on distance and the driving speed, but also on the number of trips, the time between them, and whether the vehicle was warmed up or not when started (Recker and Parimi, 1999). The activity-based prediction of trips as parts of a tour can identify whether a trip is a cold or a hot start.

Furthermore, an activity-based model predicts which activities are conducted, where, when, for how long, with whom and the transport mode involved, giving accurate information about transportation variables like VMT, travel by mode and occupancy rate, and travel by time of day. Since the accuracy of emissions and air quality estimates can be no better than the underlying transportation information (Int Panis *et al*, 2004), the activity-based approach will contribute to an improved emission assessment.

2.3 Advantages for policy makers

One of the main advantages of the activity-based modeling system is its ability to consider the secondary effects of TCMs (Shiftan, 2002). Secondary effects are adjustments to the activity pattern that have to be made in response to the primary effect. For example, a public transport subsidy may make a commuter change his travel mode from drive alone to public transport; this is the primary effect of the TCM. However, because the person no longer drives to work, there can be no stop on the way back to do the shopping. Therefore, upon returning home, the person takes the car and drives to a nearby store. This is the secondary effect. In such cases, the environmental advantages of this TCM may be limited, and the reduction of the work auto trip is partially offset by a new shopping auto trip. Only an activity-based approach can deal with these secondary effects.

In addition to the ability of activity-based models to evaluate traditional TCM such as subsidies for public transport or for transit, the activity-based approach also allows for impact analyses of alternative policy measures like changing shop opening hours, introducing flexible work hours and promoting telecommuting. Activity-based models are able to evaluate the impact of these measures on travelers' responses, and due to this, the impact on travel behaviour and air quality can be better assessed.

2.4 Dynamic exposure assessment

Conventional exposure studies take into account both temporal and geographical fluctuations of emission sources, but assume the receptor conditions as static. According to this approach people are always at home and, therefore, only exposed to pollutants at their home address. By using an activity-based approach, on the other hand, accurate information is not only provided on the fluctuations of the traffic emissions but also on the temporal and geographical variations of the pollution receptors. In addition to the advantages on emissions and air-quality estimates, the use of activity-based models therefore offers opportunities to improve the assessment of human exposure to traffic air pollution (Beckx et al., 2005). When temporal information is available on both the sources and the receptors of the air pollution, a dynamic exposure procedure can be established.

3. CONCLUSIONS

This paper reports on the use of activity-based models for air quality research. Due to the richer set of concepts which are involved in activity-based transportation models the activity-based approach provides important advantages for air quality analyses. The use of activity-based models in combination with environmental models offers an improved evaluation of policy measures to reduce human exposure to traffic air pollution. Further, the activity-based approach allows for an enhancement of transportation and emission assessments, and offers the possibility to apply alternative policy measures to the problem of traffic air pollution. Therefore we can conclude that the use of an activity-based model will put a new perspective on the research of air quality and exposure assessments.

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