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TRACKING DOWN THE EFFECTS OF TRAVEL DEMAND POLICIES

INTRODUCTION

This chapter addresses two issues related to tracking people through mobile technologies and spatial planning decisions. The first major part deals with the question of how knowledge developed through the use of new tracking technologies can impact the *spatial planning process*. We argue that global positioning system (GPS) data are valuable – if not vital – for the improvement of travel demand forecasts by means of an activity-based transportation model when assessing travel demand management (TDM) policies such as spatial planning strategies. Based on a brief historical outline with regard to planning policies and an overview of various travel demand models, the need for advanced data and their use in modelling practice is shown. In the next section, the other topic of this chapter discusses what kind of *spatial interventions* can be expected due to the use of new tracking technologies. Here, four application areas related to travel demand modelling are identified and subsequently explained: the use of route knowledge and the concepts of accessibility, activity spaces and mental maps.

THE USE OF GPS DATA IN THE PLANNING PROCESS

Brief historical outline: rise of the sustainable development paradigm and its implications for transportation policy making

To fully understand the use and usefulness of GPS data in research related to the transportation and *spatial planning process* in general and travel demand modelling efforts specifically, a rough outline of the historical context is required. Since the 1950s most industrialised Western countries have faced a baby boom, a massive growth in individual motorization and the rise and expansion of urban sprawl. Originally, planning policies focussed on mastering the increasing travel demand by adjusting – i.e. expanding – the supply of transportation infrastructure. These policies were adopted in an immediate response to the predicted growth in car ownership and use. But growth continued steadily and additional infrastructural capacity even induced new traffic flows (Kitamura & Fujii, 1998).

In the course of time, the negative effects of the vast amounts of motorized traffic – congestion, traffic accidents, emissions, the monopolization of urban space and excessive land consumption – became a growing concern. There was a rising general environmental awareness, stimulated by the Club of Rome and its most famous report of 1972: *Limits to Growth* (Meadows et al, 1972), and growing concern as to how to manage the environment in the pursuit of economic wealth, which was expressed in the Brundtland report: *Our Common Future* published in 1987 (World Commission on Environment and Development, 1987). This document pushed sustainable development into the mainstream political agenda.

In this context of increasing environmental awareness and the generally accepted policy paradigm of sustainable development, transportation policies shifted from facilitation to reduction and control (Dijst, 1997). Moreover, an integrated approach with other policy areas such as spatial planning and environmental policies is still being further developed. Although there is still some way to go, promising examples of integrated policy-making are arising. For instance in the region of Flanders (Belgium), mobility and transportation analysis, views and goals constitute a vital part of all recent 'spatial structure plans' at different policy levels, while in recent 'mobility plans' an integration of spatial context, traffic and transportation networks and flanking policies in three defined scopes is mandatory (Zuallaert, 1998).

A general term for policy strategies that result in more efficient use of transportation resources is travel demand management (TDM). Objectives of such measures are to: (1) alter travel behaviour without necessarily embarking on large-scale infrastructure expansion projects, (2) encourage better use of available transport resources, and 3) avoid the negative consequences of continued unrestrained growth in private mobility (Krygsman, 2004).

Besides supply-oriented measures for all travel modes, TDM measures typically touch various factors of influence in travel scheduling and execution. Examples are the spreading of peak-period travel through relaxing working, school and shopping hours, congestion charging, ridesharing schemes, and suchlike. Besides, TDM measures can adopt spatial planning schemes serving similar policy goals of reducing energy consumption and the need to travel, e.g. Transit Oriented Development (USA), Carfree Cities (worldwide), the Dutch ABC approach (Townshend, 2006) and Transport Development Areas (TDAs), a UK practice (Hines et al., 2002). Scenarios of spatial concentration, which can be implemented by moving facilities from smaller concentrations and merging them with larger clusters of facilities in the neighbourhood, as well as spatial separation scenarios occur in reality. Victoria Travel Policy Institute (2007) offers an overview of successful TDM, including land use management schemes.

Shift in scientific support to transportation policies: from 'four step' to 'activity-based' modelling of travel demand

Parallel to this shift in political programmes and planning content, methodological changes could be witnessed in the scientific support of planning policies in the second half of the 20th century. Since the early sixties, a rational process view of planning was widespread and faith in the application of science in policy-making was rapidly increasing (Taylor, 1998). Definitions of planning problems or goals, or even plans and policies themselves, could thus be equated with scientific hypotheses that needed to be subjected to severe empirical testing before being implemented.

Transportation policy issues were treated in this way. Originally, the estimation and forecasting of travel demand and behaviour were handled by a standard methodological approach, commonly referred to as the four-step modelling approach (Ruiter & Ben-Akiva, 1978). Obviously, these initial estimations mainly focused on policies with regard to infrastructure expansion. In these models, trip generation, trip distribution, mode choice and route assignment are handled likewise. Earliest trip-based models of travel demand overly simplify complex patterns of daily activities and travel. This is illustrated in **Illustration 11.1**. Trips are modelled independently, and the time component is lacking, as is the direction and further sequential information, thus resulting in an isolated modelling of travel. Moreover, most of these models are macroscopic, using aggregate data and generating aggregate outcomes.

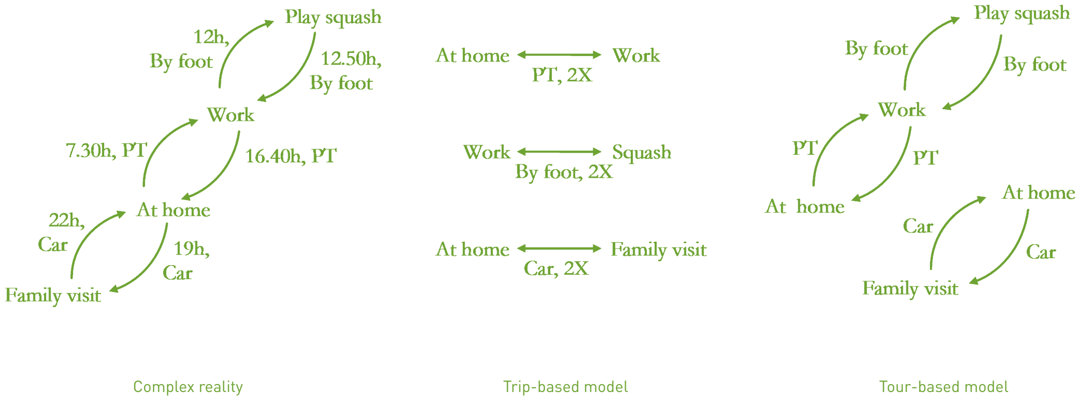


Illustration 11.1 Simplification of complex activity travel patterns in trip-based and tour-based models

Next generation tour-based models sought to overcome some of the shortcomings of the earliest trip-based models in that they model home or work-based travel tours, taking the sequential information partially into account. Still, spatial limitations are numerous, the time component is lacking and some tours remain independent of each other.

As policy approach is shifting from rather simple supply-oriented measures to more complex TDM measures, the need to effectively analyse, evaluate and implement a range of scenarios is giving rise to the awareness that an improved understanding of individual travel choices and behaviour is essential to accomplish reliable and policy responsive forecasts. Traditional four-step methodologies have proved to be inadequate in achieving this. The advanced travel demand models need to embody a realistic representation and understanding of the travel context and the decision-making process of individuals in order to mimic their sensitivity to a wider range of transport policy measures.

The major insight that enabled researchers to gain such a better understanding of travel behaviour is the idea that travel demand is generated by the activities that individuals and households need or wish to perform. Travel is merely seen as a means to pursue goals in life, rather than a goal in itself. Therefore, modelling efforts should primarily concentrate on modelling activities or on a collection of activities that form an entire agenda which triggers travel participation, also commonly referred to as the activity-based modelling approach. These approaches enable transportation forecasting through the evaluation of TDM measures and aim at predicting which *activities* are conducted *where*, *when*, for *how long*, *with whom*, as well as the *transport mode* involved. In addition to this shift from trip-based to activity-based models of travel demand, modelling techniques have evolved rapidly from aggregate approaches to the microsimulation of individual behaviour, favoured by the dramatic increase in computational capacity during the last decades.

An example of an operational activity-based microsimulation model for travel demand is Albatross (Arentze & Timmermans, 2000). This model is sensitive to changes in various groups of variables that can be affected by TDM measures, including population, schedule skeletons, opening hours, land-use, travel costs and travel times. The number of possible scenarios to calculate in terms of these groups of variables is almost infinitely large.

Growing need for accurate data: tracking people can make the difference

Obviously, in order to model and predict all these different facets of individual daily activity-travel by means of an activity-based transportation model, accurate data is needed to start with. A hand-held logging system based on a Geographic Information System (GIS) can be used to collect data for all these facets of travel behaviour and its context. Compared to other common methods of data gathering, there are numerous advantages.

The travel diary shaped as a paper-and-pencil questionnaire, asking people for their travel behaviour during a certain time period, has long been and in fact still is the dominant form of data collection in transportation research. Its technological simplicity and the fact that it can be completed anywhere are undeniably advantages. However, due to the required detail, this method is tedious, complex, prone to errors and answers may lack consistency.

Alternatively, desktop computer-assisted data collection tools may be used for filling out activity scheduling surveys in order to provide activity-travel diary data. Such methods can provide user guidance and enhance data quality, but these systems are not able to trace the actual activity-travel execution in real time due to their limited portability.

In order to solve this portability problem, a Personal Digital Assistant (PDA) equipped with GPS technology can be used to enhance the data collection tool's mobility (Kochan et al., 2005) (see **Illustration 11.2**) (cf. chapter 10). The portability of a PDA data collection tool enables in-situation data input while preserving the ability to perform consistency checks on the data provided by the respondent.

Illustration 11.2
Personal Digital Assistant (PDA) equipped with GPS technology

There are five clear potential advantages of equipping a PDA with GPS technology to supplement activity-travel data: (1) when using a desktop computer-assisted data collection tool, the respondents have to remember the exact locations of their start and end positions - a tricky job and a well-known source of error - whereas with a PDA equipped with GPS, trip origin, destination, and route data are automatically collected without burdening the respondent with the data; (2) as the respondent may forget to report an activity trip, there is another advantage in the recovery of unreported trips, as all routes are recorded automatically; (3) accurate trip start and end times are also automatically determined, as well as trip lengths; (4) the GPS data can be used to verify self-reported data; (5) both the data entry cost and the cost of pre and post-processing the data constitute a significant share of the total data collection cost (Zhou, 2004). Fortunately, both can be reduced to a minimum with computer-assisted forms of data collection (cf. chapter 10).

In addition, more can be expected from GPS data in the near future. Recent research outcome shows promising results in modelling attempts to predict activity types based on the combination of GPS tracks, GIS data and demographic information (Mc Gowen, 2006). In this way, GPS tracks could replace the daily travel diary and thus decrease both response burden and data gathering costs of surveys to a large extent.

All arguments mentioned above in favour of the use of GPS tracks are particularly applicable to the (spatial) planning process as all other things being equal, they should result in higher quality spatio-temporal data. Higher quality data is obviously a precondition for a more reliable travel demand modelling. The latter may even be more applicable for spatial scenarios as these are highly dependent on accurate spatial information, which can only be provided by means of a PDA with accurate GPS technology.

Use of GPS tracks: some examples and future expectations

Unfortunately, the evaluation of a PDA with GPS technology has only rarely taken place within the context of transportation research. However, in recent years, the topic has been receiving increased attention. Two well-known examples are the semiautomatic data collection device used in the Lexington Travel Survey (Batelle, 1997) and the computer-based intelligent travel survey system used by Resource Systems Group Inc. (1999), which used interactive geo-coding and other intelligent functions that can be provided by GIS to reduce the reporting burden on the survey respondents.

Currently, a comprehensive and extensive research program that has been funded by the IWT, an Institute for the Encouragement of Innovation through Science and Technology in Flanders

(Belgium), is contributing to this line of research (see Janssens & Wets, 2005). Among other things, the data to be collected by this program will be on 2401 households. Approximately one half of the sample will receive a PDA module, equipped with GPS. The other section of the sample will be questioned by means of a traditional paper-and-pencil method. This choice enables the researchers to carry out comparative studies with respect to the reporting behaviour of both target groups in terms of response rates, experience, etc. Households have been selected using a stratified cluster technique, which ensures a geographical and spatial distribution in the sample representative for the study area of Flanders.

The survey asks the members of the selected household to fill out an activity schedule, an activity-travel diary and to report rescheduling decisions (the reasons for rescheduling are reported as well) during a one-week period. In comparison with other activity-based studies, this survey period is particularly long, especially in combination with the high number of households that will participate in the survey. Finally, detailed cost estimates have already been made and a description of logistics and required computer assisted telephone interview (CATI) support are currently being investigated and will also be reported in the study. The data will be used as input for a state-of-the-art activity-based transportation model, which will enable the researchers to calculate the impact of a range of TDM measures and spatial planning scenarios.

With regard to the forecast of future developments, there are high hopes for a simplification of the collection of individual route tracks. A serious alternative for GPS location positioning is based on mobile phones (cf. chapter 8). Firstly, mobile phones are widely spread across the population. As a result, no additional hardware is needed on the user side (in contrast to a GPS receiver), enabling larger samples to be included in a survey at virtually no additional cost. Secondly, although the location positioning accuracy strongly depends on the density of the mobile phone network, new algorithms are being more widely adopted to reduce the measurement error on the location positioning.

SPATIAL INTERVENTIONS BASED ON GPS DATA

The second topic of this chapter discusses the kind of spatial interventions to be expected due to the use of new tracking technologies. Four application areas related to travel demand modelling are identified in this respect: the use of route knowledge and the concepts of accessibility, activity spaces and mental maps.

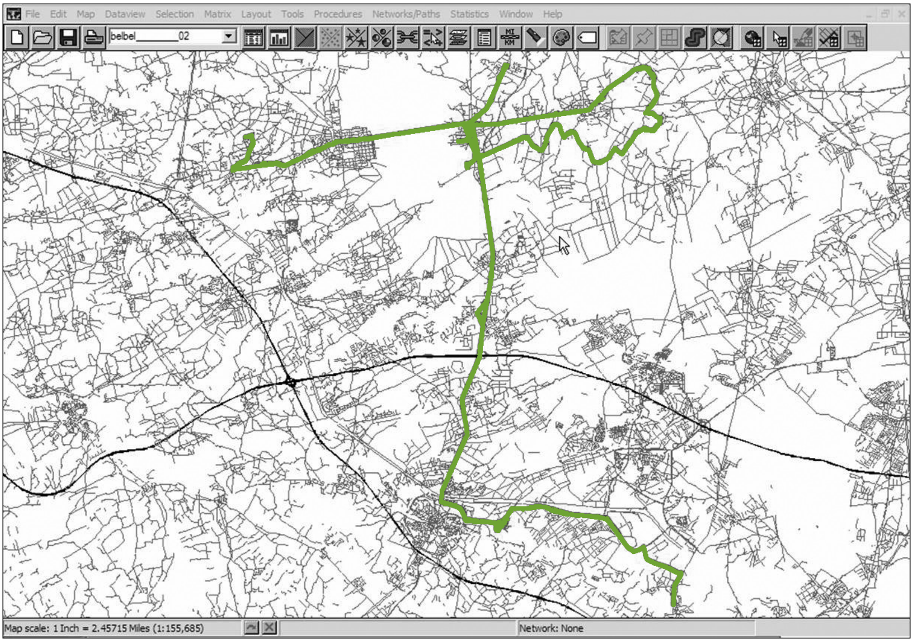
Route knowledge

The use of route knowledge is first explained. As briefly mentioned above, the use of a PDA with GPS technology will enable researchers to track the route followed to reach a particular destination (see Illustration 11.3). The use of this information has a number of important advantages.

Firstly, it will be possible to achieve a more realistic behavioural modelling of route choice in transportation models. While this latter component is mainly lacking in activity-based models to date, it is often over-simplified in current four-step transportation models. In these, route assignment is usually based on the use of straightforward shortest-path algorithms, whether it be distance or time sensitive. When GPS information is coupled with activity diary data, it will be possible to link the actual route choice and the activities conducted. This will enable the implementation of more robust traffic assignment approaches in transportation modelling.

In addition, a second opportunity offered by this detailed route knowledge consists of the fact that it will also be possible to specifically determine the spatial factors that influence route choice when GPS tracks are combined with other spatial databases in a GIS environment. Indeed, when this can be achieved, it will be possible to evaluate and model the effects of future spatial interventions in cities in order to influence route choice behaviour (e.g. at city traffic network level, what are the effects of a cut in certain links in the network).

Illustration 11.3
GPS route data visualized in TRANSCAD



A third advantage of GPS track recording is the fact that both static (infrastructure) and dynamic factors (night or day, seasons, events, traffic conditions) of the environment can be taken into account in view of the fact that (in certain environmental circumstances) the route choice is observed at a given point in time.

Accessibility

Second is the concept of accessibility. This is an important construct which can be better evaluated thanks to the use of a PDA tracking device. The accessibility measure represents the ease of access to certain destinations. Measured for different modes of transport, accessibility can be an important benchmark in assessing how 'smart' the growth of an area is in terms of the potential to use sustainable modes of transport.

In econometric models of travel demand, accessibility is expressed as a certain cost which can be a compound of travel distance, travel time, travel costs, etc. causing some form of disutility for the individual. In activity-based models, accessibility is also a measure of testing the feasibility of generated activity travel schedules.

Sometimes the accessibility measure is computed in a simple way, for example by multiplying the distance as the crow flies or from the core of the origin zone to the core of the destination zone with an average measure of car speed. More advanced methods like calculating logsums are also used taking detailed specifications of the accessibility into account, such as mode choice, time of day (peak and off-peak), travelled route over the network, level of service (LOS), travel purpose, route choice options, individual differences, etc.

An important improvement in the measurement and computation of accessibility can be established through the integration of GIS in the travel demand model (Kim & Kwan, 2003), and the exploitation of the knowledge of actual route choices. There is a strong tendency to disaggregate individual-based accessibility measurement, using space-time constraints to generate potential path areas (PPA) – the accessibility between two consecutive fixed activities (Chen & Li, 2006) – and to identify feasible opportunity sets (FOS).

Activity spaces

Related to the previous concept of accessibility is the next concept of activity spaces or the physical mapping or enumeration of places visited in the past. Although reasonably new, this concept constitutes an important application field related to travel demand modelling. The analysis of individual activity spaces (using longitudinal travel data) can be motivated by an interest in spatial behaviour from a planning point of view.

Indeed, the enumeration of daily-life activity locations and the analysis of the distribution of such places reveal both the supply structure of activity opportunities in space and the destination choice behaviour of travellers given their perceived supply. This invites transport planning and research even more to evaluate and present future urban structures from the perspective of sustainable transport policy. This evaluation includes for example measures to increase the amount of opportunities (i.e. potential destinations) to satisfy the activity demand in the household's neighbourhood which eventually reduces travel expenses, further congestion and emissions.

There is evidence that local accessibility oriented land-use planning matters (Banister, 2000). However, the complexity and non-linearities in the interaction between locational supply and the actual choice of destinations (Schönfelder & Axhausen, 2003) should not be neglected. Nevertheless, precise quantification of these activity spaces for various population groups requires a significant amount of data on activity behaviour (Morency & Kestens, 2006). It is exactly these data that can be generated by an activity travel survey designed for a PDA equipped with GPS technology.

Mental map

Finally, the development of the mental map concept can benefit from the knowledge provided by individual tracking technologies. At an individual level it is important to realise that the relationship between travel decisions and the spatial characteristics of the environment is established through the individual's perception and cognition of space. As an individual observes space, for instance through travel, the information is added to the individual's mental map (spatial learning). Among other things, the mental map subsequently shapes the individual's travel decisions, since it reflects what an individual knows and thinks about the environment and its transportation systems (spatial planning).

Although this concept is often referred to in theoretical frameworks of travel demand models, actual model applications are scarce, mainly due to problems in measuring the construct and putting it into the model's operation (Hannes et al, in press).

A clear example of the opportunity for the development of this concept offered by GPS tracks is the following; when stated travelled routes and stated distance estimates can be compared to actual travelled routes and actual distance information as recorded, there will be an idea of how the mental map is formed and how it affects individual future decision-making when operating in a spatial environment. This insight will enable both spatial planners and transportation modellers to take this information into account in their planning decisions and modelling attempts.

SUMMARY

In this chapter we have indicated a major benefit derived from the use of GPS data in the activity-based modelling of travel demand aimed at the evaluation of transportation and spatial planning policies, namely the refinement and improved predictive accuracy of the forecasts of the effects of TDM. As such, an increased efficiency of such policy measures can be achieved. Over and above this, we have specified four spatial application areas related to travel demand modelling that could benefit from the use of new tracking technologies. The exploitation of route knowledge, accessibility, activity spaces and mental maps largely depends on knowledge acquisition from individual activity travel tracks. The accumulation of such knowledge will lead to a better understanding of individual choices and their spatial determinants, a prerequisite for any policy that aims to alter individual behaviour in order to attain sustainability objectives.

REFERENCES

- Arentze, T.A., & Timmermans, H.J.P. (2000) *Albatross: A Learning-Based Transportation Oriented Simulation System,* European Institute of Retailing and Services Studies, Eindhoven.
- Banister, D. (2000) Sustainable urban development and transport – a Eurovision for 2020. *Transport Review*, 20(1), pp. 113-130.
- Chen, C. and Wei, L. (2006) The evolution of accessibility over time. In: IATBR (International Association for Travel Behaviour Research), *11th International Conference on Travel Behaviour Research.* Kyoto, Japan 16-20 August 2006.
- Dijst, M. (1997) Spatial policy and passenger transportation, *Netherlands Journal of Housing and the Built Environment*, 12, pp. 91-111.
- Hannes, E., Janssens, D. and Wets, G., (in press) Does Space Matter? Travel Mode Scripts in Daily Activity Travel, *Environment and Behavior* (accepted for publication September 2007).
- Hines, P., Marsay, A., Edge, J. and Gal, K., (2002) *Transport Development Areas: Guide to good practice*, RICS, London.
- Janssens, D. and Wets, G. (2005) The presentation of an activity-based approach for surveying and modelling travel behaviour, *Proceedings of the 32nd Colloquium Vervoersplanologisch Speurwerk 2005: Duurzame mobiliteit: 'Hot or not?'*, Edition 32, part 7, Antwerp, Belgium, pp. 1935-1954.
- Kim, H. and Kwan, M. (2003) Space-time accessibility measures: a geocomputational algorithm with a focus on the feasible opportunity set and possible activity duration, *Journal of Geographical Systems*, 5(1), pp. 71-91.
- Kitamura, R. & Fujii, S. (1998) Two computational process models of activity-travel behaviour. In: T. Gärling, T. Laitila and K. Westin, eds, *Theoretical Foundations of Travel Choice Modelling,* Pergamon, Oxford, pp. 251-279.
- Kochan, B., Janssens, D., Bellemans, T. and Wets, G. (2005) Collecting activity-travel diary data by means of a hand-held computer-assisted data collection tool. In: EWTG (Euro Working Group on Transportation), *10th EWGT Meeting/16th Mini EURO Conference*, Poznan, Poland, 13-16 September 2005.
- Krygsman, S. (2004) *Activity and Travel Choice in Multimodal Public Transport Systems*, PhD thesis, Utrecht University.

- Battelle (1997) *Lexington Travel Survey*, Batelle.
- Mc Gowen, P.T. (2006) *Predicting Activity Types from GPS and GIS Data*, University of California, Irvine.
- Meadows, D.H., Meadows, D.L., Randers, J. and Behrens III, W.W. (1972) *The limits to growth: a report for the Club of Rome's project on the predicament of mankind*, Universe, New York.
- Morency, C.P. and Kestens, Y. (2006) Measuring activity spaces of people, households and population segments. In: IATBR (International Association for Travel Behaviour Research), *11th International Conference on Travel Behaviour Research.* Kyoto, Japan 16-20 August 2006.
- Resource Systems Group, Inc. (1999) *Computer-based Intelligent Travel Survey System,* Research Systems Group, White River Junction (VT).
- Ruiter, E.R. and Ben-Akiva, M.E. (1978) Disaggregate travel demand models for the San Francisco bay area, *Transportation Research Record*, 673, pp. 121-128.
- Schönfelder, S. and Axhausen, K.W. (2003) *On the variability of human activity spaces*, Arbeitsbericht Verkehrs- und Raumplanung, 149, Institut für Verkehrsplanung und Transportsysteme (IVT), ETH Zürich, Zürich.
- Taylor, N. (1998) *Urban Planning Theory since 1945*, Sage Publications, London.
- Townshend, T. (2006) From Inner City to Inner Suburb? Addressing Housing Aspirations in Low Demand Areas in NewcastleGateshead, UK, *Housing Studies*, 21(4), pp. 501-521.
- Victoria Policy Institute (2007) *TDM Encyclopedia.* http://www.vtpi.org/tdm/index.php, accessed November 22, 2007.
- World Commission on Environment and Development (1987) *Our Common Future (Brundtland report)*, Oxford University Press, Oxford.
- Zhou, J. (2004) Real-time Tracking of Activity Scheduling/Schedule Execution Within Unified Data Collection Framework. In: TRB (Transportation Research Board), *83th Annual Meeting of the Transportation Research Board*, USA, Washington, 11-15 January 2004.
- Zuallaert, J. (1998) Het Mobiliteitsplan - Fase 2: Opbouw van het Plan. In: *Het Mobiliteitshandboek - Afl. 5*, Ministerie van de Vlaamse Gemeenschap, pp. 73-88.