An estimation of total vehicle travel reduction in the case of telecommuting. Detailed analyses using an activity-based modeling approach.

B. Kochan[1]
T. Bellemans[2]
M. Cools[3]
D. Janssens[4]
G. Wets[5]

Abstract: *Transportation Demand Management (TDM) is often referred to as a strategy adopted by transport planners with the goal to increase transport system efficiency. One of the possible measures that can be adopted in TDM is the implementation of telecommuting. A significant number of studies have been conducted in the past to evaluate the effect of telecommuting on peak-period trips. However it is less studied whether telecommuting also effectively and significantly reduces total vehicle travel. For this reason, a conventional modeling approach was adopted in this paper to calculate total kilometers of travel saved in the case telecommuting would materialize in the Flanders area. In a second part, the paper also introduces the use of an activity-based modeling approach to evaluate the effect of telecommuting. By doing so, an operational activity-based framework is externally validated by means of another completely different model, both calibrated for the same application and study area.*

Keywords*:* Telecommuting, Activity-Based modeling, Feathers, Albatross

1. Introduction

According to a study by the United Nations (Anon., 2004), population growth will show a significant rise in the years to come. Population growth together with employment and motor vehicle growth in cities and even rural environments can have a large effect on the region's transportation system. Travel demand management (TDM) is therefore seen as an important means to counteract travel. Moreover, it increases the performance of the transportation system through the encouragement and support of alternative modes of travel such as carpooling, vanpooling, transit, bicycling, and walking. However, TDM also endorses for example different work tables and reorganization of work implementations such as flex-time work schedules, which can rearrange and roll back demand on the transportation system.
The past decade showed a trend in increasing telecommunications technology. The emergence of this technology offers employees the opportunity to work from distant locations, other than the employer's site. Employees choosing for this type of work conditions are referred to as 'telecommuters'. As a TDM, telecommuting could offer some prospects for reducing trips, however it is not clear whether telecommuting also effectively and significantly reduces total vehicle travel.

[1] Transportation Research Institute (IMOB), Hasselt University, Wetenschapspark 5 bus 6, B-3590 Diepenbeek, e-mail: Bruno.Kochan@UHasselt.be, tel : 011/269147
[2] Transportation Research Institute (IMOB), Hasselt University, Wetenschapspark 5 bus 6, B-3590 Diepenbeek, e-mail: Tom.Bellemans@UHasselt.be, tel : 011/269127
[3] Transportation Research Institute (IMOB), Hasselt University, Wetenschapspark 5 bus 6, B-3590 Diepenbeek, e-mail: Mario.Cools@UHasselt.be, tel : 011/269131
[4] Transportation Research Institute (IMOB), Hasselt University, Wetenschapspark 5 bus 6, B-3590 Diepenbeek, e-mail: Davy.Janssens@UHasselt.be, tel : 011/269128
[5] Transportation Research Institute (IMOB), Hasselt University, Wetenschapspark 5 bus 6, B-3590 Diepenbeek, e-mail: Geert.Wets@UHasselt.be, tel : 011/269158

At the start of the millennium, telecommuting has been adopted in nearly all of the European countries. Many of these countries with an already relatively high degree of telecommuting also experienced higher growth rates in the five year period 2000 to 2005 (Welz, 2010). Among these countries, the percentage of telecommuters more than doubled in Belgium. The figures from the previous study have been confirmed by Statistics Netherlands (Centraal bureau voor statistiek, CBS) who came across the conclusion that the share of companies employing telecommuters has doubled within four years (Statistics Netherlands, 2009). Because of the growing interest in telecommuting, both by employers and employees and because telecommuting could be used as a TDM, it is interesting to investigate the impact of telecommuting on traffic in terms of total vehicle travel.
This paper therefore addresses the assessment of the impact of telecommuting on traffic in terms of total vehicle travel by means of the activity-based simulation platform FEATHERS (Bellemans, Kochan, Janssens, Wets, Arentze and Timmermans, 2010). However, next to FEATHERS another method for assessing the impact of telecommuting will be employed so that both results can be compared.

2. The FEATHERS Activity-Based Simulation Platform

Transportation problems are structurally multi-dimensional by nature. Indeed, traffic congestions are related to CO_2 emissions but they also have an influence on for example the economy. At the same time the necessity for transportation infrastructure is high due to globalization, urbanization, sprawl, etc. and in addition to this governments cannot afford transportation hindrances to have a negative impact on future competitiveness. However, changing the current infrastructure is sometimes costly, there is not always a certainty for success and changing infrastructure is not always easy or feasible due to existing spatial zones, constitutional constraints by local and federal governments, etc. Therefore, transportation models are often used as they can assist in ex-ante management decision making and they can make predictions in unforeseen and uncertain situations. Therefore, the goal of these models is to mimic reality as close as possible.
In the past different approaches have been used, such as conventional trip-based models where single trips are predicted following a simple 4-step mathematical calculus (Ruiter, 1978), without taking information about timing or sequences of trips into account. Therefore these conventional trip-based models were often replaced by tour-based models. While the tour-based approach captures more of the behavioral interactions across trips, it can still miss some important ones. For example, the mode of travel and departure times for the work-based sub-tour will tend to be constrained by the mode of travel and departure times for the home-based work tour that "surrounds" it. Also, changes to one tour can also influence the aspects of other tours made during the day. Activity-based models, on the other hand, aim at predicting *which* activities are conducted *where*, *when*, for how *long*, with *whom*, the *transport mode* involved and ideally also the implied *route* decisions. The major advantages of this type of models is that (i) it can deal simultaneously with the participation in various types of activities across the full day, which means that inter-tour relations can be accounted for and (ii) a micro simulation approach is often adopted which allows for taking into account a higher behavioral realism of the individual agent in the model.
The activity-based scheduling model that is currently implemented in the FEATHERS framework is based on the scheduling model that is present in Albatross (Arentze and Timmermans, 2005). Currently, the framework is fully operational at the level of Flanders. The real-life representation of Flanders, is embedded in an agent-based simulation model which consists of over six million agents, each agent representing one member of the Flemish population. The scheduling is static and based on decision trees, where a sequence of 26 decision trees is used in the scheduling process. Decisions are made based on a number of

attributes of the individual (e.g., age, gender), of the household (e.g., number of cars) and of the geographical zone (e.g., population density, number of shops). For each agent with its specific attributes, it is for example decided if an activity is performed. Subsequently, amongst others, the location, transport mode and duration of the activity are determined, taking into account the attributes of the individual.

3. Travel demand management (TDM) strategies that can be addressed within FEATHERS

It is well-known from literature that one of the major promises and reasons for existence of the activity-based modeling approach is an increased sensitivity for scenarios that are generally important in transport planning and policy making. In contrast to trip-based and tour-based models, activity-based models are sensitive to institutional changes in society in addition to land-use and transportation-system related factors. Such changes may be related, for example, to work times and work durations of individuals and opening hours of stores or other facilities for out-of-home activities. Furthermore, the models should not ideally only be sensitive to primary but also to secondary responses to land-use and transportation-related changes that in the past have been responsible for unforeseen and unintended effects of transport demand measures by policy makers. Examples of a primary response are changing transport modes, reducing frequency of trips or changing departure time. The primary response can thus be defined as the choice of a strategy which is aimed at reducing a negative impact or increasing a positive impact of the policy. A secondary response then involves adaptations which are required to make the broader activity pattern consistent with the change. Typical examples of such possible effects are an increase of out-of-home social activities in response to measures stimulating telecommuting or an increased use of cars for shorter trips as a secondary effect of stimulating car-pooling for trips to work (car stays at home and can then be used by other members of the household). Also, by means of example, switching from car to public transport for trips to work may limit the possibilities for trip chaining and hence induce extra separate trips as a secondary response.
Potentially, activity-based models should be sensitive to several groups of TDM, including: population, schedule, opening-hours, land-use measures as well as travel costs and travel times scenarios. As Arentze and Timmermans (2005) described, in terms of population scenarios, several large trends can be potentially evaluated, for instance the increasing participation of women in the labor force, the increasing number of single-adult households resulting in a decreasing average number of persons per household, the increasing household income as a consequence of general economic growth, the aging of the population in terms of graying and de-greening, the increasing number of cars per household etc. Also institutional changes in society, for instance by means of the implementation of a workweek or work start time changes can be modeled in an activity-based framework. A similar application is the widening and shortening of opening hours of for instance service related facilities. Not only time-specific measures can be evaluated, but also spatial scenarios can be computed. For instance, there might be a need to evaluate the result of an increasing spatial separation of locations for residence, work and facilities as a consequence of sub-urbanization or alternatively, a concentration of facilities in commercially attractive neighborhoods. Finally, typical travel-time or pricing scenarios can be computed by means of the new operational activity-based models.
However, in addition to the more traditional policy measures mentioned above, the applicability of TDM can be increased to environmental and health effects, using the activity-based paradigm as a starting point. Indeed, general traffic policy measures influence road safety, emissions and human health in an indirect way, i.e. indirectly through exposure. First

results, using an activity-based model for analyzing emission and health impacts, have been reported in Beckx *et al.* (2007).

4. Estimating the impacts of telecommuting on travel: method of Mokhtarian

4.1. Introduction

Before explaining the employment of the FEATHERS system to calculate a possible reduction in travel, another method is being used as a benchmark. One such method, by Mokhtarian (1998) allows one to estimate the impacts of telecommuting on travel, given a series of variables. The model consists of two parts. In the first part an estimation is made of the current number of telecommuters based on the total number of employees and the possibility and willingness of the employees to implement telecommuting. The second part estimates the reduction in total vehicle travel by telecommuters which will subsequently be expressed as a percentage with respect to the total vehicle travel in Flanders on one working day. In the next section the different calculation steps of the model are elaborated.

4.2. Calculation steps

Table 1 lists all the different steps for calculating the reduction in total vehicle travel in the case of telecommuting.

Variable	Definition	Result
E	The number of employees during a average work day	2504000
C	Proportion of employees that are able and willing to telecommute	0.106
F	Average telecommuting frequency	0.36
O	The expected number of telecommuters during an average work day	95553
D	Average back and forth home-work distance during a non-telecommuting work day	57 km
α	Proportion of the number of telecommuting opportunities that eliminates a home-work trip	0.501
V	The total eliminated home-work distance during an average work day	2728707 km
P	The net change in total vehicle travel as a proportion of the total vehicle travel during an average work day	-0.016

Table 1 : The impact of telecommuting on travel (method of Mokhtarian)

The model starts with the number of employees during an average work day (*E*). This first determinant equals to 2504000 for Flanders in 2002.
A study performed by Empirica (Kordey, 2002) showed that the proportion of employees that are able and willing to telecommute (*C*) amounted to 10.6% for Belgium in 2002. Since there are no data available for the number of telecommuters in Flanders, the data for Belgium is used in this model (Kordey, 2002).
According to a study performed by Walrave and De Bie (2005) 53.3% telecommute less then 1 time per week, 21.3% 1 to 3 days per week and 25.2% more than 3 days per week. This means that for telecommuting employees, the average telecommute frequency (*F*), equals 1.8 days per week or 36% of the work week.

The expected number of telecommuters during an average work day (*O*) is calculated by multiplying all preceding variables, that is $O = E \times C \times F$. For study area Flanders this multiplication equals 95553 telecommuters per work day.
According to the Flemish study OVG (Zwerts and Nuyts, 2002) the average home-work distance amounts to 19 km. This means that, on average, employees cover 38 km between the home location and the employer's premises. However, other studies also indicate that on average telecommuters live further away from their actual place of work when compared to non-telecommuters (Pidaparthi, 2003). Therefore, a factor of 1.5 is being considered as a correction factor (Verbeke, Dooms and Illegems, 2006). Because of this factor the average back and forth home-work distance during a non-telecommuting work day for telecommuters equals to 57 km.
The proportion of the number of telecommuting opportunities that eliminates a home-work trip (α) is calculated by dividing the share of car drivers by the average seat occupancy. According to OVG (Zwerts and Nuyts, 2002) 68.6% of employers use transport mode car as an option to commute. In addition to this, Statistics Belgium (Anon., 2002) reports a seat occupancy of 1.369 so that variable α equals to 0.501.
The total eliminated home-work distance during an average work day (*V*) is calculated by multiplying the expected number of telecommuters during an average work day (*O*) with the eliminated home-work distance (αD) as a result of telecommuting. For Flanders this yields 2728707 of eliminated home-work kilometers during an average work day.
The net change in total vehicle travel as a proportion of the total vehicle travel during an average work day (*P*) is calculated according to following formula: $V \times 5 / (R \times M)$ where *R* stands for the number of persons in Flanders in possession of a driver's license and *M* stands for the average distance in kilometers per capita in possession of a driver's license during a calendar week. In Flanders, in 2002, approximately 4043573 persons had a driver's license (Zwerts and Nuyts, 2002) and the average distance in kilometers came to 210 km. On the basis of these data the net change in total vehicle travel as a proportion of the total vehicle travel amounts to 1.6%. This means that in 2002, in Flanders, the total travel distance decreased with 1.6% as a result of telecommuting.

5. Estimating the impacts of telecommuting on travel: FEATHERS

5.1. Introduction

A second approach for calculating the impacts of telecommuting is based on the Activity-Based model FEATHERS. This method first aggregates travel demand in OD matrices and subsequently assigns these OD matrices to a transportation network. This method is followed by the calculation of the total vehicle travel for a null scenario and for a telecommuting scenario. Afterwards both the null and telecommuting scenario are compared so that the change in total vehicle travel can be obtained.
Since FEATHERS is run for a specific day, 7 predictions are worked out and averaged for a week so that the reduction in vehicle travel can be compared with the first method.

5.2. Implementation of the telecommuting scenario

Currently the FEATHERS framework incorporates the core of the Albatross Activity-Based scheduler. This scheduler assumes a sequential decision process, consisting of 26 decision trees, that intends to simulate the way individuals solve scheduling problems.
The scheduler first starts with an empty schedule or diary where after it will evaluate whether or not work activities will be included. If this is the case, then the number of work activities will be estimated (1 or 2 work activities), their beginning times, their durations and also the time in-between the work activities in case 2 work activities are present.

In a second step the locations of the work activities are determined. The system sequentially assigns locations to the work activities in order of schedule position. This is done by systematically consulting a fixed list of specific decision trees.
After the locations of the work activities have been determined, the telecommuting scenario comes into play. A dedicated procedure randomly selects employees as telecommuters and assigns a new location to the work location(s) in the schedule. The proportion of telecommuters selected is exactly the same as for the first method, namely $C \times F = 0.038$. Furthermore, the selection procedure also takes into account the fact that telecommuters show an average back and forth home-work distance during non-telecommuting work days that equals to 57 km. This last assumption is necessary to make a correct comparison with the first method.
After the selection of telecommuters has been done, their work location(s) will be replaced by the home address and their schedules will be updated with this new information. This way telecommuters work at home instead of the usual employer's premises.
Now that telecommuting has been enforced, the scheduler returns back to normal scheduling and proceeds with the next decision steps, that is: selection of work related transport modes, inclusion and time profiling of non-work fixed and flexible activities, determination of fixed and flexible activity locations and finally determination of fixed and flexible activity transport modes.

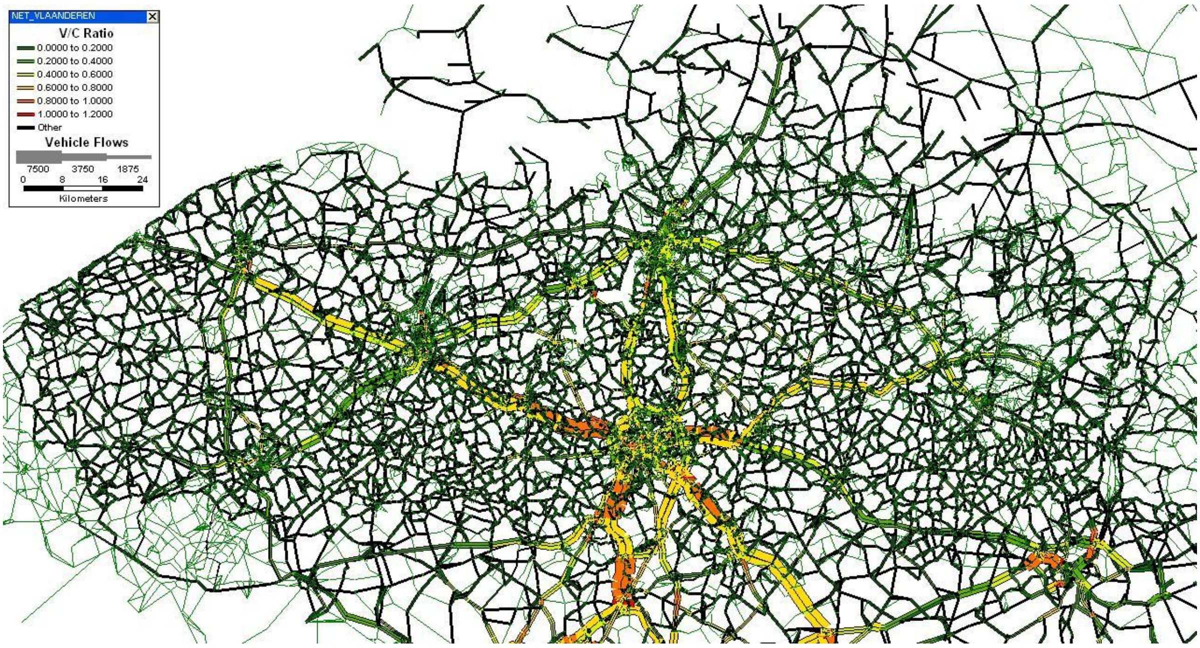
5.3. Derivation of OD matrices

The output of FEATHERS consists of activity-travel diary data sets for 7 days for both the null and telecommuting scenario. These diaries include several modes of transport, however, since we focused on car mode only in the first method, only trips done by car are taken into account.
For each hour of the day and for each day of the week, these diary data sets are processed yielding 168 OD matrices when focused on car mode only. This large amount of OD matrices will then serve as input for the traffic assignment part.

5.4. Traffic assignment

Traffic assignment models are used to estimate the flow of traffic on a network. These models take as input a matrix of flows that indicate the volume of traffic between origin and destination pairs. The flows for each OD pair are loaded onto the network based on the travel time or impedance of the alternative paths that could carry this traffic.
A wide variety of traffic assignment methods exist. A well-known assignment method is the All-or-Nothing assignment, which uses a shortest path method to assign traffic to the network. This method, however, ignores the fact that link travel times are flow dependent. Therefore, for this study, an equilibrium traffic assignment model was selected. This kind of traffic assignment uses an iterative process to achieve a convergent solution in which no travelers can improve their travel times by shifting routes. In each iteration, network link flows are computed which incorporate capacity effects and flow-dependent travel times.
As an illustration, figure 1 shows the equilibrium traffic assignment of the FEATHERS output for 8 o'clock on Monday.

Figure 1 : Equilibrium traffic assignment in Flanders



5.5. Calculation steps

Once the OD matrices are assigned for each scenario, for each hour and for each day of the week, the traffic intensity on each link is known. By selecting Flemish roads only and by aggregating the products of network link lengths and traffic intensities on the associated links one can obtain the total vehicle travel for 1 specific hour and day combination. By doing so for all 168 OD matrices and by assuming that each simulation day is representative as an average day across a year, total vehicle travel can be calculated. Table 2 summarizes these calculations from Monday till Sunday. If the total vehicle travel for the telecommuting scenario is compared with the null scenario situation then we can highlight a reduction of 1.68%.

	Null scenario	Telecommuting	
Day	vkm (10^9)	vkm (10^9)	Difference (%)
Mon	0.137	0.134	-1.96
Tue	0.141	0.138	-1.89
Wed	0.135	0.132	-2.16
Thu	0.138	0.135	-2.11
Fri	0.136	0.134	-1.96
Sat	0.119	0.118	-0.95
Sun	0.102	0.102	-0.31
Total sum	0.909	0.894	-1.68

Table 2 : Total vehicle travel by car

6. Conclusions

This paper presented the calculation of the reduction in total vehicle travel for two entirely different methods. Nonetheless, the outcomes are quite similar. The first method shows a reduction in vehicle travel of 1.6% whereas the second approach, based on the Activity-Based modeling framework FEATHERS, displays a reduction of 1.68%. This can be seen as an extra validation result for FEATHERS specifically but it also gives a lot of credibility in the

application of Activity-Based models in general when dealing with travel demand management strategies.
Secondly, because of the usage of an Activity-Based model for calculating the total vehicle travel reduction, it is now also possible to obtain the reductions not only on a weekly basis, but also on specific days and even specific hours. This is hard to do with the more conventional straight-forward models such as the one used in this study.
Thirdly, because Activity-Based models are able to differentiate between many household and person characteristics such as gender, age, number of cars, etc., it is also possible to explore the effect or impact of a scenario such as telecommuting according to these characteristics. This could be an extension of this study for future research.

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