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

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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 potential 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 the amount of peak-period trips. However it is less studied whether telecommuting also effectively and significantly reduces total vehicle travel in terms of kilometers traveled throughout the day. 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, this paper introduces the use of an activity-based modeling approach to evaluate the effect of telecommuting on a more detailed time scale. As the second approach provides a more disaggregate result, both models can be compared on the more aggregate level to validate whether they correspond.*

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

1. Introduction

According to a study by the United Nations (Anon., 2004), population is expected to show a significant increase 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 an important instrument to manage the growing needs for travel. Moreover, TDM has the ability to increase 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 is characterized by a significant increase in the availability of 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 policy, telecommuting could offer some prospects for reducing trips, however the impact of telecommuting on total car travel throughout the days of the week is less clear.

At the start of the millennium, telecommuting had been adopted to some extent in nearly all of the European countries. Many of these countries also experienced increased growth rates of telecommuting over the five year period 2000 to 2005 (Welz, 2010). In Belgium, of which the

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study area Flanders used in this paper is a part, the percentage of telecommuters more than doubled over the period 2000 to 2005. 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 further investigate the impact of telecommuting on traffic in terms of total car travel over different days of the week.

This paper addresses the assessment of the impact of telecommuting on traffic in terms of total car travel by means of the activity-based simulation platform FEATHERS (Bellemans, Kochan, Janssens, Wets, Arentze and Timmermans, 2010). As a reference to interpret the simulation results, a more aggregated method for assessing the impact of telecommuting (Mokhtarian, 1998) will be implemented for the Flemish region so that the results from both methodologies can be compared on an aggregated level.

2. The FEATHERS Activity-Based Simulation Platform

Transportation problems are structurally multi-dimensional by nature. Indeed, traffic congestion is related to CO_2 emissions but it also has an influence on for example the economy. At the same time the need 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 costly, success is not always guaranteed and changes in the infrastructure can be hard to even infeasible due to e.g. existing 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 closely as possible.

In the past different approaches to modeling 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. These conventional trip-based models are now often replaced by more detailed 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 is typically 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 details 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 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 a particular activity is performed. Subsequently, amongst others, the location, transport mode and duration of the executed activities are determined, taking into account the attributes of the individual and its surroundings.

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 the existence of the activity-based modeling approach is an increased sensitivity for scenarios that are generally important in transport planning and policy making (Arentze and Timmermans, 2005). 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. 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.

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

4.1. Introduction

Before discussing the application of the FEATHERS system to calculate the impact of telecommuting on car travel, a more aggregated method is applied to the study area to serve as a benchmark. This method (Mokhtarian, 1998) allows one to estimate the impact of telecommuting on car 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 car travel by telecommuting. This reduction will be expressed as a percentage with respect to the total car 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 the different steps according to the method proposed by Mokhtarian for calculating the reduction in total vehicle travel in the case of telecommuting.

Variable	Definition	Result
E	The number of employees during an average work day	2 504 000
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	95 553
D	Average back and forth home-work distance during a non-telecommuting work day	57 km
A	Proportion of the number of telecommuting opportunities that eliminates a home-work car trip	0.501
V	The total eliminated home-work distance during an average work day	2 728 707 km
P	The net change in total vehicle travel as a proportion of the total vehicle travel during an average work day	-1.6%

Table 1 : Steps to determine the impact of telecommuting on car travel according to the method of Mokhtarian.

The model starts with the average number of employees during a work day (*E*). This first determinant equals to 2 504 000 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 than 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 the study area Flanders this multiplication yields 95 553 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 work related kilometers 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 for telecommuters on a non-telecommuting work dayto be accounted for in Flanders equals to 57 km.

The proportion of the number of telecommuting opportunities that eliminates a home-work car 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 employees in Flanders use the car as an option to commute. In addition to this, Statistics Belgium (Anon., 2002) reports a seat occupancy of 1.369 so that α equals to 0.501.

The total eliminated home-work car distance due to telecommuting 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 2 728 707 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 4 043 573 persons had a driver's license (Zwerts and Nuyts, 2002) and the average distance driven in kilometers per week amounted 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 using 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 the travel demand as generated by the acticvity-based model in OD matrices and subsequently assigns these OD matrices to a transportation network. This method is followed by the calculation of the total car kilometers traveled for a null scenario and for a telecommuting scenario. Afterwards both the null and telecommuting scenario are compared so that the change in total car travel can be obtained.

Since FEATHERS is run for a specific day of the week, 7 predictions of car kilometers in Flandersare worked out, one for each day of the week, 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 starting 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 samples employees as telecommuters according to a

preset distribution and assigns the home location as the work location in the schedule of telecommuters. The proportion of telecommuters that is selected to telecommute on a working day 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. These assumptions are necessary to be able to make a 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 during their telecommuting day instead of at 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 (only for individuals not telecommuting on that day), 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.

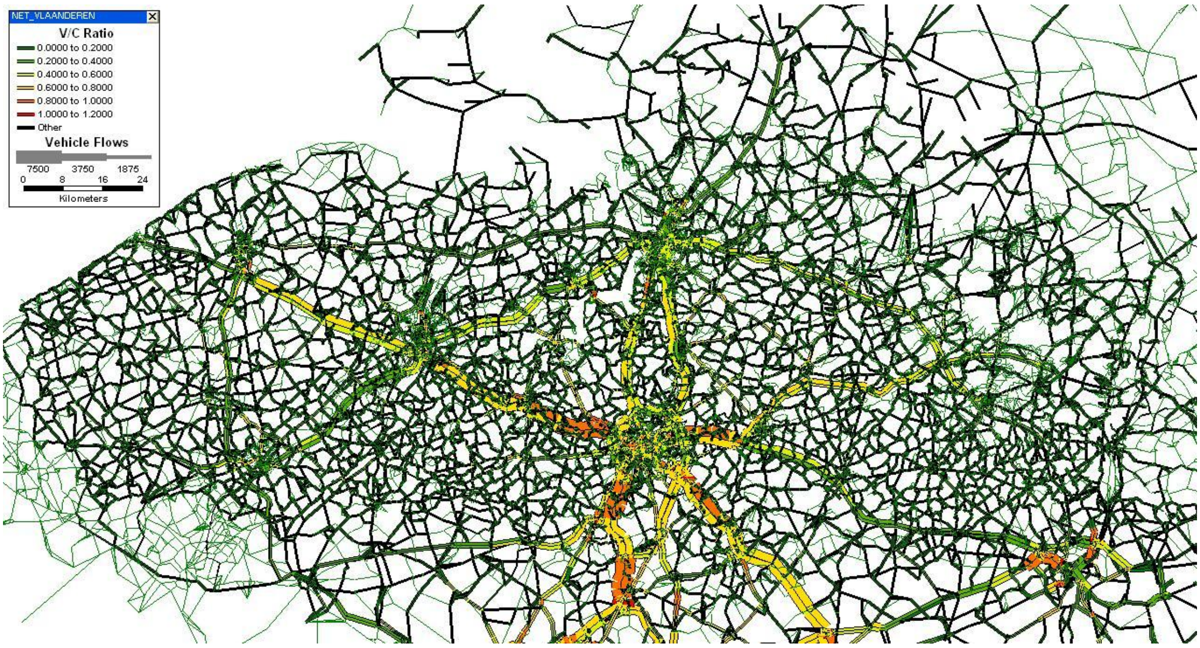
5.3. Derivation of OD matrices

The output of the FEATHERS runs consists of activity-travel diary data sets for the Flemish population for 7 days of the week 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 will be used for further analysis.
For each hour of the day and for each day of the week, these diary data sets are processed yielding 168 (7 times 24) OD car mode matrices. These OD matrices will serve as input for the subsequent traffic assignment.

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 impedance, e.g. time or cost, of the alternative paths between origin and destination.
A wide variety of traffic assignment methods exists. For this study, an equilibrium traffic assignment model that is readily available in TransCAD was selected. This kind of traffic assignment uses an iterative process to achieve an equilibrium solution in which no travelers can improve their travel times by shifting routes (Nash equilibrium). 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 Flanders at 8 am on Monday.

Figure 1 : Equilibrium traffic assignment on Monday at 8 am in Flanders.



5.5. Aggregating vehicle kilometers traveled

Once the OD matrices are assigned for each scenario, for each hour and for each day of the week, the corresponding traffic intensities on each link are 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 car travel for a 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 yearly vehicle travel can be calculated. Table 2 summarizes these calculations from Monday till Sunday for an average week. If the total vehicle travel for the telecommuting scenario is compared with the null scenario situation a reduction of 1.68% in total car kilometers traveled per year can be observed. This figure lies in the range of the result that was obtained using Mokhtarian's method (-1.6%). It can also be observed that during the weekend, when less work activities are being performed, the impact of telecommuting is smallest while the impact of telecommuting according to FEATHERS is largest on Wednesdays and on Thursdays.

	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 (10^9 veh km/week)

6. Conclusions

This paper presented the calculation of the reduction in total car travel in Flanders due to telecommuting based on two entirely different methods. Nonetheless, the outcomes on an

aggregate level 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%.
Although the results of both methodologies are similar, the methodologies by themselves are totally different. The activity-based approach uses disaggregate modeling and as such allows for a more detailed analysis of the reduction of car travel due to telecommuting. Based on an activity-based approach, on top of modeling the reductions on a weekly (yearly) basis, also the reduction on specific days and even specific hours of the day can be obtained as was illustrated in this paper. This level of detail cannot be achieved using aggregated methodologies such as e.g. the method of Mokhtarian.
Moreover, since 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 impact of a scenario such as telecommuting on specific segments of the population. This is the subject of future research.

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