TRAVEL BEHAVIOUR AND EMISSION ASSESSMENT IN THE NETHERLANDS: A DIFFERENT APPROACH

Carolien Beckx[1,3], Theo Arentze[2] and Davy Janssens[3]

[1] VITO, Vlaamse Instelling voor Technologisch Onderzoek.
Boeretang 200, 2400 Mol – Belgium.
Fax: +32(0)14 32 11 85 – Email: carolien.beckx@vito.be

[2] TU/e, Eindhoven University of Technology – Urban Planning Group.
PO Box 513, 5600 MB Eindhoven – The Netherlands.
Fax: +31(0)40 247 58 82 – Email: T.A.Arentze@bwk.tue.nl

[3] IMOB, Instituut voor Mobiliteit, Universiteit Hasselt – Campus Diepenbeek.
Agoralaan Gebouw D, 3590 Diepenbeek – Belgium.
Fax: +32(0)11 23 22 17 – Email: davy.janssens@uhasselt.be

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Samenvatting

Verplaatsingsgedrag en emissies in Nederland: een nieuwe benadering

In deze paper worden de eerste resultaten voorgesteld van een nieuw onderzoeksproject waarin m.b.v. een *activiteitengebaseerd* transport model voertuigemissies in Nederland berekend worden. In tegenstelling tot de traditionele *tripgebaseerde* aanpak waarbij enkel trips voorspeld worden, voorspelt deze alternatieve aanpak eerst de volledige activiteitenpatronen van individuen, van waaruit daarna de trips, de verkeersstromen en de emissies afgeleid kunnen worden. Meer concreet komt deze procedure in dit onderzoek neer op, achtereenvolgens, het runnen van het activiteitengebaseerd model ALBATROSS, het extraheren van de trip matrices uit de activiteitenpatronen, het toedelen van de trips m.b.v. een toedelingsalgorithme en het converteren van de resulterende verkeersstromen in emissies. Een eerste validatie van de resultaten van dit project is alvast veelbelovend. De gemodelleerde emissies van het personenverkeer in Nederland blijken gemiddeld slechts 5% af te wijken van de cijfers die elders gerapporteerd werden.

Nu, een hele andere aanpak om uiteindelijk gewoon dezelfde cijfers te bereiken? Men kan zich afvragen wat daar nu het vernieuwende aan is. Maar, in vergelijking met de traditionele aanpak houdt dergelijke nieuwe benadering zeker een meerwaarde in. De voorspelde trips (en dus ook de bijhorende berekende emissies) bevatten immers veel meer extra informatie over de trips zoals het doel van de trip en allerlei socio-demografische informatie over de uitvoerder van de trip. Hierdoor krijgen beleidsmakers in de toekomst een beter inzicht in de oorzaken van de verkeersemissies en zal het eenvoudiger zijn om de impact van (alternatieve) beleidsmaatregelen in te schatten.

1 Introduction

During the past few decades, traffic has become the dominant source of air pollution at several places. Advances in technology have played and will continue to play a role in managing the emissions associated with vehicular transport. However, the increasing number of vehicle miles traveled substantially offsets the emission reduction through advances in technology. Therefore, the use of other kinds of policies to reduce vehicle emissions, focusing more at the driving forces of this problem, should be studied. Unfortunately the benefits of these transportation control measures (TCM) are often unknown as there are limited data available to measure the travel effects of individual TCM strategies. The lacking of the interactions among individual and household travel decisions in response to TCM lay at the heart of the failings of conventional models to provide adequate measures of their potential impact (Recker, 1998). Questions that involve the linkages between a set of travel decisions and activities can not be examined through a traditional four-step transportation model. This kind of model focuses on individual trips where the spatial and temporal interrelationships between all trips are ignored. Further, there is only little information about trip aspects like the purpose of the trip, the trip timings and the trip performer. These arguments and the inability of the four-step models to evaluate responses to TCM have prompted the development of a new approach to travel analysis, the activity-based approach.

The use of an activity-based travel model puts a new perspective on the research of policy measures offering a lot of advantages for air-quality purposes and policy evaluations (Recker, 1998; Shiftan, 2000). 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. An activity-based model allows for spatio-temporal linkages between the collection of activities that individuals and households perform as part of their daily schedule. Besides providing detailed activity-travel information, the advantages of activity-based modelling lie in its ability to give a better prediction of travelers’ responses to TCM and, therefore, to provide a more accurate estimate of the changes in some important transportation variables.

One of the main advantages of the activity-based modelling system is its ability to consider the secondary effects of TCM. 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 or her mode from drive alone to public transport; this is the primary effect of the TCM. Because, however, 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 advantages of TCM may be limited, and the reduction of the work auto trip is offset by a new shopping auto trip. Only an activity-based model 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, Beckx et al (2005) already mentioned the use of the activity-based approach for impact analyses of alternative policy measures like:

- changing shop opening hours;
- introducing flexible work hours;
- promoting telecommuting;
- reducing the number of cars per household.

Activity-based models are able to evaluate the impact of these measures on travel behaviour and transport, and due to this the impact on air-quality can be assessed and decisions can be made by the policymakers. Moreover, activity-based models are able to take into account several demographic changes to make accurate prognoses of travel behaviour in time eg. changes in family size, number of driving licenses in the community,… providing a more realistic forecast of the impact of policy measures in the future.

Over the last years, several research teams have focused on building activity-based models of transport demand (e.g. Vovsha et al. 2003, Bhat et al. 2004, Arentze and Timmermans 2005 and Pendyala et al. 2005). Partial and fully operational activity-based micro simulation systems include the Micro-analytic Integrated Demographic Accounting System (MIDAS), the Activity-Mobility Simulator (AMOS), Prism Constrained Activity-Travel Simulator (PCATS), SIMAP, ALBATROSS, Florida’s Activity Mobility Simulator (FAMOS) and other systems developed and applied to varying degrees in Portland, Oregon, San Francisco, and New York.

But, although the potential advantage of an activity-based approach for air-quality purposes has been recognized from the beginning (e.g., Spear, 1994) and has been re-iterated more recently (e.g. Shiftan, 2000), to the best of our knowledge- models that have been developed along these lines are still scarce.

The remainder of this paper is organized as follows. Section two describes briefly the methodology to use an activity-based approach for the evaluation of vehicle emissions. In section three, this methodology will be illustrated for the Dutch situation and the first results of this case will be presented. Finally, the paper concludes and defines some topics for further research.

2 Methodology

The methodology to use an activity-based approach for estimating the emissions caused by personal vehicle travel in a certain region consists of three successive steps. This method was already explained in a former CVS paper (Beckx et al., 2005), but in this section each of these steps will be described briefly.

2.1 Activity-based modelling

The first step in the methodology involves the application of an activity-based travel demand model. Based on a very detailed data set including activity and trip information of a large population sample, the activity-based model is able to predict activity schedules for the population of a certain country or region. After the prediction of activity schedules, detailed origin-destination (O/D) matrices can be extracted from the simulated activity-travel patterns. This procedure provides detailed information about the travel behaviour of the individuals within the modeled population. The activity-based approach hereby offers information on different facets of the individual trip like the trip purpose, the trip duration and the characteristics of the trip performer. Of course, when concentrating on the impact of personal vehicle travel, other transport modes can be ignored.

2.2 Traffic assignment

In a second step, the O/D matrices that are predicted by the activity-based model will be assigned to a transportation network using a traffic assignment algorithm. According to data and software availability, different traffic assignment algorithms can be used (all or nothing, shortest route, fastest route, …) and, of course, different results will be obtained. The results of this assignment will usually consist of hourly traffic flows per hour and per link, but, also data about hourly vehicle speeds can be obtained if more advanced assignment algorithms are used. The accuracy of the assignment results will not only depend on the applied assignment algorithm, but also on the available link information and the number of traffic zones that are used.

2.3 Emission calculation

Finally, in the last step of the proposed methodology, the traffic flows on the different traffic links are converted into vehicle exhaust emissions based on emission factors (in g/km). The most common emission factors result from the Copert/MEET methodology (MEET, 1999). This methodology assumes that vehicle data and average speed data are available for the year that is modeled. Specific emission functions for every vehicle type will combine the average speed data with vehicle specific emission parameters to estimate vehicle emissions for a certain time period and for a certain region.

In some regions, in stead of working with separate emission factors per vehicle type, vehicle park emission factors are also present, taking into account the composition of the whole vehicle park (or only the personal vehicles) and the characteristics of the road network. In that case, only information about the traveled distance is needed to be able to calculate the produced vehicle emissions.

3 Results

The developed methodology was applied on the assessment of vehicle emissions in the Netherlands. This section presents some results from the three successive steps in the methodology for the vehicle emission calculation for this country.

3.1 Activity-based modelling with Albatross

To illustrate the activity-based approach for the evaluation of vehicle emissions, the activity-based model Albatross, A Learning-Based Transportation Oriented Simulation System (Arentze and Timmermans, 2000), was applied for the Dutch situation. Albatross is a computational process model that relies on a set of decision rules to predict activity-travel patterns. It was developed for the Dutch Ministry of Transportation, Public Works and Water Management as a transport demand model for policy impact analysis and is able to predict which activities are conducted, when, where, for how long, with whom, and the transport mode involved. Information about the scheduling process of this model and an overview of other computational process models can be found in Arentze and Timmermans (2000, 2005).

For this study, Albatross version 3.0 was used to predict schedules for 30% of the Dutch population. First a the synthetic population was created using iteratively proportional fitting methods, representing 30% of the households in the Netherlands in the year 2000. A synthetic population of 30% was, at that moment, the maximum size that could be achieved by the model. Next, activity schedules were predicted for each individual within this synthetic population using decision-tree induction methods. For a synthetic population of 30% the number of household cases in the Netherlands amounts approximately 2 million. Finally, origin-destination (O/D) matrices were extracted from the predicted activity schedules. As we focused on vehicle trips in this study, only O/D-matrices from trips made as a car driver were selected for further analysis. To account for differences in travel behaviour within one week, trip matrices were analyzed for three different days in a week: a weekday, a Saturday and a Sunday. Further, trips were divided into six time periods a day (before 10 am, between 10 am and 12 am, between 12 pm and 14 pm, between 14 pm and 16 pm, between 16 pm and 18 pm, and trips after 18 pm) and 1308 zones were used as origin or destination.

3.2 Traffic assignment

The O/D-matrices, predicted by the activity-based model Albatross, represent the trip behaviour for 30% of the Dutch population during different times per day and on different days of the week. Before assigning these trips to a road network, the matrices were extrapolated to represent the travel behaviour of the whole Dutch population. Next, these trip matrices were assigned to the Dutch road network by using an 'all-or-nothing' traffic assignment algorithm embedded in the software package TransCAD. A more dynamic assignment, in stead of this static 'all-or-nothing' assignment, was not (yet) possible since no information about road capacity was available. Approximately 120000 traffic links were present in the Dutch road network and the region was divided into 1308 traffic zones, corresponding to the origin and destination zones used in the Albatross application (sub zonal classification). Figure 1 presents the study area with its 1308 traffic zones. The average area size of a traffic zone is approximately 20 km².

Figure 1. Presentation of the 1308 traffic zones in the study area.

After the traffic assignment procedure, detailed information is present about the traffic flows on the road links during different times of a day an on different days a week. By aggregating these results and extrapolating the values for a whole year, the total travel distance during the modeled year (2000) can be calculated. In Table 1 this calculated value is presented next to the reported value on this topic. The reported value originates from Dutch travel statistics.

Table 1. Total travel distance by personal vehicle travel in the Netherlands ([a]CBS, 2000)

	Travel distance (x 10^9 km)
Modeled travel distance	93.3
Reported travel distance[a]	89.1
Relative difference (%)	4.6 %

Since geographical information is also present about the different traffic links and their traffic flows, the result of the traffic assignment can also be visualized (Figure 2).

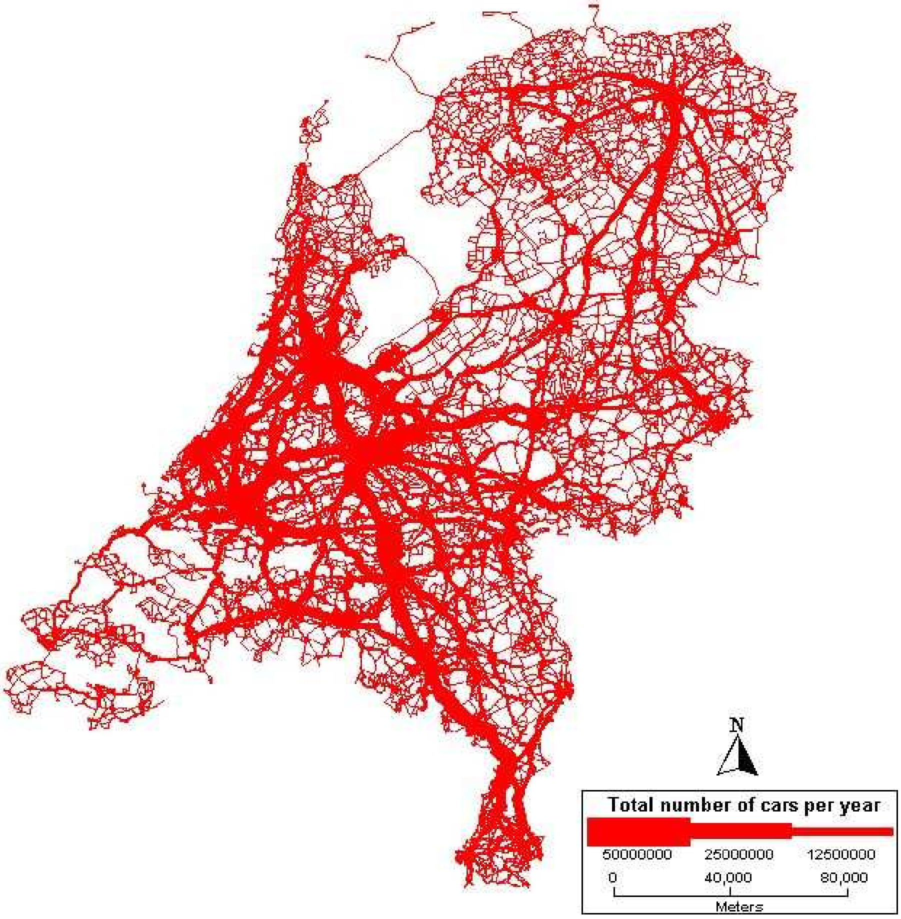

Figure 2. Geographical presentation of the modeled traffic flows during the year 2000.

When aiming hourly traffic flows (and emission estimates), the trips predicted by the Albatross model need to be split up since trips in Albatross are only present in six time periods. To perform this action properly, the results from another travel behaviour study, "*onderzoek verplaatsingsgedrag*", were used, taking into account the relative frequency of trips during the different time periods (CBS, 2000). When applying the calculated relative frequencies from this travel study on the trips modeled by Albatross, hourly traffic flow data can be presented. Figure 3 shows e.g. the traveled distance during an average weekday that was calculated with Albatross.

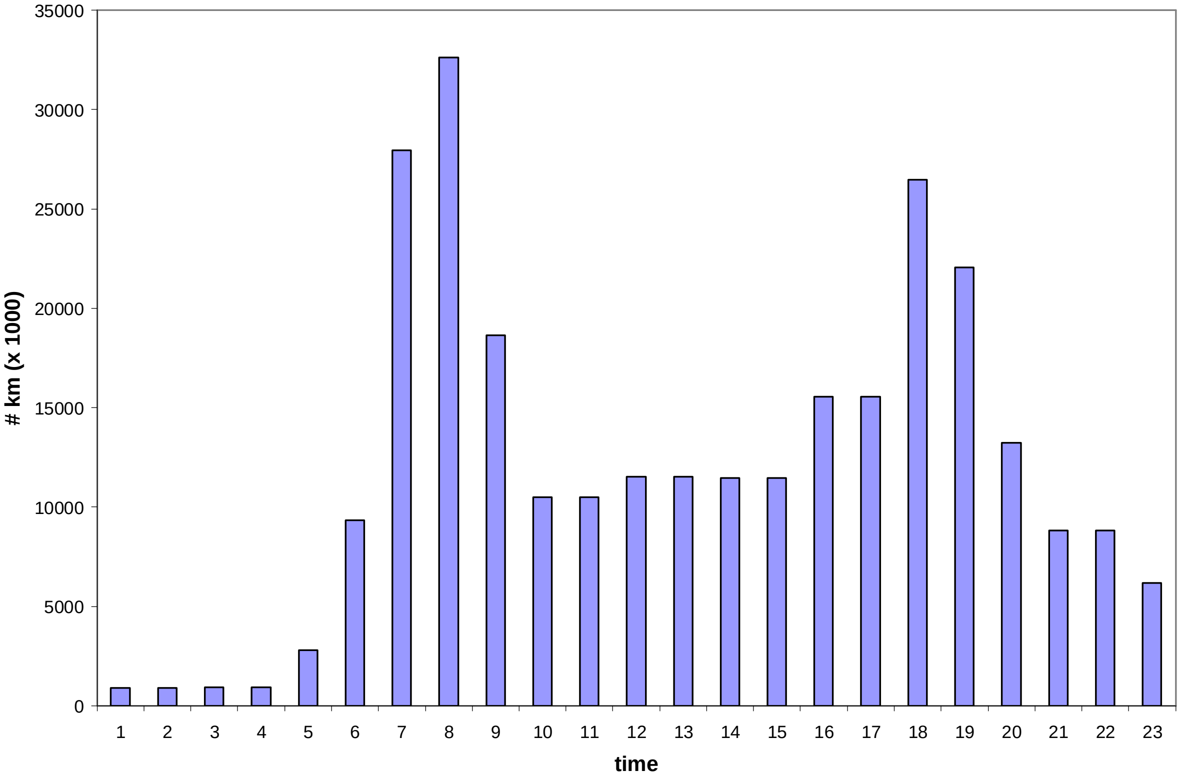

Figure 3. Hourly distance traveled during an average weekday

3.3 Emission calculation

Based on the traffic flows that result from the assignment procedure emission estimates can be made for the personal vehicle travel in the Netherlands. Total emission values, hourly emissions and geographically spread emissions can all be calculated. In this study, vehicle emissions were calculated by two different methods. The first one uses one 'total' emission factor per pollutant to calculate the emissions for the whole vehicle park (see 'total' in Table 2). This emission factor takes into account the composition of the personal vehicle park in the year 2000 and the characteristics of the road network. The second method works with different park emissions factors per pollutant according to the type of traffic link where traffic flows occur (Table 2). According to this second method three different emission factor are present, for urban links, rural links and highways, and the traveled distance needs to be multiplied, per link, with the appropriate emission factor. The results of the emission calculations for method 1 and method 2 are presented in Table 3 and Table 4 respectively. Both tables also present the reported emission values for the same model year.

Table 2. Vehicle park emission factors (CBS, 2000)

	CO_2 (g/km)	CO (g/km)	NO_x (g/km)	SO_2 (g/km)	PM10 (g/km)
Total (1)	190	2.9	0.7	0.014	0.032
Urban (2)	257	7.3	0.8	0.016	0.044
Rural (2)	162	1.9	0.5	0.010	0.022
Highway (2)	182	1.6	0.7	0.015	0.034

Table 3. Calculation of total vehicle emissions for the year 2000, using 1 emission factor per pollutant ([a]CBS, 2000)

	CO_2	CO	NO_x	SO_2	PM10
Modeled emissions in 2000 (x10^6 kg)	17729.06	270.60	65.32	1.31	2.09
Reported emissions in 2000[a] (x10^6 kg)	17346.00	263.60	60.10	1.26	2.88
Relative difference (%)	2.21	2.66	8.69	3.97	-27.43

Table 4. Calculation of total vehicle emissions for the year 2000, using 3 emission factors per pollutant ([a]CBS, 2000)

	CO_2	CO	NO_x	SO_2	PM10
Modeled emissions in 2000 ($x10^6$ kg)	18498.65	339.73	60.18	1.22	2.99
Reported emissions in 2000[a] ($x10^6$ kg)	17346.00	263.60	60.10	1.26	2.88
Relative difference (%)	6.65	28.88	0.13	-3.17	3.82

Table 3 presents the emission estimates when the calculated traveled distance is multiplied by only one park emission factor. These results were compared to the reported emission values for the year 2000. Model results for most pollutants seem to correspond well to the reported values. Except for the PM10 value, the relative differences between modeled and reported values are less than 10%. In Table 4 the emission estimates from the second method are presented. In this case, the modeled results for CO seem to differ from the reported value. For the rest of the pollutants the predicted results correspond very well with the reported emission values.

Differences between the values in Table 3 en Table 4 can be explained by the traffic assignment procedure. Since no capacity information was present in the road network data file, the assignment procedure was limited to an “all-or-nothing” assignment. If the results from this assignment differs strongly from reality, e.g. more kilometers are modeled on rural links than traveled in reality, than this will have its implications for the emission estimates.

Conclusion

In this study we demonstrated the ability of an activity-based model to make accurate predictions of the travel behaviour of people. More specifically, modeled travel distance and emission estimates for the situation in the Netherlands were compared with reported values on these topics and seemed to correspond well with these estimates. These results are very promising for further research since the activity-based approach offers more possibilities for policy impact analysis than the traditional travel demand model.

Future research will not only involve impact analyses of different transportation control measures, but will also focus on further enhancements of the traffic assignment and emission calculation procedure to improve the vehicle exhaust assessments. Topics in this future research include the assignment of intra-zonal trips (not included in this study) and the calculation of cold start emissions by taking into account the time between two successive vehicle trips.

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