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Impact of trip purpose on driving behaviour: case study on commuter traffic in Belgium

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Abstract

This study explores the relationship between the purpose of a trip and the vehicle exhaust emissions caused by the driving behaviour during this trip. More specifically, this research focuses on the difference in driving behaviour between commuter traffic and other traffic. The hypothesis formulated is that people driving to work produce more emissions per kilometer than drivers with other trip purposes, for instance due to a different driving behaviour. To examine this hypothesis, a methodology was developed to relate trip driving behaviour and vehicle emissions to trip purpose, and this method was applied to a small case study. This paper reports on the methodology developed for this research and presents the first results from the case study.

Keywords: *driving behaviour, emissions, trip purpose, activity-based, GPS.*

Résumé

Cette recherche examine les relations causales entre la destination d'un tour en voiture et les émissions produites par la conduite de l'automobiliste. Plus spécifiquement, cette recherche traite des différences de conduite entre des tours de la migration pendulaire et des tours avec une autre destination. L'hypothèse formulée suggère que les personnes qui vont au travail produisent plus d'émission par kilomètre que les personnes avec une autre destination, par exemple à cause d'une conduite différente. Pour examiner cette hypothèse, une méthodologie a été développée pour relier la conduite de l'automobiliste et les émissions du véhicule à la destination d'un tour, et cette méthode a été appliquée à une étude de petite échelle. Cet article rapporte la méthodologie développée pour cette recherche et présente les premiers résultats de l'étude de cas.

Mots-clés: *conduite, émissions, destination, activity-based, GPS.*

1 - INTRODUCTION

For the last decade, activity-based (AB) transportation models have certainly set the standard for modelling travel demand. The major idea behind AB models is that travel demand is derived from the activities that individuals and households need or wish to perform (Ettema and Timmermans, 1997). In order to summarize the most important features of AB modelling, the work of McNally (2000) is cited, who has nicely listed 5 themes which characterize the AB modelling framework:

- (i) Travel is derived from the demand for activity participation;
- (ii) sequences or patterns of behaviour, and not individual trips are the relevant unit of analysis:
- (iii) household and other social structures influence travel and activity behaviour;
- (iv) spatial, temporal, transportation and interpersonal interdependencies constrain activity/travel behaviour;
- (v) AB approaches reflect the scheduling of activities in time and space.

AB approaches aim at predicting *which* activities are conducted, *where*, *when*, for *how long*, *with whom* and the *transport mode* involved. Obviously, data is needed for all these facets in order to develop an AB model. For this purpose an AB survey, collecting activity diary data, is conducted involving the questioning of a large number of households during two or more consecutive days. To acquire information of higher quality but still taking into account the respondent's burden, new data collecting technologies are being developed (e.g. Kochan *et al.,* 2005). Accurate information on facets like activity location and route choice, for example, can be obtained through the use of a GPS receiver.

In combination with the use of environmental models this AB approach can have important advantages for air quality purposes (Recker and Parimi, 1998; Shiftan, 2000). Macroscopic emission models, for instance, are able to convert the predicted flows of traffic into emission estimates (Beckx *et al.,* 2005). Microscopic emission models, on the other hand, are able to calculate the instantaneous vehicle emissions by using the microscopic activity data together with data from the GPS tracking device. In this way vehicle driving dynamics (the variation in average speed, acceleration and deceleration, time spent stationary,…) are taken into account when estimating vehicle exhaust emissions, resulting in a very accurate emission calculation (Beevers and Carslaw, 2005). Furthermore the use of these microscopic driving data together with the activity diary data allows to study the relationship between the driving behaviour of the respondents and the associated activity data. In this way the underlying factors of the observed driving behaviour and the associated exhaust emissions could be explained. This information can be important for policy makers aiming vehicle exhaust reduction knowing that fuel consumption could increase up to 40% for more aggressive driving compared to normal driving dynamics (De Vlieger *et al.,* 2000).

2 - METHODOLOGY

This section describes how the database with details on the activities and driving behaviour of people was obtained and how the data were processed.

2.1 Data collection

Activity data were obtained in a small scale AB data collection using self-reporting of activities and trips by respondents in a paper activity diary. A Personal Digital Assistant (PDA) with built-in GPS receiver was used to acquire information about the exact location of activities and to provide more accurate information on the reported trips (route choice, trip distance, driving speed,…). The original data set contained AB information of 32 respondents, men and women, varying in age, education, income,… They all filled in the activity diary for a period varying from two days to one week. In total 1014 trips were reported in the paper activity diaries of which 303 trips were made as a car driver.

2.2 Data processing

After data collection, data were organized and converted into usable formats. The activity diary data were adjusted to provide more useful information about the vehicle trips. An important step in the data processing concerned the classification of the trips according to trip purpose. Trips were classified as commuter trips when going directly to or from work, or making part of a trip to or from work. Trips with other purposes, like shopping or going out, and not making part of a commuter trip, were classified as 'other trips'. The GPS logs, consisting of second-by-second information on location, time, speed and date were downloaded from the GPS receiver. Next, these NMEA GPRMC sentences were converted into formats usable for further analysis.

The next step in the data processing was linking the activity diary data and the GPS logs, based on the trip departure and ending times. A manual check was performed to ensure that all the GPS records associated with vehicle trips were included in the analysis and, if necessary, trip timings were adjusted. After this processing procedure 235 vehicle trips were detected.

2.3 Emission modelling

Within the EU 5th framework project DECADE (2001-2003) a vehicle level simulation tool was developed for the simulation of fuel consumption and emissions for real traffic transient vehicle operation. A specific task in the project was to include a method for calculating dynamic emissions, and thereby reaching higher accuracy than traditional emission simulation modelling (Pelkmans *et al*, 2004). The final simulation tool, which is called VeTESS (Vehicle Transient Emissions simulation Software), calculates emissions and fuel consumption made by a single vehicle during a defined 'drive-cycle'. The VeTESS emissions model uses new methods based on experimental characterization of engines and aims to provide a more realistic simulation by incorporating transient engine behaviour (Beevers and Carslaw, 2005). Together with the associated speed profiles, the actual power demands allow a detailed calculation of emissions.

VeTESS calculates the emissions per second for CO_2, CO, NO_x, HC and PM, but for the moment detailed engine maps are only available for three types of passenger cars: a Euro II LGV, a Euro III diesel car and a Euro IV petrol car. Since all the participants in the AB survey drove a diesel car and, moreover, most vehicle kilometers in Belgium are covered by diesel vehicles, this study was limited to the EURO III diesel car, described in Table 1. The other assumptions used in the model include flat terrain, 'normal' driving and gear change assumptions and no air conditioning or additional payload carried by the vehicle.

<INSERT TABLE 1 HERE>

Speed profiles, based on the instantaneous speed data from the GPS receiver, were composed for every detected vehicle trip and used as input for the VeTESS tool. The model output consisted of second-by-second emission data, total emission data and emission factors for every trip.

2.4 Driving behaviour

Speed and acceleration profiles were estimated based on the data from the GPS receiver and a set of driving parameters was calculated. The driving parameters applied in this study include average speed, average positive acceleration, relative positive acceleration (RPA) and the percentage of stop time (PST) (see Table 2). RPA is calculated from the power that is needed for all vehicle accelerations in the cycle, divided by the distance driven. It gets high when the driving pattern includes a lot of high power-demand accelerations and is found to increase exhaust emissions and fuel consumption (Ericsson, 2005). RPA is calculated as:

$\frac{1}{x}\int_0^T va^+ dt$, where T = total cycle time (s), v = speed (m/s), a^+ = positive acceleration (m/s²) and x = total distance (m).

<INSERT TABLE 2 HERE>

2.5 Analysis

The analysis aimed at answering the following question: What could be the influence of the purpose of a certain trip on the driving behaviour of its driver and/or amount of vehicle exhaust emissions caused by this trip. To answer this question, the calculated emission factors and driving parameters needed to be reunited with the information on the trip. Since the trip number was attached to every calculation, each driving pattern and emission estimate could be coded with information concerning the purpose of the trip. In this study trips were classified either as a commuter trip going to or from work, or as a trip with 'other' purpose. An analysis was then performed to find out if there was a difference between the calculated emission estimates and driving patterns of trips with a different trip purpose.

3 - RESULTS

This section presents the first results from the small scale survey where 32 respondents participated in an AB survey with GPS tracking technology. Both the results from the emission estimates and the driving parameters are shown for different trip purposes. In total 235 trips were analyzed.

3.1 Emission estimates

The emission model VeTESS calculated the emission values based on second-by-second speed measurements. Both the total amount of exhaust emissions as well as the emission factors (g/km) were calculated. Table 3 and table 4 present respectively the average total emission values and the average emission factors per trip as calculated by the emission model VeTESS. An unpaired two-sided t test was performed to check the differences between the values of different trip purposes (p-value <0.05).

<INSERT TABLE 3 HERE>

<INSERT TABLE 4 HERE>

The results in table 3 show clearly that there is a difference between the total emissions from commuter trips and other trips. The total amount of emissions per commuter trip is almost twice as high comparing to the total emissions from other trips ($p<0.05$). When taking into account the distance for every trip, table 4 shows however no significant differences between the emission factors of the different polluents. The mean emission factor values for commuter trips are always equal to or higher than the values for trips with other purposes, but apparently these differences are not statistically significant.

3.2 Driving behaviour

Driving parameters used in this study include average speed (v_{avg}), average positive acceleration (a^{+}_{avg}), relative positive acceleration (RPA) and percentage of stop time (PST). Table 5 presents the calculated driving parameters for the trips in this study.

<INSERT TABLE 5 HERE>

The average driving speed for commuter trips is significantly higher than the average speed for trips with other purposes ($p<0.05$). Trips going to or returning from work are driven at 39,20 km/h on average whilst other trips have a mean driving speed of 33.30 km/h. The parameters concerning the positive acceleration, a^{+}_{avg} and RPA, both seem to be higher for commuter trips than for other trips, but in this small scale survey this difference is not statistically significant ($p=0.10$ and $p=0.13$). The driving parameter PST is slightly higher for other trips compared to commuter trips, but this difference is not at all significant in this survey.

4 – DISCUSSION

The methodology and results presented in this paper demonstrate that useful information can be obtained by enlarging an AB survey with GPS technology and linking trip information to other parameters like driving parameters and emission estimates. This approach can provide interesting information on the reasons behind the environmental pollution by traffic and is able to evaluate the impact of the driving behaviour on the vehicle exhaust emissions.

But still there are some aspects that need to be considered when applying this methodology. Firstly, for future use trip detection needs to be done automatically based on the GPS records in stead of using the trip timings of the respondents to link the data. This method will increase the accuracy of the results since the notes of trip timings by respondents aren't very accurate. Secondly, the emissions are calculated assuming only one vehicle type for all the recorded speed profiles. This assumption needs to be validated since changes in vehicle type have an impact on emission simulations. On the other hand, the use of only one vehicle type offers advantages for the analysis excluding the influence of the vehicle type. Another aspect that needs our attention deals with gear changing behaviour. When calculating the emissions, we have used the default gear changing values provided within the VeTESS model. Since gear shifting behaviour can have a great influence on the emission exhaust, this needs to be taken into consideration. If possible, future research could include an in-vehicle tool recording this information.

The first results from the small scale survey demonstrate the application of the developed methodology but real explications of the calculated values will require more data. Future research will therefore also include a large scale survey.

5 – CONCLUSION

This paper demonstrates the methodology to link trip information to driving behaviour and emission estimates. This method includes the completion of an activity-based survey, collecting activity diary data, extended with a GPS tracking technology to examine the relationship between the purpose of a trip and other parameters like the average positive acceleration or the average emission factor. Differences were found between the emission values of commuter trips and trips with other purposes, but more data are needed to acquire meaningful results. Future research will therefore include the application of the developed methodology on a large scale survey.

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Table 1.The EURO III diesel car in the VeTESS emissions model (Beevers and Carslaw, 2005).
Tableau 1. La voiture diesel EURO III dans le modèle d'émissions VeTESS.

Make of car	**Skoda Octavia 1.9 Tdi**
Engine size	1896 cm^3 diesel engine
Fuel system	Direct injection
Euro class	EURO III certified
Max. power	66 kW at 4000 rpm
Max. torque	210 Nm at 1900 rpm
Engine aspiration	Turbo + intercooler
Exhaust gas recirculation	Yes
Emissions control device	Oxidation catalyst

Table 2. Driving pattern parameters for the study.
Tableau 2. Les paramètres de conduite pour cette étude.

Driving pattern parameter	**Denotation**	**Unit**
Average speed	v_{avg}	km/h
Average positive acceleration	a^+_{avg}	m/s^2
Relative positive acceleration	RPA	m/s^2
Percentage of stop time	PST	%

Table 3. Total emissions and fuel consumption. Averages per trip and per trip purpose.
Tableau 3. L'émission totale et la consommation. Les moyennes par trajet et par destination.

	Distance (km)	**Fuel (l)**	**CO_2 (g)**	**CO (g)**	**NO_x (g)**	**HC (g)**	**PM (g)**
commuter	17.72	1.13	2963.95	0.60	13.97	0.12	1.48
other	8.32	0.53	1385.91	0.32	6.37	0.07	0.69
p-value	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05

Table 4. Emission factors and fuel consumption. Averages per trip and per trip purpose.
Tableau 4. Les facteurs d'émission et la consommation. Les moyennes par trajet et par destination.

	Distance (km)	**Fuel (l/100km)**	**EF CO_2 (g/km)**	**EF CO (g/km)**	**EF NO_x (g/km)**	**EF HC (g/km)**	**EF PM (g/km)**
commuter	17.72	7.23	188.86	0.06	1.02	0.01	0.09
other	8.32	7.09	185.15	0.05	0.94	0.01	0.09
p-value	< 0.05	0.53	0.51	0.39	0.09	0.15	0.79

Table 5. Driving parameters. Averages per trip and per trip purpose.
Tableau 5. Les paramètres de conduite. Les moyennes par trajet et par destination.

	v_{avg} (km/h)	**a^+_{avg}**	**RPA**	**PST**
commuter	39,20	0,64	0.25	24.29
other	33,30	0,60	0.23	24.66
p-value	<0.05	0.10	0.13	0.85