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Cross-border Car Traffic in Dutch Mobility Models

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Cross-border travel generates a substantial amount of mobility near the borders, but is not a large percentage of total Dutch mobility. However in the border regions of the country, these flows are important. For the Dutch national transport model LMS, O-D matrices are required that include cross-border car travel. This is a challenging task, due to scarcity of data. First, a production model (by travel purpose) is used to calculate the total production of car journeys. Next, these journeys are distributed over domestic and foreign destinations using a simplified destination choice model. From the resulting matrix, domestic journeys are removed and only the border crossing journeys are kept. Domestic journeys are then replaced by the results of the existing much more detailed mode-and destination choice models.

The new models are estimated on the Dutch national mobility survey (MON) and are of reasonable quality. The predicted numbers of border crossing journeys to Belgium and Germany are lower than the numbers from traffic counts, and therefore an additional calibration to count data totals is carried out.

The results indicate that for commuting the resistance to cross the border is equivalent to 35 (Belgium) or 46 (Germany) minutes extra travel time. Also for all other travel purposes in the model, it is found that the border resistance for journeys to Belgium is smaller than that for journeys to Germany, which can be explained by the additional factor of language difference. The smallest border resistance for both countries is found for shopping journeys.

Keywords: cross-border mobility, border crossings, transport models, border resistance

1. Introduction

This paper deals with a small, but non-negligible issue in national and regional traffic modeling: border crossing passenger traffic by car. In what follows, first some figures will be given for cross-border mobility of the Dutch population. Next, a simple model will be presented, together with its embedding in the existing national and regional models. The model only deals with car

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traffic on an average working day, excluding other modes like airplane. Trips that take place completely in a foreign country and holiday trips are not modeled either.

The question that this paper deals with is how border crossing car traffic can be included in national and regional traffic models for the Netherlands. Most traffic models in Europe deal with trips on an average working day and only a small part of these trips are cross-border. But even in a small country like the Netherlands, with lots of "abroads", border crossing traffic is only a tiny percentage of all trips. Traditionally, the traffic volumes on border-crossing roads are much lower than on domestic roads and hence there are not many congestion problems.

There are, however, two good reasons to deal with these trips. In the provinces close to the border the relevance is obviously larger: particularly in the province of Limburg, which is a kind of "peninsula" between Belgium and Germany. Also in the province of Zeeland border crossing travel is substantial: where the Southern part of the province, Zeeuws Vlaanderen, borders on Belgium, it is only accessible from the rest of the Netherlands by a tunnel and by a ferry for cyclists and pedestrians only. The first aim of this article is therefore to include cross-border mobility in the national travel model.

In traffic modelling, the country's borders are also relevant for *non*-border-crossing trips. Most models, even disaggregate ones, are basically of the gravity type. Near borders, the conventional gravity-based description breaks down, because the border acts as a much bigger deterrence than expected on the basis of travel impedance in terms of travel times and costs. The second aim is therefore to determine the resistance of the borders.

1.1 Cross-border mobility in figures

Cross-border travel generates a substantial amount of mobility, but is not a large percentage of total Dutch mobility. Important categories, when travel purpose, mode of transport and geographical area are taken into account, are holiday travel, business travel and border-crossing commuting.

The population of the Netherlands (NL) consist of roughly 16.5 million people. In 2008 the Dutch made 35.9 million holidays, of which 18.4 million, or 51,3%, abroad. In 54% of the holidays abroad, the private car was used, air travel made up 34% of the total, rail 4%, and coach 5% (CBS Statline, website).

For travel abroad other than holidays, the dominant data source is the annual Dutch National Travel Survey (Mobiliteits Onderzoek Nederland, abbreviated as MON). Trips are recorded in trip diaries during one day. Holiday travel and, as goes without saying, trips that take place completely in a foreign country, are excluded from MON. Of trips originating from or terminating in NL only the domestic kilometrage is included in the statistics. The destinations of those trips, however, are coded, and they are kept in the survey database.

Based on MON 2007[4], less than 1% of all trips cross the Dutch border, less than 160 thousand trips per day. By far the main number of these, 77%, use the car. With 8%, the plane takes second place. The distribution of border crossing trips between travel purposes over all modes is: commuting 4%, business 10%, shopping 1.5%, social visits 6%, recreation 53%, touring/walking 25% (Rijkswaterstaat, 2008).

Given that commuting trips are performed every working day, the percentage for cross border commuting to Germany or Belgium is surprisingly low. No data are available on commuting in the other direction: Germans or Belgians working in NL, or Dutch living abroad (for tax reasons or cheaper housing prices) and working in their motherland.

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[4] More recent MON data, 2008 or 2009, is not publicly available. From 2010 onwards the data collection methodology has changed.

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1.2 Border crossing car traffic in other transport models

National and regional models usually treat cross-border traffic in a very rudimentary fashion or ignore it altogether. An important exception are models that focus on international corridors, such as the models for the Fehmarn Belt (Fehmarnbelt Traffic Consortium, 1998) between Denmark and Germany and the Øresund (Øresundkonsortiet, 1999; Petersen, 2004) between Denmark and Sweden. The estimation of these models was only possible because of targeted data collection, including many interviews with travelers intercepted on the corridor.

For the Swedish national and regional system of models for passenger transport SAMPERS, special modules for domestic long distance and for international travel were developed. The latter module (HCG, 2000) includes models for travel by Swedish residents to the rest of Europe and for European foreigners to/from Sweden. The module includes mode/route choice models (with choice alternatives such as air, car, train, but also different ferry routes) as well as frequency models for international trips. The data sources used were those collected for Fehmarn Belt and Øresund and the Swedish national travel survey (Riks-RVU), but the latter only for the trips by Swedish residents.

The German national transport model (BVWP model; ITP and BVU, 2007) includes trips from Germany to other countries, from other countries to Germany and transit that could use German infrastructure. One of the data sources used was again that collected for Fehmarn Belt, together with similar surveys for travel to/from Austria and France.

Furthermore, there are transport models at the European level, which by nature deal with cross-border travel. The latest version of the European Transtools model (Tetraplan et al, 2009) contains modules for short distance travel and for long distance travel. The latter was estimated on the European long distance travel survey DATELINE.

For trips between NL and Belgium and between NL and Germany (as for most relations between countries in Europe), no specific large surveys such as those for Fehmarn Belt or Øresund are available, and DATELINE does not provide sufficient specific information on this either. Therefore in modeling cross-border traffic in the Dutch national model, we had to rely on national survey data (besides traffic counts at the border).

2. The Dutch National Model

For strategic decision making on national transport, the Dutch National Model System (Dutch abbreviation LMS) is in use (DVS, 2011; Significance, 2011). Besides the LMS, there is also a set of four regional models (Dutch abbreviation NRM) in the Netherlands, their main aim being to provide inputs for transport scheme appraisal of infrastructure projects. NRM follows the same structure as the LMS, but contains more detail in terms of number of zones, networks and level-of-service.

The principal objective of the LMS, when first developed in the eighties, was to make provision for the preservation of access for strategic road and rail links that were then yet to be developed. It had to be *national* because it was used for a national document on transport policy, the so-called Structure Scheme for Transport (SVV2). At a later stage, it became an important tool for the development of a national environment plan, and also found use as a forecasting tool for the Dutch national railways. A twenty-five year time horizon was originally set, having the year 2010 as the reporting year. In current applications, the furthest away future year is 2030.

The model system addresses both passenger and freight, but the focus is essentially on the passenger side. Air transport is not included. Travel is represented in the form of home-based journeys for the purposes of forecasting growth and change, but as individual trips for

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assignment to networks. The time period for the models is an annual average day during the working week, for car drivers and train travellers morning and evening peaks are distinguished as well.

In its present form LMS is capable of modelling the following travel dimensions:

- driving licence holding

- car-ownership

- journey frequency for home-based travel, trip frequency for non-home-based travel

- choice of primary destination and mode for home-based journeys and non-home-based trips

- time of day choice for trips

- trip route choice.

The journey concept (in Dutch: tour-concept) has been introduced for reasons associated with behavioural realism; most travel patterns involve leaving the house for one particular activity - be it work, education, shopping or other. Secondary (and subsequent) destinations may be visited in the process, but their frequency (and mode and location) is frequently dictated by the demand for the 'primary destination' and how the choice of frequency, travel mode and destination is resolved for that activity. For this reason, in the LMS each car journey can have up to a maximum of eight trips, four trips on the outbound leg of a journey, and four on the return leg. Time-of-day choice is represented separately for outward and inbound legs; i.e. at a trip level. Finally, growth in journey 'legs' by time of day is used to imply growth in trips recorded in a 'base matrix' of trips, leading to matrix of forecasted trips for assignment.

All of the models share the characteristic of being *logit* models; these models predict the probability of selecting one option from a number of options, according to characteristics of the option and characteristics of the decision maker. The theoretical basis for the models is that they are consistent with the choice mechanism of rational decision makers, given that the factors taken into account in the decision are to some extent unobservable. They do not predict the outcome of a given decision context as a certainty that a particular outcome would be preferred, but as probabilities with which each alternative would be chosen.

The mode, destination and time-of-day choices are modeled simultaneously. These choices dependend on a number of factors such as congestion, which can only be determined after assignment. In the model system this is dealt with by iterating between different sub-models; a 'feedback loop'. The logit models are embedded in a forecasting system, called SES (Sample Enumeration System). For SES a sample of individuals is taken from MON and the models are repeatedly applied to this sample, successively reweighted for every model zone.

The model system is also responsive to different societal developments in terms of licence holding, car ownership or fuel consumption and implications of developments in automotive engineering. The influence of different policies concerning land-use and transport networks, and of different scenarios concerning socio-economic and demographic changes, is also represented.

The current version of the LMS model system covers ten travel purposes:

- home-based work (commuting) journeys

- home-based business journeys

- home-based education (age 12+) journeys

- home-based education (age <12) journeys

- home-based shopping and personal business (age 12+) journeys

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- home-based shopping and personal business (age <12) journeys

- home-based social, recreational and other (age 12+) journeys

- home-based social, recreational and other (age <12) journeys

- work-based business journeys

- work-baded social, recreational and other journeys

Travel modes distinguished in the model system are:

- car driver

- car passenger

- rail

- tram, bus, metro

- cycling

- walking

Destinations are modelled in terms of the 1379 zones distinghuished in LMS. The LMS road network contains roughly 75,000 links in both directions. There is also an explicit train timetable.

The model period is an average working weekday. The following periods are modelled:

- 24 hour day

- AM peak period (07.00 - 09.00)

- PM period (16.00-18.00)

- Off-peak period.

The LMS was designed, primarily by Hague Consulting Group (later RAND Europe, most recently Significance), for the Dienst Verkeer en Scheepvaart (DVS) of Rijkswaterstaat, the public works department of the Dutch Ministry of Infrastructure and the Environment.

3. Submodel for border crossing traffic in the National Model

3.1 General

The objective in LMS is to construct matrices for the base-year, 2004, and the forecasting years (by travel purpose) that include cross-border car travel. This is a challenging task, due to lack of data and a coarse zoning system outside NL. Dutch trips to destinations abroad have been recorded in MON 2004 and 2005 and have been coded at zip code level. But because of the limited sample size and the relative rareness of cross-border trips, there are not many of these in the survey database. Moreover, trips by foreigners to NL are lacking completely and the assumption is made that the behaviour of foreigners travelling into NL is identical to domestic travellers going abroad[5]. This means that for these the same model can be used. Hence, trips by foreigners will be estimated by applying the model to foreign zonal data.

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[5] The assumption of symmetrical behavior can be questioned: Germans and Belgians might experience less or more border resistance than the Dutch. Even within a population the perception of border resistance might differ, for instance, by gender, income or education. An exploration of these behavioral differences goes beyond the purpose of this article. The availability of suitable data to estimate border resistance for different person types will be a major challenge.

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For the forecasting years there is a big problem with the availability of planning data for the zones abroad. The only available data for foreign countries are population, labour force and the number of jobs. Therefore, the number of explanatory variables in the models is kept to a minimum.

First, a production model (by travel purpose) is used to calculate the total production of car journeys. Next, these journeys are distributed over domestic and foreign destinations. For this, a simplified destination choice model and a coarse zoning system are used. In this model, the resistance to cross the border, mentioned in paragraph 1.2 above, is explicitly included. From the resulting matrix the domestic journeys are removed and only the border crossing journeys are kept. The domestic journeys are replaced by the results of the much more detailed SES models.

3.2 Production

For every domestic and foreign zone an estimate of the number of car journeys is needed . The number of travel purposes mentioned above is reduced from 10 to 5: commuting, business, education, shopping, other. Childeren below the age of 12 are not allowed to drive a car and both work-based purposes are assumed to be negligible in cross-border traffic. The car journey rate per person in a zone is dependent upon its population, broken down by gender and age class, or its labour force, broken down by gender.

Table 1. Travel purpose-dependent differentiation in journey rates

Purpose	Average journey rate per person per work day according to the MON 2004	Applied to persons in the
Commuting	0.232	Labour force
Business	0.020	Labour force
Education	0.008	Population
Shopping	0.102	Population
Other	0.180	Population

Additional person or household characteristics like income or car ownership could not be used, because this information is unavailable for Germans or Belgians traveling to the Netherlands.

3.3 Destination choice

3.3.1 Description of the model

Table 2 gives the number of car journeys by travel purpose for an average working day in the MON 2004/2005 and the share of border crossing journeys to the two adjacent countries of the Netherlands (after expansion of the MON sample to population statistics using expansion factors from the MON).

Table 2. Journeys in MON 2004/2005 by travel purpose and % border crossing

Travel purpose	Car journeys	Of which to Belgium	Of which to Germany	Percentage border crossing MON2004 (expanded)
Commuting	18880	63	52	0.54%
Business	1799	25	22	2.46%
Education	616	5	2	1.39%
Shopping	9013	21	60	0.97%
Other	15532	71	49	0.82%

Because data for zones abroad are not available to the same extent as for domestic zones, a simplified Multinomial Logit destination choice model is estimated. To be able to estimate the

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effects of the border, the model is estimated on the basis of all journeys, domestic and cross-border. Later, in the forecasting stage, domestic journeys are replaced by the results from the much more detailed SES models.

Table 3 shows the variables in the simplified destination choice model.

Table 3. Variables in the simplified destination choice model

Coefficient	Variable
FFTime	Travel time over the network in minutes
crossBBe	Dummy for crossing the border to Belgium
crossBDe	Dummy for crossing the border to Germany
intraDist	Intrazonal distance in kilometres
Attraction variables (by zone)	
Total number of jobs or total number of jobs in retail or total number of jobs minus those in agriculture	
Total population or population between 15 and 34 years old	

For *destinations abroad*, free flow travel time is used and travel costs are left out of consideration. For *domestic trips* skims are used based on *generalized* travel time, in which travel costs are converted into extra travel times (using the official Dutch values-of-time). The reason for this is that making a detour to avoid congestion increases the fuel costs. For following this procedure, however, the car network should be detailed enough to show alternative routes. For cross-border trips, the network is too coarse to be able to allow for this.

Another important consideration in the model is zone size abroad. Because LMS just models an average working day and does not include holiday travel, the more distant France is a relatively unimportant destination and is only divided into two zones. Belgium and Germany consist of 50 respectively 106 zones. The estimation of the model is based on Dutch data, but applied for both domestic and foreign zones. Therefore, there should be variation in zone size in the estimation dataset. The domestic zones in LMS have been artificially aggregated during estimations only to compensate for the rather homogeneous zone size. For example the Randstad (the densely populated Western part of NL) has been made one zone.

Intrazonal distance is calculated as $0.5*\sqrt{(area/\pi)}$.

3.3.2 Estimation Results

For each destination zone 'z', the following utility (excluding the size variable) is estimated (only the purpose 'commute' presented here):

$$U_z = \alpha \times FFTime_z + \beta_1 \times Intradist_z + \beta_2 \times if(Intradist_z > 1km) + \beta_3 \times if(Intradist_z > 2km)$$
$$+ \beta_4 \times if(Intradist_z > 10km) + \gamma_1 \times if(Dest_z = Belgium) + \gamma_2 \times if(Dest_z = Germany)$$

The model specifications have been tested for commuting first, because this travel purpose comprises the largest number of observations. For all purposes, two functional specifications of time were estimated, a linear and a natural logarithmic form. The best functional specification, in terms of final loglikelihood was selected. Only for commuting the linear form proved to be superior.

The final result after a number of intermediate estimations is given in Table 4. Size variables are used and these have a coefficient constrained to 1.

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Table 4. Model estimation for destination choice models by purpose (t ratios in brackets). Empty cells indicate that coefficients were insignificant.

	commuting	business	education	shopping	other
FFTime	-0.046 (-138.7)				
Log(FFTime)		-2.232 (-64.9)	-2.856 (-38.7)	-3.308 (-121.3)	-2.929 (-180.0)
IntraDist	0.474 (21.9)	-6.914 (-24.3)	-8.424 (-18.8)	-8.094 (-70.0)	-7.934 (-98.3)
IntraDist>1km		9.665 (18.5)	9.722 (12.4)	9.059 (51.2)	9.459 (72.2)
IntraDist>2km	-0.590 (-17.8)	-2.967 (-10.9)	-1.483 (-3.6)	-1.295 (-11.9)	-1.741 (-25.6)
IntraDist>10km	-0.137 (-5.1)			0.150 (2.8)	
CrossBBe	-2.468 (-19.1)	-1.561 (-7.5)	-2.120 (-4.5)	-0.955 (-4.6)	-1.796 (-14.9)
CrossBDE	-2.535 (-17.8)	-2.410 (-10.9)	-3.437 (-4.9)	-0.752 (-5.3)	-2.735 (-18.6)

Different size variables (see Table 3) are tested for each purpose. The size variables that give the highest loglikelihood in the estimations were selected. Table 5 lists the size variables for the five travel purposes.

Table 5. Variables in the simplified destination choice model

Purpose	Size variable
Commuting	Total number of jobs
Business	Total number of jobs
Education	Population
Shopping	Total number of jobs in retail
Other	Total number of jobs + population

All the estimated coefficients in Table 4 are statistically significant, and they have the expected (negative) signs for travel time and border resistance. The negative signs for the border resistance dummies mean that when two destinations are compared that are identical (e.g. same travel time from origin), but for the fact that one is in The Netherlands and the other is in Belgium or Germany, the one in The Netherlands is more likely to be chosen as destination. For four out of five travel purposes – shopping forms the exception- the border resistance to Belgium - where Dutch is spoken in nearly all of the part of the country bordering on The Netherladnds - is less than that to Germany. This may be explained by the the fact that a different language is spoken in Germany.

A striking result is that for shopping one has the least resistance to cross the border, as shown by the coefficients of the border dummies. An explanation can be either that in shopping, the linguistic barrier is less important than in the other travel purposes and/or that some products in Belgium or Germany are cheaper than in the Netherlands and people are willing to travel cross border on order to save money.

3.3.3 Initial validation and forecasting

Given the scarcity of exogenous data and the simplicity of the models, it will not come as a surprise that the validation results are not perfect. They will not be presented in detail here. The model predicts the share of border crossing journeys from MON quite well. However, the predicted number of border crossing journeys is lower than the number of crossings based on traffic counts at the borders. This is due to under-representation of cross-border traffic in MON 2004/2005. As a result, values of the border resistance dummies estimated above will be too low. In the next section of this paper, recalibrated cross border dummies will be reported, i.e. dummies that are calibrated to make the model represent the observed (from traffic counts) number of border crossings to Belgium and Germany.

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3.3.4 Recalibration of border resistance dummies

The traffic count data do not distinguish between travel purposes. In the recalibration to the observed number of border crossings it is assumed that the split over travel purposes was predicted correctly (i.e. the under-representation of international trips in MON is uniform across travel purposes)[6]. The number of border crossings from the count data (88,000 trips on a working day to Belgium and 84,000 to Germany) were used as targets in an iterative calibration procedure. The border resistance dummies before and after recalibration are shown in Table 5.

Table 5. Border resistance coefficients before and after recalibration to count data

	Belgium		Germany	
Purpose	Before recalibration	After recalibration	Before recalibration	After recalibration
Commuting	-2.468	-1.618	-2.535	-2.131
Business	-1.561	-0.702	-2.410	-2.013
Education	-2.120	-1.468	-3.437	-3.571
Shopping	-0.995	-0.117	-0.752	-0.352
Other	-1.796	-0.960	-2.735	-2.340

Recalibrated cross border coefficients are clearly lower than the ones estimated on MON alone, except for the one for Germany for education. All cross border dummies for Belgium – i.e. also those for shopping - are less negative than those for Germany. This is even more so than before, which points to a stronger influence of difference in language than with the uncalibrated dummies.

3.3.5 Cross border resistance expressed in time and money

In the estimated models there are also coefficients for travel time. These can be used to convert the cross border resistance dummies into travel time (minutes). For commuting, where there is a linear time coefficient, border dummies simply are divided by the time coefficient. For the other travel purposes, to which the natural logarithm of time applies, the border dummies are divided by the ratio of the time coefficient to expected travel time. The results for the border resistance expressed in time are shown in Table 6.

Table 6. Border resistance expressed in minutes travel time

	Belgium		Germany	
Purpose	Before recalibration	After recalibration	Before recalibration	After recalibration
Commuting	53.45	35.04	54.91	46.18
Business	36.63	16.48	56.54	47.23
Education	38.87	26.92	63.02	65.48
Shopping	9.00	1.10	7.09	3.32
Other	25.87	13.83	39.39	33.70

Border resistance in minutes can be regarded as additional travel time on top of the standard travel time for a journey. For travel several purposes (commuting, business, education), people are willing to accept a considerably longer journey to avoid crossing the border. For shopping however, the implied dejourneys are quite small. Other travel purposes (social and recreational journeys) have a border resistance of 14 (Belgium) or 34 (Germany) minutes additional travel time.

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[6] Because there is only a very limited number of road-side interviews at the borders available on a national scale, this assumption can't be tested. As the MON data is assumed to reflect the travel behavior of the Dutch population without selection bias, the assumption of uniform under-representation is the most evident.

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On the basis of the number of minutes travel time, also monetary values for border resistance have been calculated. For this, the officially recommended values of time for a car driver for 2010 (8.84 euro/hour for commuting, 30.63 for business and 6.11 for other) (Rijkswaterstaat, 2010) have been used. The outcomes are as given in Table 7.

Table 7. Border resistance expressed in euros (2010)

	Belgium		Germany	
Travel purpose	Before recalibration	After recalibration	Before recalibration	After recalibration
Commuting	7.88	5.16	8.09	6.80
Business	18.70	8.41	28.87	24.11
Education	3.96	2.74	6.42	6.67
Shopping	0.92	0.11	0.72	0.34
Other	2.63	1.41	4.01	3.43

Table 7 shows the extra costs of crossing the border (due to language and cultural differences) on a journey for different travel purposes. If the monetary cost (after recalibration) of crossing the border for commuting – the principal single travel purpose – is multiplied by the annual number of working days, i.e. 233 (Ecorys, 2009), an amount of 1202 euro per year is obtained for Belgium and 1584 euro per year for Germany. So Dutch workers would need a wage premium of these levels in order to make a job in Belgium or Germany equivalent to a job in The Netherlands.

The results from Table 7 can also be used, in combination with the observed annual number of trips from The Netherlands to Belgium and Germany by travel purpose, to calculate the monetised disutility of border crossings to Belgium and Germany. This leads to a total disutility costs of 180 million euro anually.

4. Conclusions

The development of a model that can predict international car traffic is highly dependent on the available data. The main focus of the Dutch national travel survey is on domestic mobility, the number of observations to destinations abroad is low in itself, and when compared to car traffic counts, they are underrepresented. Data of foreigners travelling by car to the Netherlands is lacking in general leading to the strong assumption that their behaviour is similar to Dutch travel behaviour.

Given the data limitations, a simple production-attraction model was developed to estimate the cross-border car traffic which is of importance for regions close to the Dutch borders. Cross-border car traffic will influence congestion in these regions. The second aim of this article was to estimate cross-border resistance to Belgium and Germany. The resistance to cross the border to Germany turned out to be higher for four out of five purposes, most likely due to the linguistic barrier.

To overcome the underrepresentation of cross-border car traffic in the MON border resistance coefficients were calibrated making use of traffic counts. This led to lower values of the coefficients, albeit that the resistance to go to Germany remained higher than to Belgium. The smallest border resistance for both countries is found for shopping journeys.

The results indicate that for commuting the resistance to cross the border is equivalent to 35 (Belgium) or 46 (Germany) minutes extra travel time. Using values-of-time it is possible to monetise border resistance and even value the impact of policies that diminish border resistance,

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for instance the introduction of the Euro or the free movement of persons within the European Union.

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