Distance decay in activity chains analysis
A Belgian case study

H. Hammadou [1,5]
I. Thomas [1,2,3]
D. Van Hofstraeten [4]
A. Verhetsel [4]

[1] *Department of Geography, Université Catholique de Louvain, Louvain-la-Neuve, Belgium*
[2] *Center of operational research and econometrics, UCL, Louvain-la-Neuve, Belgium*
[3] *National fund for scientific research, Brussels, Belgium*
[4] *Departement of Transport and Regional Economics, University of Antwerp, Belgium*
[5] *Departement of Economics, MEDEE, University of Lille, France*

Corresponding address: isabelle@geog.ucl.ac.be
Fax.: 00-32-10-47 28 77

Paper presented at the ERSA 2003 Congres
September 2003 in Jyvaskyla, Finland.

Paper # 119

IMPORTANT NOTE : this is a draft version (31 March 2004) of a paper in progress. Please contact *dries.vanhofstraeten@ua.ac.be* for the latest version of the paper.

Distance decay in activity chains analysis
A Belgian case study

H. Hammadou, I. Thomas, D. Van Hofstraeten and A. Verhetsel

Abstract

This paper deals with the mobility of persons and more particularly with the effect of distance on travel behaviour. More particularly, this activity-based approach aims at measuring, testing and analysing the nature of the relationship between distance and the number of trips and chains performed within 24/48 hours. Two Belgian databases are used: one conducted at a national level (MOBEL), the other at a regional level (OVG Antwerp). An exponential model containing the number of trips (or chains) and the distances covered by the respondents is used. Distance decay analyses are conducted for (1) several transport modes, (2) several trip and chain purposes, (3) different categories of households and (4) different urban levels of the trip and chain destination(s). Significant differences are observed according to individual and spatial characteristics, as well as to the definition of the trip and the chain. Trips/chains made on foot are the most discriminated in terms of distance decay; geographical data such as the level of urbanisation also discriminates distance decays through socio-demographic spatial segregation process. This exploratory data analysis enables one to gain information about the spatial aspects of trips and activity chains, to get a better fit in the gravity type as well as in the further destination choice models.

Keywords

Distance decay, activity-based modelling, spatial analysis, Belgium.

1. Introduction

This paper is part a research project that aims at making a contribution to the modelling and understanding of travel behaviour by adding the spatial dimension to travel resulting from household activities. In view of this objective, this paper aims to make a first explanatory data analysis of a spatial variable, namely distance, in order to describe the distance decay effect for different transport modes, travel purposes, compositions of the household, etc. on the national and the regional level. The emphasis in this paper is on the spatial characteristics of travel. As a result of this distance decay analysis, hypotheses on distance and travel behaviour are formulated to be tested in further modelling and analyses, e.g., destination choice modelling on activity chains.

The research is developed from an activity-based approach to travel. The main idea of the activity-based approach is that travel decisions are activity-based and that any understanding of travel behaviour is secondary to a fundamental understanding of activity behaviour. McNally (2000) sees travel as a physical mechanism to reach an activity site to participate in some activity.

According to McNally (2000) and Bhat *et al.* (2001) the characteristics of the activity-based approach are first of all that not individual trips are the relevant unit of analysis, but patterns of behaviour or the travel-activity pattern. Next, the activity-based approach (ABA) reflects the activities in time and space. They also state that household and other social structures determine travel and activity behaviour. Finally McNally (2000) and Bhat *et al.* (2001) point out that interpersonal interdependencies, location of activity facilities, time of day and the availability and cost of the transport mode constrain activity and travel behaviour.

Travel demand analysis is intrinsically spatial; yet in travel modelling spatial analysis is seldom recognized (Bhat and Zhao, 2002). Bates (2000) pointed out that spatial separation is the essence of travel demand. It is clear that there is a variation in transport demand over time, but there are also spatial implications. We want to insist on the fact that literature is lacking papers on activity chains models including spatial components. Two exceptions are the papers of McNally (2000) and Dijst & Vidakovic (1997). They consider the ‘spatialisation’ of the activities but they do not meet all our expectations.

Trip distance is the key geographical variable and in many travel behaviour research this is the only available spatial variable. Fotheringham (1981) for example pointed out empirical findings suggesting a relationship between distance decay parameter estimates and the spatial structure. Studying the distance decay from an activity-based point of view is one way to introduce the spatial dimension in travel behaviour analysis. In the past, this friction of the distance has only been studied on trips but never on activity chains. The trip, defined as a displacement of a household member from an origin to a (different) destination, is one part of the chain. When analysing only the distance decay for trips you are supposing that the distance of one trip will not affect the following trip in the chain. The question remains whether or not the impact of distance on trips is different from the impact on chains?

Distance decay research aims at measuring and testing the impact of distance in trips and activity chains. According to the 'Dictionary of Geography (Oxford University Press, 1997) distance decay is *"The lessening in force of a phenomenon or interaction with increasing distance from the location of maximum intensity; the inverse distance effect."* Another definition for distance decay is '*the decline of an activity, function or amount of interaction with increasing distance from point of origin'* (Cromley, 2002).

By studying this distance decay effect for trips and activity chains an exercise in modelling a spatial variable, namely distance, is made. The exponential model that is constructed shows to what extent distance determines travel behaviour, particularly how sensitive respondents were in travelling longer distances for different trips and trip chains. Two Belgian databases are used: one conducted at the national level (MOBEL), the other at the regional level (OVG Antwerp 1999).

The structure of the paper is as follows: first we define (1) the methodology, (2) examine our data sets and study areas, followed by (3) the definitions of trips and chains and (4) the problems with the data. Secondly, the main part of the paper is the empirical analysis by means of an exponential model for both trips and chains on (1) several modes of transport, (2) several purposes of trips and chains, (3) different categories of households, (4) different urban levels of the trip and chain destination(s) and finally (5) a cluster analysis on all variables categories. This exploratory data analysis enables one to gain information on the spatial aspects of trips and activity chains.

2. Methodology and data

2.1. Adopted methodology

An interesting conventional model in transportation studies that focuses on the relationship between distance and interaction is the *gravity model* (1). A gravity model is any type of model that expresses interaction between two places as a function of the size of the two places and the distance between them. It uses for example trip origins and trip destinations as two masses:

$$I_{ij} = a \frac{o_i d_j}{D_{ij}^{\,b}} \qquad (1)$$

where I_{ij} is the interaction, o_i is the number of trips leaving zone i and d_j the number of trips terminating in zone j. The formula the number of trips is divided by the distance D_{ij}, because of the inverse relationship with interaction. The constant a is there to have a useful measure of interaction (otherwise you would have square people per square mile). The exponent b for the distance can be interpreted as the *friction of distance*.

Next to gravity models, more recently the relationship between distance and spatial interaction has been put forward by a power deterrence function (Pareto) and an exponential deterrence function. Both functions also contain a parameter b representing the sensitivity of the interaction volume with respect to physical distance (Glenn et al, 2000, p.2).

This is the formula for the power function (also known as the Pareto model)(2):

$$I_{ij} = aD_{ij}^{-b} \qquad (2)$$

where I_{ij} is interaction, D_{ij} is distance and a and b are constants (Haynes, 1974). However, it was subjected to some theoretical criticism. It is said that the model falls short of accurate data description: the model overestimates close and distant contacts and underestimates at medium distances (Hägerstrand, 1957). Wilson (1967) shows an exponentially and negatively related distribution of trips between zones. Other models have been developed: Gaussian distribution, log normal,… (for more details see Taylor, 1975).

The exponential model (3), however, is left as the most reliable approach for distance decay (Haynes, 1974). That is why, further on in this paper, the exponential model is used to study the distance decay in trip and chain approach. The model has the form:

$$I_{ij} = ae^{-bDij} \qquad (3)$$

where I_{ij} is the interaction, D_{ij} is the distance, *a* and *b* are constants and *e* is the base of the natural logarithms. The basic parameters are the regression coefficients (also called *the distance gradients*) indicating the amount of interaction intensity that falls with one unit of distance (or *the distance decay*) (Taylor, 1975, p.28). Highly negative parameter estimates indicate that distance is perceived to be a strong deterrent to interaction; slightly negative estimates indicate a weak deterrent to interaction (Fotheringham, 1981, p.425). Fotheringham also points out some empirical findings suggesting a relationship between distance decay parameter estimates and the spatial structure. First of all, as the accessibility of an origin declines, the parameter becomes more negative. Secondly, the parameter should be fairly constant in a relatively homogeneous society. Most of the times, this is not the case (Fotheringham, 1981, p.428). Next, it is said that positive estimates of distance-decay parameters are only occasionally reported. This means that as distance increases, the interaction increases too, which only occurs in very accessible areas. Fourthly, less accessible origins have greater mean trip lengths and more negative parameter estimates. Finally, the value of the parameter estimates themselves can indicate a relationship. Less negative parameter estimates indicate active long distance interaction, while more negative estimates indicate a more passive long distance travel behaviour.

The estimation of this model can be done in two different ways. First of all directly, by using non-linear estimation techniques such as the maximum likelihood or the non-linear least-squares. On the other hand indirectly, by using a logarithmic transformation of the model leading to a classical linear model that is easily estimated by ordinary least-squares.

In fact, it is tested whether or not the distance decay parameter *b* varies significantly with the characteristics of trips and activity chains, trip purpose, mode of transport, household composition and urban level of the residential location and the destination(s). Therefore a maximum likelihood test is used. Graphical outputs (i.e. the distance decay curves) are presented to visualise the hierarchy of trips by sensitivity to distance.

In this section it is demonstrated that the exponential model is chosen to obtain the necessary distance decay parameters. In the following section, data sources and study areas are explored to be able to select the appropriate data to put in our exponential distance decay model.

2.2. Study area and data sources

Two Belgian databases are used: one conducted at the national level (MOBEL), the other at the regional level (OVG Antwerp 1999). The dataset at the regional level - OVG Antwerp - is part of the Flemish Travel Behaviour Research-project (OVG) which consists of nine data sets: seven at the level of city regions and two at the Flemish level. The data set of MOBEL (1999) was the first Belgian national household mobility survey (Hubert and Toint, 2002).

One difference between the regional OVG survey and the national MOBEL survey is that in the regional survey respondents are concentrated in the Antwerp city region. The travel and activity patterns that result from this survey mostly take place in the Antwerp city region (Tindemans *et al.*, 2003). On the contrary, since the MOBEL survey on the national level includes different urban and non-urban areas, travel and activity patterns in this data set are spread out over the entire Belgian area. The second difference between both surveys is that respondents of the national survey had to fill the activity diary for only one day while the regional survey was based on household activity diaries for two consecutive days. This leads to the fact that for OVG Antwerp fewer persons are making more trips than compared to MOBEL. Consequently, in the OVG Antwerp survey 5248 persons in 2527 households performed 30 462 trips (Tindemans *et al.*, 2002), while in the MOBEL survey 7027 persons in 3063 households performed 21 093 trips (Hubert & Toint, 2003).

Both surveys also have resemblances: each survey is based on household activity diaries containing an extensive description of socio-demographic characteristics of the households and of each individual, as well as a travel diary filled in by all members of the household over the age of five. These characteristics can be grouped into three broad categories (Toint & Cirillo, 2001):

1) background information on the household (e.g. household structure, household location, household resources, i.e. means of transport and their use);

2) background information on individuals (e.g. year of birth, gender, education level, driving licence);
3) description of each trip including information on associated activity (e.g. street name, zip code, hour of departure and arrival, distance, time, means of transport, purpose, etc.).

Table 1 and *2* give a good indication of the difference between the study areas on the national and the regional level. The household survey of OVG Antwerp was organised on a local scale, namely the city region of Antwerp (*see table 1*): 90% of the trips in the data set are made by respondents in the agglomeration of Antwerp. The agglomeration is the urban area that consists of the city centre (or the hart of the city), the 19th century area (or the densely built-up areas surrounding the city centre) and the suburbs (or the more recent less dense extensions)(see also Van der Haegen *et al.*, 1996). Finally, in the urban fringe of Antwerp (or the vaster residential urban growth zone) approximately 500 respondents filled in the activity diary. The MOBEL dataset (*see table 2*) has respondents over the entire Belgian area. Here also respondents of the commuter residential areas (or the communities characterised by a high commuting interaction with one specific city region) and outside the Belgian urban areas (i.e. rural communities that are not linked to one or another city region) are questioned (see Van der Haegen *et al.*, 1996).

Both the travel data set of MOBEL and OVG Antwerp are structured as a trip data table: each row represents a trip and has values and categories for different spatial, household, personal and travel variables. The following section defines trips and chains and the different approaches that result from these definitions.

Table 1: Number of trips and number of respondents per type of urban zone – OVG Antwerp

Metropolitan areas of Antwerp data	Number of trips by respondents of the metropolitan area	% of trips by the respondents of the metropolitan area	Number of respondents
Antwerpen agglomeration	27533	90,4%	4752
Antwerpen city centre	*1031*	*3,4%*	*197*
Antwerpen 19th-century area	*9516*	*31,2%*	*1505*
Antwerpen suburbs	*16986*	*55,8%*	*3050*
Antwerpen urban fringe	2929	9,6%	496
Total	30 462	100,0%	5248

Table 2: Number of trips and number of respondents per type of urban zone – MOBEL

Urban zones of MOBEL data	Number of trips by respondents of the zone	% of trips by the respondents of the zone	Number of respondents
Brussel agglomeration	5983	28,4%	2051
Brussel urban fringe	1043	4,9%	325
Brussel commuter residential areas	1319	6,2%	465
Other agglomerations	4646	22,0%	1511
Other urban fringes	1817	8,6%	576
Other commuter residential areas	1589	7,5%	542
Outside urban areas	4696	22,3%	1561
Total	21093	100,0%	6738

2.3. Trips and Chains

In our first approach of the distance decay, the **trip** is the unit of analysis; in the second approach the unit of analysis is **tours** or **chains**. McNally (2000) defines the tour or the chain as the combination of all trips performed by an individual starting from a given base (usually home or workplace) until the considered individual returns to this base. A 2-trip chain for example contains two trips, two trip purposes, two distances,… e.g. Home-Work-Home. It is however still possible to go one step further: the **activity-based approach** (or day-based approach) based on the notions of activity programs and activity schedules. An activity program is an agenda of activities by a household member over a particular time period (usually one day) along with all the attributes (mode, duration,…). *Figure 1* gives an overview of the three approaches.

Figure 1: Three approaches to travel and activity pattern analysis

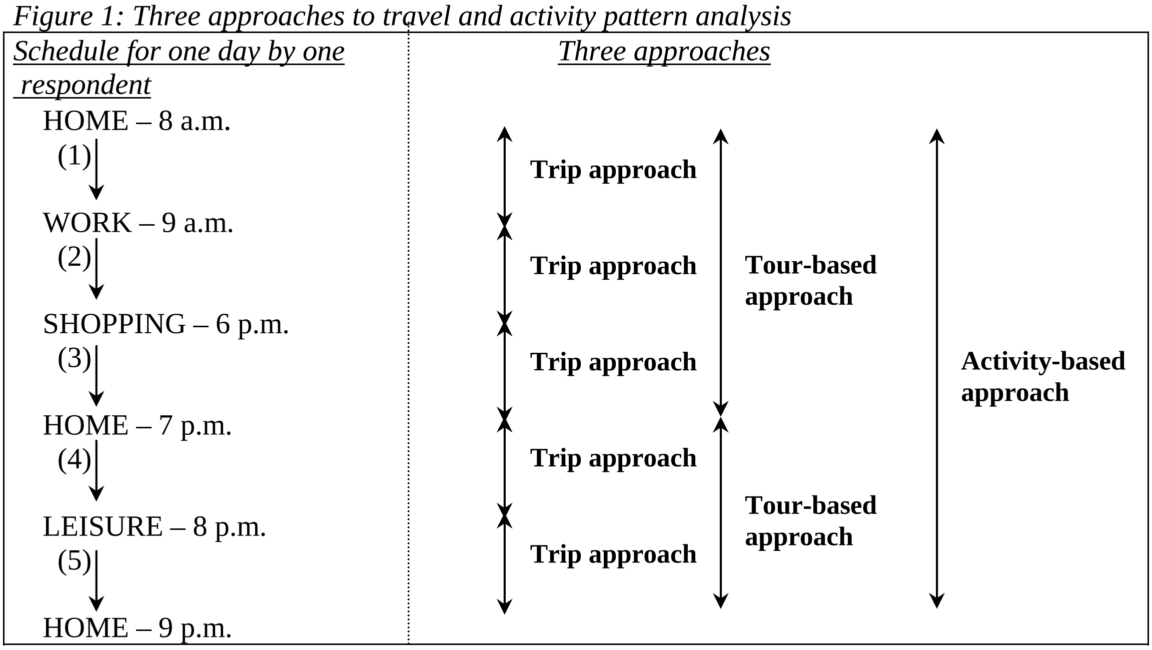


Table 3 represents the distribution of the number of different chain types over the tour-based and the activity-based approach for OVG Antwerp and MOBEL. In the two surveys the number of trips in chains in the activity-based approach and the tour-based approach have more or less the same distribution. This means first of all that the trip and chain distribution of the survey on the national level is similar to the survey on the regional level. Secondly studying the distance decay effect from a tour-based approach is less complex than from an activity-based approach. In order to simplify the structure of trip chaining only chains that contain less than 4 trips are analysed. Some authors (see e.g. Hensher & Reyes 2000) suggest to simplify the chain of activities by – for instance – reducing the number of purposes or the number of transport modes and hence by reducing the size of the chains (i.e. limiting the chains to 4 or 5 trips). For the activity-based approach only 70% of the chains remain; for the tour-based approach 90% of the chains can be analysed.

Table 3: Number of chains (activity or day based method versus tour approach)

Chain Type	**Activity-based approach**				**Tour-based approach**			
	OVG Antwerp		MOBEL		OVG Antwerp		MOBEL	
	N	%	N	%	N	%	N	%
1-trip	58	0,7%	291	5,4%	234	1,2%	172	2,1%
2-trip	3960	45,5%	1877	35,0%	8740	70,7%	5309	64,8%
3-trip	1082	12,4%	587	10,9%	1912	15,5%	1346	16,4%
4-trip	1662	19,1%	1003	18,7%	860	6,9%	768	9,4%
5-trip	647	7,4%	408	7,6%	348	2,8%	301	3,7%
6-trip	554	6,4%	430	8,0%	140	1,1%	126	1,5%
7-trip	277	3,2%	260	4,8%	62	0,5%	73	0,9%
8-trip	194	2,2%	204	3,8%	34	0,3%	43	0,5%
9-trip	100	1,1%	114	2,1%	13	0,1%	29	0,3%
10-trip	131	1,5%	69	1,3%	17	0,1%	13	0,2%
11-trip	30	0,3%	49	0,9%	-		7	0,1%
12-trip	-	-	79	1,5%	-		7	0,1%
	8695	100,0%	5371	100,0%	12360	100,0%	8194	100,0%

One group of variables used for the study are the characteristics of the trip and the chain of activities. There is a problem to segment trips and chains for these kinds of variables. Here trip chaining modelling techniques have to be used: what is the purpose of a trip when the chain of activities includes several different purposes? This question remains the same for all the other variables concerning the characteristics of the trip (transportation mode etc). Here the same problem occurs as above mentioned on the complexity of the activity chain. Less complex chains must be obtained by defining one simple characteristic. In *figure 2* an example of this application is given. A chain containing only work trips (without taking into account the number of trips in the chain) receives the single characteristic ‘work’. When work and shopping are the only purposes in the chain (without taking into account the order in the chain and the number of trips in the chain), the characteristic retained is ‘work-shopping’. Since the temporal dimension of the activity chain is not taken into account to study the distance decay, it is possible to adopt this methodology.

Table 4: Characteristics of complex chains

Chain type	Complex Chain	Characteristic retained
2-trip chain 3-trip chain	HOME → WORK → HOME HOME → WORK → WORK → HOME	**Work**
3-trip chain 3-trip chain	HOME → WORK → SHOPPING → HOME HOME → SHOPPING → WORK → HOME	**Work – Shopping**

In the previous section the difference between the trip, chain and activity-based (or day-based) approach is demonstrated. To obtain the best results, distance decay analysis is made on the trips and chains in the travel data sets. When analysing chains, to each chain a single characteristic has to be assigned to obtain less complex chains. In the following section some data set problems are explored together with the solutions to correct them.

2.4. Assessing data set problems

Other chain data issues are elaborated namely the problems of rounding in the reported distance (2.4.1) and of incomplete chains (2.4.2).

2.4.1. Rounding distances

The distance reported by the respondents in the MOBEL and OVG data is often a multiple of 5 (modulo 5). This is a phenomenon that occurs very often when treating data that result from revealed preferences and it can not be ignored (Rietveld *et al.*, 1999). Rietveld (1999) estimates the reported distances resulting from surveys for different distance definitions: network distance, distance as the crow flies,… He introduces different ways to correct the problem of rounding distances, but his methodology can not implemented to our data because they do not include these different distance definitions.

However, since there is a possible risk to obtain a bias of estimation on the distance decay models and to affect the analysis of the likelihood ratio test, we have to find another solution to this problem of rounding distances.

To measure the importance of this bias, an estimation without modulo 5 is made and afterwards the model is compared with one containing modulo 5. Finally a test is included to check whether or not there is a significant difference between the parameters estimated by these two models.

Table5a : Results of estimation of the model of distance decay and likelihood ratio test

Distance decay	a	t_a	b	t_b	R^2
Model with modulo 5	3857	26,53	-0,224	-21,07	0,94
Model without modulo 5	4214	44,44	-0,271	-33,78	0,98
Likelihood ratio test					
H0 : $a_{with\ modulo\ 5} = a_{without\ modulo\ 5}$					
Likelihood ratio	*34,45 >* $\chi^2(1) = 3,84$		*We reject hypothesis H0* k_i *is significantly different*		

The estimated coefficients differ significantly. The model with modulo 5 tends to underestimate the friction of the distance on the number of trips. On the other hand for the model without modulo 5 there is an overestimation of the parameters. It implies that the true value of this parameter must be between 0,271 and 0,224 and certainly closer to the second coefficient. A statistical investigation would be needed to check econometrically whether this suspicion could be confirmed or not. In the current state modelling the distance by leaving modulo 5 present can not be pursued. It is necessary to fix a temporary rule of correction for modulo 5.

Our solution consists in replacing modulo 5 by an average. Choosing between the two following averages is possible:

$$Y_{distance\ modulo\ 5,\ i} = (Y_{distance\ modulo\ 5,\ i-1} + Y_{distance\ modulo\ 5,\ i+1})/2$$

$$Y_{distance\ modulo\ 5,\ i} = (Y_{distance\ modulo\ 5,\ i-1} + Y_{distance\ modulo\ 5,\ i} + Y_{distance\ modulo\ 5,\ i+1})/3$$

So by using this solution we can reduce the bias of estimation of distance decay.

Rounding distances might modify the conclusions of the likelihood ratio test. The likelihood ratio test allows analysing whether or not the frictions of the distance differ significantly for different characteristics of households and for different spatial, purpose and mode characteristics of the trips and the chains. In Table 5b it is tested whether or not the friction of the distance is the same according to the gender on data with modulo 5 and corrected data.

Table 5b: Likelihood ratio test for gender

Likelihood ratio test for gender			
H0 : $a_{men} = a_{women}$	Data with modulo 5	First correction	Second correction
Likelihood ratio	*31 > $\chi^2(1)$= 3,84*	*35 > $\chi^2(1)$= 3,84*	*36 > $\chi^2(1)$= 3,84*

The results of the tests of likelihood ratio do not change and lead to a significant difference in friction to distance between men and women. The likelihood ratio can be used to analyse whether or not the friction to distance differs significantly for different variable categories. The same exercise is made for all the variables that are included in this paper and similar results can be found.

2.4.2. Incomplete chains: trips not finishing at home

In the original data of MOBEL there were more than 800 chains that did not finish at home[1]. This means that these chains were incomplete and the total distance of the chain was incorrect. When chains are not corrected, it can cause a bias of estimations that can not be eliminated because a maximal number of chains has to be retained to study the distance decay.

The solution focuses essentially on the analysis of the last trip purpose[2]. Indeed, for the trip purpose 'walking' it is quite logical that the destination is by default the place of residence. On the other hand for work trips, it has to be noticed that certain individuals that work during the night do not return to their place of residence at the end of the day of departure. They return home on day 2. It is necessary to define a general rule that allows reconstituting a maximum of incomplete chains. This rule consists in filling in the missing distance of the return-home trip by that of the identical leaving-home trip (if it exists in the chain). *Figure 3* below makes it clearer.

Figure 3: Reconstituting incomplete chains

Incomplete tour : Home —1,2 km→ Work —4 km→ Shopping —2 km→ **Work** —**? km**→ **?**

Solution : Home —1,2 km→ Work —4 km→ Shopping —2 km→ **Work** —**1,2 km**→ **Home**

Table 5 is the result that can be obtained after correcting the maximum of the incomplete tours in the data set. It represents the chains that finish and do not finish at home before the end of the day for OVG Antwerp and MOBEL. In total it can be noticed that in 4% to 7% of the cases, chains do not finish at home and it is impossible to fill in the missing distance. In conclusion, total distances of more than 90% of all

[1] representing more than 10% of the chains in the MOBEL data
[2] see also Table 15A in annex for the distribution of the purpose of the trips not finishing at home

the chains in the data set are ready to be put into our exponential model on distance decay.

Table 6: Trips (not) finishing at home by number of trips in the chain

Chain Type	Finish home MOBEL		Not at home MOBEL		Finish home OVG Antwerp		Not at home OVG Antwerp	
1-trip	146	84,9%	26	15,1%	232	99.1%	2	0,8%
2-trip	5113	96,3%	196	3,7%	8207	93.9%	533	6,1%
3-trip	1289	95,8%	57	4,2%	1746	91.3%	166	8,7%
4-trip	732	95,3%	36	4,7%	779	90.6%	81	9,4%
5-trip	288	95,7%	13	4,3%	307	88.2%	41	11,8%
6-trip	124	98.4%	2	1,6%	123	87.9%	17	12,1%
7-trip	70	95.9%	3	4,1%	50	80.7%	12	19,3%
8-trip	41	95.3%	2	4,7%	30	88.2%	4	11,8%
9-trip	26	89.7%	3	10,3%	10	76.9%	3	23,1%
10-trip	11	84.6%	2	15,4%	14	82.3%	3	17,6%
11-trip	7	100%	-	-	-		-	
12-trip	3	42.9%	4	57,1%	-		-	
	7850	95,8%	344	4,2%	11498	93.0%	862	6,9%

It is clear that before running the model on the travel data that resulted from the household activity diaries, these data issues first had to be clarified. It is now time to start off with the empirical analysis.

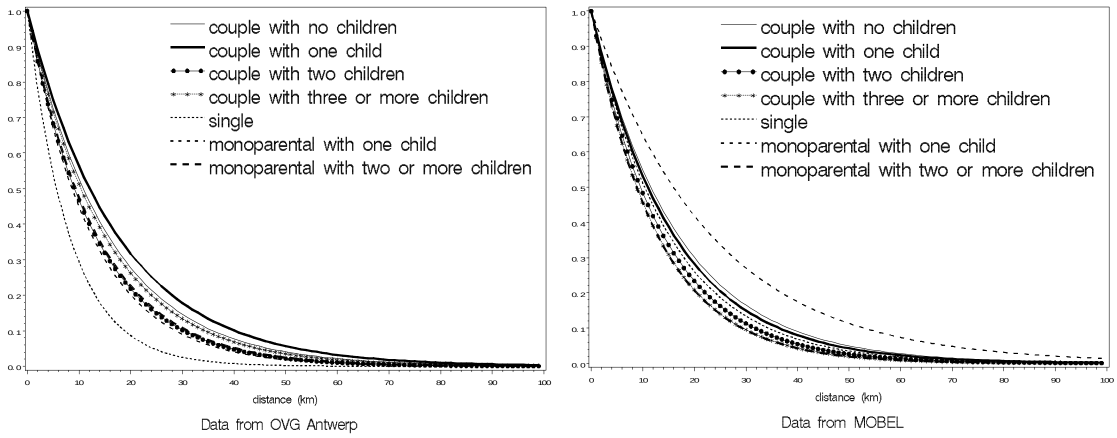
3. Empirical analyses

In this section the results of the distance decay analyses are elaborated for five travel behaviour variables: household composition, urban level of the household residence, urban level of the destination, travel purpose and transport mode. As it is stated in section 2, the distance decay model has parameters that indicate the friction to distance for each subgroup both for MOBEL and OVG Antwerp. All distance decay parameters are in annex (*tables 1A to 4A*); the most interesting parameter in these tables is *b*, representing the sensitivity to distance. In the first step of this discussion, graphs are included for each variable to present the results for this sensitivity parameter *b*. Since the results of the trip approach do not differ much from the results of the chain approach, the graphs of the chain approach are presented. When parameter values of different variable categories are compared, we refer to the results of the likelihood ratio tests (*tables 5A to 14A)*. These tests indicate whether or not for each variable different categories have a significantly different sensitivity to distance decay, both for MOBEL and OVG Antwerp. Finally, for both the trip and the chain approach and for both the OVG Antwerp and the MOBEL survey a cluster analysis indicates whether or not there are significant differences between categories of the different variables. The objective is to detect groups of variable categories that have a similar friction to distance.

3.1. Household composition

The first variable is the household composition. To each trip a variable has been assigned containing the number of parents and the number of children in the household. Since for this variable the model gives similar results for trips and chains, the chain approach is illustrated by *figure 4.*

Figure 4: Distance decay for the household typology – Chain approach



For the variable 'household composition' on the level of the city region (OVG Antwerp) the distance decay effect of respondents living single is deviating strongly from the other household typologies. For the chain approach this deviation is more remarkable and significant than for the trip approach. Also mono-parental households with children have a high sensitivity to distance in the city region. This might be due to the fact that single parents living in the city are usually poorer, often own less cars and by this are less mobile and use public transport more frequently than couples. On the national level (MOBEL), it can be concluded in general that there is a relationship between the number of children in the household and the friction of distance. The higher the number of children, the higher the sensitivity to distance. Both on the national and the regional level, couples with one child and with no children are the least restricted by distance.

However, apart from the mono-parental households with one child, the MOBEL distance decay parameters for the different household compositions do not differ significantly. So it is not a factor that strongly discriminates the distance decay. On the national level, most household types have very similar distance decay in their trips.

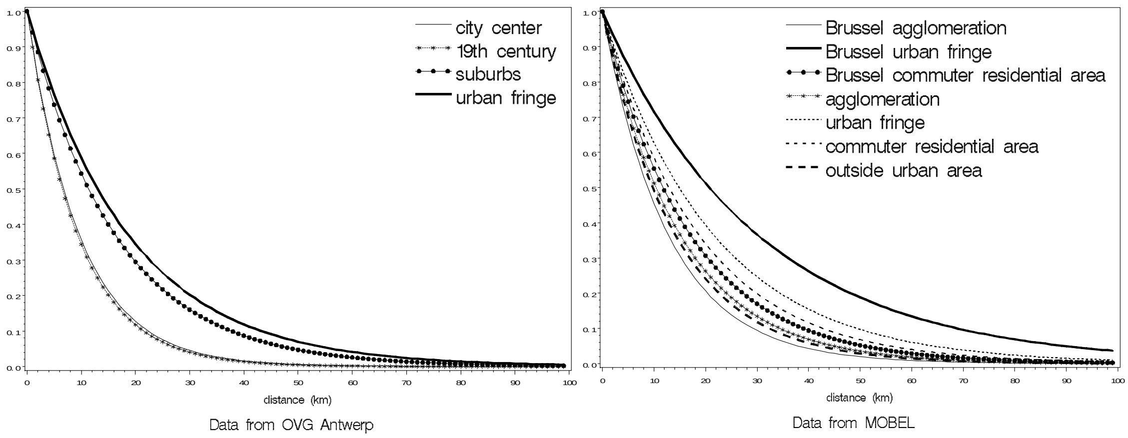
3.2. Urban level

The spatial characteristics of the household location and the destination of the travel can have an influence on the friction of distance. A two-level approach is introduced: first of all analysing the distance decay effect for the variable ‘urban level of the household location’ results in parameters indicating the friction of distance of individuals living in a certain urban or non-urban area. Secondly, the distance decay analysis of the variable ‘urban level of the destination(s)’ gives more information on the distance sensitivity for trips and chains performed in one urban or non-urban area. In other words, household residence and the destinations of the trip or chain are in the same urban area.

<u>3.2.1 Urban level of the household location</u>

To study *the urban level of the household location* for trips and chains, the urban level of the respondents’ household residence is assigned to each trip performed by a respondent. For OVG Antwerp this means one of the four areas of the city region, as defined by Van der Haegen *et al.* (1982): city centre (or the hart of the city region), 19th-century area (or the densely built area surrounding the city centre), the suburbs (or more recent less dense extensions) and the urban fringe (or the vaster residential urban growth zone). Since the MOBEL data are surveyed on the national level, other urban levels are included e.g. agglomeration (or city centre together with the 19th century area and the suburbs), commuter residential areas (or the communities characterised by a high commuting interaction with the central city during morning and evening peaks) and household residences located outside urban areas (i.e. rural communities that are not linked to one or another city region).

Figure 5: Distance decay for the urban level of household location – Chain approach



The distance decay parameter results for both the trip and the chain approach are very similar. Since the differences between the parameters of the variable categories are clearer for chains than for trips, we included the graphs of the chain approach. In the case of OVG Antwerp, *figure 5* clearly indicates that the distance decay performed by inhabitants of both the city centre and the 19^{th} century area have similar distance sensitivity. The likelihood ratio test (*see annex*) indicates that they are significantly similar. Between the distance decay parameters of inhabitants of the suburbs and the urban fringe the similarity is less clear but the likelihood ratio test indicates that both parameters are not significantly different. Living in the central city (i.e. the city centre plus the 19^{th} century area) respondents show more friction to distance than respondents living in outer central urban areas. The higher density of facilities and services and proximity to different activity locations in the central city makes it possible for its inhabitants to perform shorter trips. Outside the central city the density of facilities and services is lower and functions become widespread causing higher distances to activity locations.

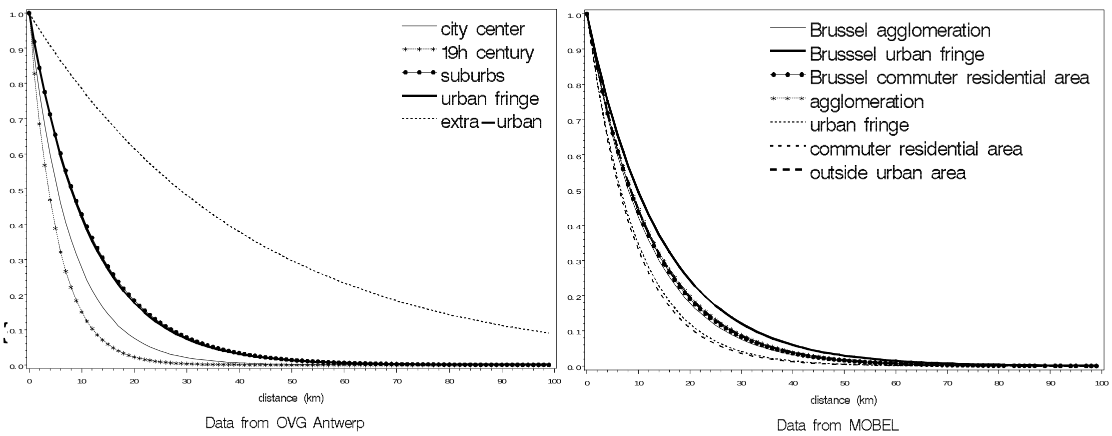
Also in the MOBEL data, the friction of the distance is higher for respondents living in agglomeration that for respondents living in the urban fringe. Commuter residential areas then again show more friction to distance than the urban fringe. Urban fringe inhabitants are less sensitive to distance because they are usually the more richer households, owning more cars, being more mobile, travelling more to different activity locations also located in the city centre. This all results in often longer trips and less sensitivity to distance decay. On the other hand, commuter residential areas are only attracted by the city region for their work activities; for other activities (shopping and leisure e.g.) they are less dependent on the city region and they tend to choose more locally situated activity locations, resulting more often in shorter trips.

3.2.2 Urban level of the destination – Range of activities

Distance decay is now analysed for different categories of destinations: in the case of Antwerp the city centre, the 19th century area, the suburbs, the urban fringe and the area outside the urban region are selected; in the case of MOBEL seven urban levels of the destination can be found. The graphs of the chain approach are included (*see figure 6*).

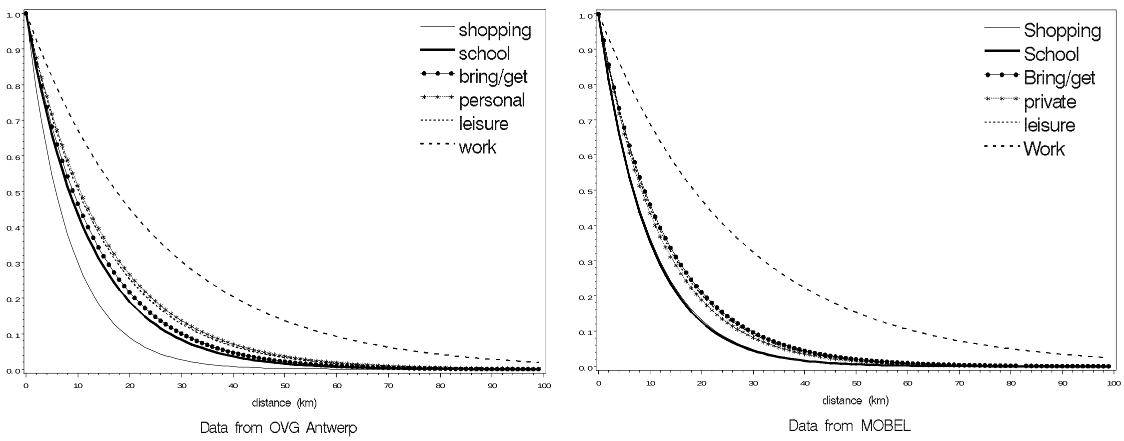
For OVG Antwerp, chains performed in the suburbs and in the urban fringe have a significantly similar friction to distance (*see also likelihood ratio tests in annex*). Between the Antwerp city centre and 19th century area however the similarity is not significant in the chain approach. Where we should expect a higher sensitivity to distance for city centre inhabitants than for inhabitants of the 19th century area, this is remarkably the contrary. When travel purposes and modes of transport of the chains in these two zones is checked, we can find no clear explanations for this deviation. It might be due to the fact that the city centre has a more concentrated specialised land use structure leading to higher distances between different activities, while the 19th century area has a more mixed land use. This hypothesis will be tested in the future when land use variables will be added to our travel data. Next to this, also the deviating distance decay of the chains with destinations outside the Antwerp urban area can be noticed. For the MOBEL data there are two classes that can be defined: the first one (including respondents who move in the agglomeration of Brussels and outside the urban area) is more sensitive to distance than the other (including all the other urban levels of the destination).

Figure 6 : Distance decay for of the destination – chain approach



Let us now analyse the distance decay of trips and chains by their purpose. Figure 7 clearly demonstrates that work has a very deviant distance sensitivity. Respondents show that they are inclined to do longer trips to their job location both on the regional and the national level. It seems that they do not tend to change their job or residential location in order to have to make shorter work trips. On the contrary for shopping, respondents choose to look for nearby locations. The high density of shops and services in the city region lead to shorter shopping trips and chains. The frequency of making long distance shopping trips and chains is rather low. The other purposes (in general we can say these are the leisure-recreation trips) have a similar sensitivity to distance (*see also the likelihood ratio test in annex*). Apart from the shopping purpose, in a general way the two surveys have very similar results on distance sensitivity.

Figure 7: Distance decay for the chain purposes – Chain approach



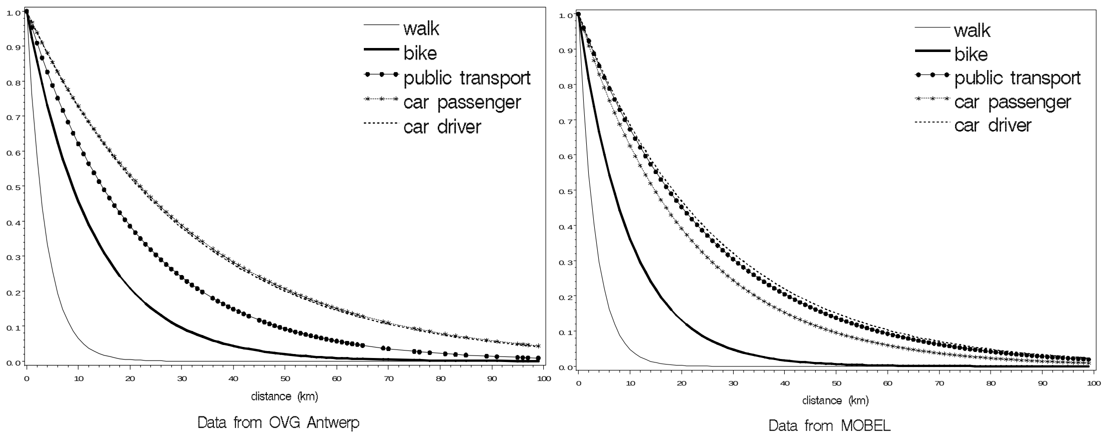
3.4. Transport mode

Finally, the five most frequently used transport modes in personal travel are examined: walking, biking, public transport (i.e. bus, tram and subway) and car (as a driver and as a passenger). *Figure 8* depicts the distance decay parameters for the chain approach. Car driver and passenger have a significantly similar sensitivity to distance (*see annex for significance tests*).

Walking and biking have more friction to distance: it goes without saying that trips made on foot are often much shorter (usually less than 3 kilometres) than all the other transport modes. The friction of distance is strongly linked to the mode of transport that is used. A remarkable split between the slower modes (i.e. bike and on foot) and the faster modes (namely car and public transport) can be noticed in figure

8. The same order of the categories appears when OVG Antwerp and MOBEL are compared. On the national level we see that the respondents who choose to go by public transport are less sensitive to distance than in the city region. The respondents on the national level use more general public transport on longer distances, while in the city region the urban public transport e.g. trams and subways is used for shorter trip and chain distances. In the Antwerp city region, a significant similarity between car driver and car passenger can be noticed, while for the MOBEL data this is not the case: when respondents travel as car passengers they are more sensitive to distance. Maybe this is due to the fact that on the national level activity locations are more divergent.

Figure 8: Distance decay for the mode – Chain approach



3.5. Cluster analysis

This cluster analysis aims at comparing simultaneously the distance decay sensitivity parameter *b* of all the variables. It can also be determined which parameter values of the different variable categories are similar to each other or on the contrary which differ from each other. Using Ward's method, five clusters for the trip and the chain approach can be found. Since not many differences between trip and chain approach can be found, the results of the chain approach are included. *Table 7* presents these results of the cluster analysis for the chain approach using Ward's clustering method on the distance sensitivity parameter *b*. The different clusters that result from the analysis are ordered by increasing sensitivity to distance. Cluster 1 groups the variables with the weakest friction to distance. On the contrary, Cluster 5 has the strongest sensitivity to distance. This last cluster contains the variable categories that are very significantly different from the others. It contains the trips and the chains made on foot with a high sensitivity to distance. In addition, but only for OVG Antwerp and only for the chain approach, this cluster contains also chains with destinations in the 19th century area.

Cluster 1, on the contrary, is a low-sensitivity cluster containing both in the trip as in the chain approach car driver and car passenger trips, destinations outside the Antwerp urban area (for OVG Antwerp) and household residences outside urban areas (for MOBEL data). The difference between the national and the regional level is that for the OVG Antwerp data work and public transport chains are not included in the first cluster of the chains. Clearly, in this cluster chains are included with usually a longer distance. By this the variable categories in this cluster have a low sensitivity to distance.

Cluster 2 includes characteristics with rather average distance decay. The cluster in the case of OVG Antwerp includes leisure, recreation and personal chains and travel performed in the areas surrounding the central city (suburbs and urban fringe). Surprisingly, this cluster also contains work and public transport chains too. The cluster results of the MOBEL data are more difficult to define: not only inhabitants of the urban fringes but also of the agglomerations are included. It contains also single persons and couples without children. Especially in the case of MOBEL, this cluster is a more general group of categories.

For OVG Antwerp Cluster 3 contains households with children going to school, doing trips by bike,… which is a logical cluster. For MOBEL this cluster includes households with many children, living and moving in the agglomeration of Brussels and in commuter residential areas. They all have a higher value of sensitivity to distance.

Cluster 4 is characterised by a high value for the parameter *b* meaning a high friction to distance. For OVG Antwerp this cluster includes shoppers, single persons, destinations in and inhabitants of the Antwerp central city. Contrary to the regional level, for the national data in this cluster the school, walking and bicycle trips can be found.

Table 7: Cluster analysis on the distance decay sensitivity parameter (chain approach)

Cluster	OVG Antwerp	Parameter *b*
1	Car driver Car passenger Destination outside Antwerp urban area	*Max: -0,024* *Mean: -0,029* *Min: -0,033*
2	Leisure Personal Residence Antwerp suburbs Couple with no children, with 1 child Couple with 3 or more children Residence Antwerp urban fringe Work Public Transport	*Max: -0,040* *Mean: -0,058* *Min: -0,068*
3	Destination Antwerp suburbs Bicycle School Destination Antwerp urban fringe Couple with 2 children Bring or get someone Mono-parental with 2 children or more Mono-parental with 1 child	*Max: -0,074* *Mean: -0,081* *Min: -0,087*
4	Residence Antwerp city centre Residence Antwerp 19th century area Shopping Single person Destination Antwerp city centre	*Max: -0,104* *Mean: -0,117* *Min: -0,129*
5	Destination Antwerp 19th century area Foot	*-0.189* *-0.220*

Cluster	MOBEL data	Parameter *b*
1	Mono-parental with 1 child Residence outside urban area Work Public Transport Residence urban fringe Car passenger, Car driver	*Max: -0,033* *Mean: -0,041* *Min: -0,046*
2	Residence Brussels urban fringe Single person Couple with no children Residence agglomeration Couple with 1 child, with 2 children Residence Brussels commuter residential area Residence commuter residential area	*Max: -0,054* *Mean: -0,064* *Min: -0,073*
3	Couple with 3 children or more Mono-parental with 2 children or more Leisure Destination agglomeration Residence Brussels agglomeration Destination outside urban area Destination Brussels commuter residential area Personal Bring or get someone Destination Brussels agglomeration	*Max: -0,078* *Mean: -0,081* *Min: -0,086*
4	Shopping Bicycle School Destination urban fringe Destination commuter residential area	*Max: -0,101* *Mean: -0,105* *Min: -0,111*
5	Foot	*-0,303*

4. Conclusions

This paper started with the discussion of different methodologies for approaching the distance decay effect. It is clear that the functional form of distance decay models for trips and chains is exponential. After defining the model, one data issue was the determination of the unit of analysis, i.e. choosing either a tour or a one-day activity schedule. The activity or day-based approach is a combination of different tours all having a different sensitivity to distance. The differences in friction to distance can not be examined when using the activity-based approach. That is why the tour-based approach is retained in this paper. Another data issue was the simplification of the characteristics of complex chains. By assigning to each chain one single characteristic we obtain less complex chains.

In the empirical analysis, the distance decay sensitivity parameter *b* was computed for different variables and variable categories by means of the exponential model. It appeared to be a good method to explore spatially our activity-based data. The sensitivity parameter *b* is easy to compute. Moreover, by means of these results, interesting conclusions on the impact of distance on travel behaviour can be draw. The main results of the empirical analysis are first of all that the different geographical scales, namely the national and the regional level, often have different results for the sensitivity parameters. Next, it can be concluded that the distance decay effect for different household compositions and urban levels of the household location is less than for the mode of transport, the purpose and the urban level of the destination. This can be explained by the fact that when a person leaves home the characteristics of the household certainly do not change during the travel chain. In the chain approach, the sensitivity to distance can be different from the trip approach because the distance decay effect for chains is determined by the cumulative structure of the chain distance.

The central idea that results from the empirical analysis is that the mode of transport, the purpose and the destination choice determine the friction to distance. If we study travel behaviour from an activity-based approach, we certainly have to take into account spatial variables like distance because they generally affect the structure of activity and travel patterns.

Acknowledgements: the authors are grateful to the OSTC (Belgium) for financing the SAMBA project

References

Cirillo, C and Ph. Toint (2001), '*An activity-based approach to the Belgian National Travel Survey*', GRT-Faculté des Sciences, Département de Mathématique, FUNDP, Namur, 24 pp.

Cromley, R.G. (2002), '*Spatial interaction/Spatial diffusion'*. Course syllabus, University of Connecticut, on-line available at: http://www.geog.uconn.edu/courses/fall2002/g104-rgc/lecture24.pdf

Fotheringham, A.S. (1981). *'Spatial structure and distance-decay parameters'.* Annals of the association of American geographers, vol.71, n° 3, p. 425-436

Hubert J. and Toint P. (2002), *La Mobilité quotidienne des Belges*. Namur, Presses Universitaires de Namur, 352 p.

Glenn, P., Thorsen, I. and J. Uboe (2000), *'Some theoretical aspects of distance deterrence functions in modelling journeys to work'*. Presented at 3rd KFB Research Conference on Transport Systems, Sweden ,on-line available at: http://www.kfb.se/junikonf/upps/Uboe.pdf

Griffith, D.A. and K. Jones (1980). '*Explorations in the relationship between spatial structure and spatial interaction'*. Environment and Planning A, vol. 12, p. 187-201

Haynes, R.M. (1974).'*Application of exponential distance decay to human and animal activities'*. Geografiska Annaler, vol. 56B, p. 90-104

Hägerstrand, T. (1957).*'Migration and area'*. In: Land Studies in Geography, Series B, n° 13, p. 27-158

Harrington, J.W. (2000). *'Spatial Interaction'*. Course Notes, University of Washington, on-line available at: http://faculty.washington.edu/jwh/207lec09.htm

Jackson, E. (2002). '*Spatial Interaction*'. Course Notes, University of Alberta, on-line available at: http://www.eas.ualberta.ca/elj/eas190/05--spatial_interaction.ppt

Nijkamp, P. and Reggiani, A. (1992). *'Interaction, evolution and chaos in space.'* Springer-Verlag, New York, 278 pp.

Taylor, P. J. (1975). *'Distance decay in spatial interactions.'* CATMOG (Concepts and Techniques in Modern Geography), London

Tindemans, H., Van Hofstraeten, D., Verhetsel, A. & Witlox F. (2002). *'Spatial Analysis and Modelling Based on Activities. A pilot study for Antwerp and Ghent'*; presented at the 5th IUPEA Symposium on creating sustainable urban environments, Oxford, September 2002

Tindemans, H., Van Hofstraeten, D., Verhetsel, A. & Witlox F. (2003), '*Dynamics in urban regions. The intra-urban travel patterns of Antwerp and Ghent';* working paper, submitted for 'The Land'

Wilson, A.G. (1967). *'A statistical theory of spatial distribution models'*. Transportation Research 1, p. 253-269

Appendix

1. Overview of distance decay parameter results

Table 1A: Overview of the results of the exponential model (trip approach: non-spatial variables)

Distance decay parameters	Antwerp Data			MOBEL Data		
	b	*t-value*	r²	b	*t-value*	r²
Household typology						
Couple with 1 child	-0.168	*-13.58*	0,88	-0,133	*-8,5*	0,75
Couple with no children	-0.183	*-19.83*	0,92	-0,126	*-10,5*	0,8
Couple with 2 children	-0.193	*-13.19*	0,87	-0,147	*-8,9*	0,81
Couple with 3 children or more	-0.209	*-8.22*	0,79	-0,164	*-9,7*	0,8
Mono-parental with 1 child	-0.22	*-18.53*	0,93	-0,117	*-5,8*	0,7
Mono-parental with 2 children or more	-0.206	*-18.97*	0,95	-0,169	*-7,6*	0,79
Single person	-0.263	*-30.53*	0,97	-0,148	*-11,2*	0,85
Purpose						
Work	-0.121	*-22.77*	0,94	-0,088	*-10,65*	0,78
Personal	-0.169	*-15.82*	0,92	-0,157	*-11,13*	0,84
Bring or get someone	-0.173	*-10.35*	0,85	-0,13	*-6,81*	0,7
Leisure	-0.183	*-14.84*	0,93	-0,134	*-7,84*	0,
Walking/Cycling	-0.197	*-13.05*	0.92	-0,176	*-5*	0,64
School	-0.216	*-9.21*	0,87	-0,172	*-6,85*	0,75
Shopping	-0.253	*-13.23*	0,9	-0,177	*-9,18*	0,83
Transport mode						
Car driver	-0.101	*-12.22*	0,83	-0,093	*-8,53*	0,70
Car passenger	-0.104	*-12.73*	0,86	-0,099	*-10,5*	0,69
Public Transport	-0.119	*-7.43*	0,8	-0,091	*-6,18*	0,69
Bicycle	-0.217	*-7.29*	0,75	-0,209	*-3,92*	0,59
Foot	-0.473	*-8.3*	0,86	-0,458	*-4,42*	0,78

Table 2A: Overview of the results of the exponential model (trip approach: spatial variables)

Distance decay parameters	***Urban level of the household residence***			***Range of activities (O-D in same area)***		
	b	*t-value*	r²	b	*t-value*	r²
MOBEL Data						
Brussel agglomeration	-0.162	-11.77	0,86	-0,165	*-10,5*	0,85
Brussel urban fringe	-0.089	-7.9	0,72	-0,088	*-9,67*	0,68
Brussel commuter residential area	-0.140	-10.45	0,82	-0,155	*-11,86*	0,87
Outside urban area	-0.146	-8.82	0,76	-0,151	*-8,2*	0,76
Agglomeration	-0.143	-10.24	0,80	-0,139	*-9,75*	0,80
Urban fringe	-0.110	-7.96	0,73	-0,133	*-6,63*	0,7
Commuter residential area	-0.127	-7.21	0,72	-0,154	*-8,2*	0,74
Antwerp Data						
Outside Antwerp urban district				-0,076	*-7,63*	0,66
Antwerpen urban fringe	-0.161	*-13.68*	0,89	-0,179	*-12,45*	0,88
Antwerpen suburbs	-0.176	*-19.65*	0,93	-0,189	*-19,12*	0,93
Antwerpen city centre	-0.245	*-10.22*	0,88	-0,276	*-9,16*	0,86
Antwerpen 19th century area	-0.257	*-23.13*	0,96	-0,29	*-23,3*	0,96

Table 3A: Overview of the results of the exponential model (chain approach: non-spatial variables)

Distance decay parameters	Antwerp Data			MOBEL Data		
	b	*t-value*	r^2	b	*t-value*	r^2
Household situation						
Couple with 1 child	-0,057	*-9,46*	0,7	-0,063	*-9,2*	0,65
Couple with no children	-0,064	*-11,12*	0,76	-0,06	*-10,1*	0,67
Couple with 3 children or more	-0,067	*-6,82*	0,61	-0,078	*-9,7*	0,58
Mono-parental with 2 children or more	-0,074	*-10,93*	0,78	-0,078	*-6,8*	0,61
Couple with 2 children	-0,076	*-9,8*	0,74	-0,073	*-6,9*	0,7
Mono-parental with 1 child	-0,08	*-10,2*	0,75	-0,044	*-6,6*	0,64
Single person	-0,123	*-10,66*	0,79	-0,067	*-10,6*	0,75
Purpose						
Work	-0,04	*-7,11*	0,51	-0,039	*-7,18*	0,48
Personal	-0,066	*-6,22*	0,54	-0,083	*-7,93*	0,65
Leisure	-0.068	*-8,31*	0.67	-0,079	*-5,68*	0,53
Bring or get someone	-0,077	*-5,96*	0,61	-0,078	*-4,95*	0,54
School	-0,083	*-6,16*	0,63	-0,104	*-6,82*	0,66
Shopping	-0,121	*-10,17*	0,8	-0,101	*-7,09*	0,66
Transport mode						
Car driver	-0.030	*-7,09*	0.49*	-0,037	*-7,5*	0,50
Car passenger	-0.033	*-6,59*	0.47*	-0,046	*-6,52*	0,49
Public Transport	-0.046	*-6,12*	0.54	-0,039	*-5,11*	0,50
Bicycle	-0.084	*-6,5*	0.64	-0,102	*-3,45*	0,52
Foot	-0.220	*-8,47*	0.82	-0,303	*-5,45*	0,76

Table 4A: Overview of the results of the exponential model (chain approach: spatial variables)

	Urban level of the household residence			***Range of activities (O-D in same area)***		
	b	*t-value*	r^2	b	*t-value*	r^2
MOBEL Data						
Brussel agglomeration	-0,079	-11,48	0,77	-0,086	*-8,82*	0,75
Brussel urban fringe	-0,033	-5,86	0,43	-0,070	*-4,05*	0,46
Brussel commuter residential area	-0,059	-6,77	0,51	-0,083	*-4,58*	0,56
Outside urban area	-0,071	-8,98	0,65	-0,081	*-7,92*	0,66
Agglomeration	-0,066	-10,23	0,72	-0,081	*-7,37*	0,70
Urban fringe	-0,046	-7,17	0,55	-0,106	*-4,06*	0,57
Commuter residential area	-0,054	-7,62	0,59	-0,111	*-5,04*	0,64
Antwerp Data						
Outside Antwerp urban district				-0.024	*-5,98*	0.31*
Antwerpen urban fringe	-0,053	*-8,35*	0,63	-0,087	*-7,22*	0.69
Antwerpen suburbs	-0,061	*-11,86*	0,78	-0,085	*-11,31*	0,79
Antwerpen city centre	-0,104	*-7,26*	0,68	-0,129	*-6,33*	0,75
Antwerpen 19th century area	-0,107	*-12,2*	0,82	-0,189	*-12,7*	0,86

** R^2 less then 0.50 (low reliability)*

2. Results of the likelihood Ratio Test - OVG Antwerp

** significant (1%), * significant (5%)

Table 5A: Urban level of the household residence

	19th century area	Suburbs	Urban fringe
City centre trips	1,36	42,89**	32,87**
chains	0,13	31,84**	25,34**
19th century trips		57,30**	41,28**
chains		36,20**	28,07**
Suburbs trips			1,59
chains			1,1

Table 6A: Household typology

	Couple1	Couple2	Couple3+	Single1	Single2	Single
Couple 0 CH trips	1,5	0,49	1,25	10,74**	5,02*	52,52**
chains	0,93	2,41	0,08	3,88*	2,25	39,80**
Couple 1 CH trips		3,46	3,4	23,00**	15,08**	40,49**
chains		6,36*	0,99	8,42**	6,71**	43,36**
Couple 2 CH trips			0,46	5,59*	1,58	17,98**
chains			0,72	0,24	0,05	18,97**
Couple 3 or + CH trips				0,9	0,07	4,03*
chains				2,54	1,12	16,33**
Single 1 CH trips					1,66	10,24**
chains					0,65	12,56**
Single 2 CH trips						22,12**
chains						24,67**

Table 7A: Purpose

	Leisure	Personal	School	Shopping	Walking	Work
Bring/get someone trips	5,79*	0,08	6,32*	18,25**	3,13	14,84**
chains	0,71	0,47	0,24	7,78**	-	11,92**
Leisure trips		1,22	17,74**	23,01**	1,04	35,25**
chains		0,08	2,2	18,75**	-	16,12**
Personal trips			13,35**	36,03**	4,07*	24,84**
chains			1,18	8,23**	-	5,74*
School trips				2,49	1,51	29,56**
chains				5,64*	-	16,44**
Shopping trips					11,10**	95,52**
chains					-	94,70**
Walking trips						39,98**
chains						-

Table 8A: Destination

	19th century	Suburbs	Urban fringe	Outside urban district
City centre trips	1,31	54,76**	30,37**	62,17**
chains	15,60**	19,43**	8,85**	24,45**
19th century trips		70,03**	37,60**	66,36**
chains		67,86**	34,16**	33,93**
Suburbs trips			0,46	33,00**
chains			0,02	16,66**
Urban fringe trips				29,41**
chains				17,03**

Table 9A: Mode of transport

	Foot	Car driver	Car passenger	Public Transport
Bicycle trips	47,42**	107,65**	103,53**	24,66**
chains	64,32**	65,27**	41,55**	14,63**
Foot trips		345,66**	345,21**	100,90**
chains		162,12**	119,53**	71,20**
Car driver trips			0,14	5,27*
chains			0,5	6,79**
Car passenger trips				3,85*
chains				4,15*

3. Results of the likelihood Ratio Test - MOBEL

** significant (1%), * significant (5%)

Table 10A: Urban level of the household location

	Brussels urban fringe	Brussels CRA	Agglomeration	Urban fringe	CRA	Outside urban areas
Brussels agglomeration trips	43,34**	3,89	9,74**	23,55**	7,23*	1,53
chains	20,39**	2,91	2,96	10,56**	6,38*	0,7
Brussels urban fringe trips		30,55**	111,4**	7,49**	38,1**	77,92**
chains		8,51**	43,5**	4,2*	9,04**	32,34**
Brussels CRA trips			0,19	8,79	0,17	1,91
chains			1,61	2,11	0,34	2,21
Agglomeration trips				10,25**	0,49	1,12
chains				4,96*	2	0,25
Urban fringe trips					9,41**	28,51**
chains					0,9	10,82**
CRA trips						2,62
chains						2,47

CRA = commuter residential areas

Table 11A: Household typology

	Couple2	Couple 3+	Couple0	Single1	Single2	Single
Couple 1 CH trips	0,89	4,39*	0,28	0,57	3,32	1,57
chain	0,76	3,76	0,24	5,29*	1,46	0,33
Couple 2 CH trips		1,17	2,76	1,97	1,14	0,00
chains		0,44	3,23	10,33**	0,21	0,61
Couple 3 or + CH trips			8,17**	4,38*	0,06	1,47
chains			6,39*	13,93**	0,0	2,37
Couple 0 CH trips				0,21	4,71*	3,29
chains				3,96*	2,19	1,16
Single 1 CH trips					7,24*	7,07*
chains					9,14**	16,92**
Single 2 CH trips						2,53
chains						2,52

Table 12A: Purpose

	Shopping	School	Bring/get	Personal	Leisure	Work	Walking
Shopping trips		19,11**	4,05*	0,0	0,00	26,90**	0,09
chains		0,03	1,95	2,00	1,54	45,34**	-
School trips			14,04**	22,65**	26,3**	2,01	37,05**
chains			2,34	2,55	1,88	47,46**	-
Bring/get trips				4,68*	5,57*	15,50**	8,68*
chains				0,25	0,02	25,11**	-
Personal trips					0,00	31,03**	0,09
chains					0,05	29,99**	-
Leisure trips						37**	0,09
chains						26,78**	-
Work trips							51,49**
							-

Table 13A: Destination

	Brussels urban fringe	Brussels CRA	Agglomeration	Urban fringe	CRA	Outside urban areas
Brussels agglomeration trips	-	2,01	5,33*	6,51*	5,69*	0,04
chains	14,97**	0,14	1,19	1,11	0,04	0,18
Brussels urban fringe trips		-	-	-	-	-
chains		40,55**	11,42	4,89*	13,1**	16,2**
Brussels CRA trips			0,03	0,01	0,01	1,39
chains			1,85	1,56	0,00	0,48
Agglomeration trips				0,23	0,17	3,49
chains				0,07	1,10	0,44
Urban fringe trips					0,00	4,65*
chains					1,76	1,05
CRA trips						4,03*
chains						0,28

Table 14A: Mode of transport

	Bike	Public transport	Car passenger	Car driver
Walk trips	14,87**	107,44**	144,29**	183,85**
chains	21,61**	114,82**	124,06**	177,59**
Bike trips		36,5**	41,71**	58,84**
chains		32,51**	28,41**	58,86**
Public transport trips			0,45	0,03
chains			1,24	0,13
Car passenger trips				0,27
chains				2,90

4. Trips not finishing at home

Table 15A: Other purposes for final trips in chains when not finishing at home

Purpose	Frequency/Percent Mobel		Frequency/Percent Antwerp	
Walk/drive/cycle	34	9,9%	95	11,0%
Work/professional	32	9,3%	37	4,3%
Visit someone	58	16,9%	101	11,7%
Shopping	33	9,6%	21	2,4%
Leisure	43	12,5%	126	14,6%
Undetermined/NR	61	17,7%	53	6,15%
Bring/get someone	53	15,4%	86	10,0%
Personal reasons	10	2,9%	-	-
School	9	2,6%	2	0,2%
Dine out, restaurant	9	2,6%	-	-
Other	2	0,6%	4	0,5%
Other house	-	-	87	10,1%
Services (bank,…)	-	-	8	0,9%
Outside Belgium	-	-	17	2,0%
‘At home-address’ or purpose is incorrect	-	-	221	25,6%
	344		862	