MODELING ROUTE CHOICE OF CAR TRAVELERS USING AN ACTIVITY-BASED SEGMENTATION

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ABSTRACT

The aim of this research is to identify the relationships between activity patterns and route choice decisions. The focus is turned to the relationship between the purpose of a trip and the road categories used for the relocation. The data for this study were collected in 2006 and 2007 in Flanders, the Dutch speaking and northern part of Belgium. To estimate the relationship between he primary road category traveled on and the corresponding activity-travel behavior a multinomial logit model is developed. The results point out that route choice is a function of multiple factors, not just travel time or distance. Crucial for modeling route choices or in general for traffic assignment procedures is the conclusion that activity patterns have a clear influence on the road category primarily driven on. Particularly, it was shown that the likelihood of taking primarily through roads is highest for work trips and lowest for leisure trips. This certainly suggests that traffic assignment procedures should be developed that explicitly take into account an activity-based segmentation. In addition, it was shown that route choices were similar during peak and off-peak periods. This is an indication that car drivers are not necessarily utility maximizers. A potential pathway for further investigating route choice decisions might lie in the roots of more psychological underpinnings.

1 INTRODUCTION

To support policy makers, traffic and transportation models can be used to make better long-term decisions. On an international level, activity-based models have become the norm to model travel behavior. The most important characteristic of these models is that the travel behavior of persons or households is a product of the activities that they wish or have to perform, procuring a more realistic description and a better understanding of people's travel behavior. Because of these advantages, researchers and policy makers in the United States have switched from conventional models to activity-based models. Although this trend is most visible in the United States, the same evolution can be noticed in Europe (*1*, *2*).

Essential for both classic and modern transportation models is the modeling of route choice behavior as it enables planners to forecast travelers' behavior under hypothetical scenarios, to predict future traffic conditions on transportation networks and to understand travelers' reaction and adaptation to sources of information (*3*). An important limitation in both traditional four-step and present-day activity-based model is the fact current route choice models have been developed largely in the absence of objective empirical evidence of actual route choices. Theories of utilization maximization have proven useful, but the underlying behavior realism of these theories, when applied to modeling route choices, has not received an adequate level of validation (*4*). After all, confronted with a multitude of route choice facets, travelers may not be able to make optimal decisions, especially when the deliberation process of various possible routes involves the anticipation of congestion (*5*). Moreover, route choice decisions are based on existing knowledge and experiences that irrefutably influence the evaluation of the different choice alternatives (*6*).

The aim of this research is to identify the relationships between activity patterns and route choice decisions. The focus is turned to the relationship between the purpose of a trip and the road categories used for the relocation as only a limited number of studies can be found in literature, in which the relationship between the purpose of the trip and the road categories used for the relocations is analyzed. Zhang and Levinson (*7*) investigated the factors influencing route choice to assess the value of traveler information. They tried to unravel the route selection process with and without traveler information for different trip purposes. From their results, it is evident that the importance of route attributes varies with trip purposes. Murakami and Wagner (*8*) ascertained that only a very small amount of variation in the use of road categories is due to different trip purposes. Ramming (*9*) stated that car travelers want to minimize their travel time, regardless of the purpose of the trip, and therefore they choose primary roads.

Studies regarding the relationship between the purpose of the trip and the travel time or distance are frequently available, e.g. Ramming (*9*) and Bierlaire and Frejinger (*10*). In literature, other factors besides route attributes (personal, household and situational characteristics) play a role in the route selection, e.g. Bayarma et al (*11*), Zhang and Levinson (*7*) and Scheiner (*12*). Therefore, the personal characteristics, province and the situational characteristic time of day are considered in the analyses.

The remainder of this paper is structured as follows. In the next section, the data is described. The data collection and data processing steps are illuminated and descriptive results of both the dependent variable (road category) and explanatory variables are expounded. In the consecutive section the adopted methodology approach is amplified and the results are discussed. Finally, in the last section, the most important findings are recapitulated and avenues for further research highlighted.

2 DATA

The data for this study were collected in 2006 and 2007 in Flanders, the Dutch speaking and northern part of Belgium, in the context of a large scale survey, conducted on 2500 households in the study area. In the remainder of this section, first, more details concerning the large scale survey will be provided. Next, some of the most important data processing steps are highlighted and the variables that are considered for the analysis are described.

2.1 Data Collection

Traditionally, travel surveys have been collected by paper and pencil or over the phone. The coming of activity-based analysis, which prompted the need for considerably more detailed data on travel behavior, identified the advantages of collecting activity or time use diary data (see Ettema et al (*13*) for an overview). At the same time, however, the use of diary data virtually precluded the use of telephone interviews and in addition substantially increased respondent burden and error proneness (see e.g. Dowling and Colman (*14*) and Sun et al (*15*)). To avoid such error or at least reduce it, computer assisted diary instruments were developed.

The data for this study stem from a large scale activity-based data collection effort conducted on households since the household context in which individuals operate has a very strong influence on individuals' decisions, particularly when household resources are shared, there are shared household responsibilities and there are decisions that are made jointly by multiple household members. The survey used a mixed-mode survey design, using a PDA application on the one hand, and using traditional paper and pencil diaries on the other hand. Cools et al (*16*) demonstrated that the use of this mixed survey design turns out to be a very suitable way of collecting detailed information about planned and executed activity-travel behavior of households as the survey mode had no direct impact on the quantities investigated.

The PDA application, called PARROTS (PDA (Personal Digital Assistant) system for Activity Registration and Recording of Travel Scheduling) was developed in such that respondents could easily provide information about their activity-travel behavior (*17*). Whenever an activity or trip was registered in PARROTS, a number of attributes for this activity or trip were collected using a customized GUI. The most important activity and trip attributes PARROTS collected are: activity type, date, start and end time, location, mode of transportation, travel time and travel party. Besides PARROTS uses the integrated Global Positioning System (GPS) to automatically record location data. This combination of GPS, and diary responses provides great insight into the route choice decision-making process (*6*). Jan et al (*4*) showed that GPS is a viable tool to study traveler's route choice decisions as GPS can reveal important travel behavioral information that was impossible to discern with earlier conventional survey methods such as interviews, respondent-administered questionnaires, or driver simulators. Moreover, these conventional methods have proved burdensome, time consuming, and error prone (*18*).

2.2 Data Processing

In order to analyze the reported and recorded travel data, advanced post-processing is necessary to make the information usable for route choice modeling (*19*). In this research only displacements made by car are taken into account. Therefore, displacements made with any other mode are filtered out of the database. Next, the GPS-data are compared to the data reported by the respondents in the diaries. If there is a mismatch between the two data sources, the displacements are not used in the analyses since it is possible that the reported displacements are incorrect. Furthermore, only respondents that filled in all personal characteristics are considered because these characteristics are used in the analyses. Given the network that will be used to analyze the trips is a national network, cross-border displacements are filtered out of the database.

The data processing leads to a dataset containing car displacements on the Belgian road network for respondents of whom the personal characteristics are known and for whom the GPS-data is consistent with the data reported in the diaries. The dataset contains 1423 car displacements, made by 299 different respondents.

2.3 Data Description

Recall that the focus in this study is turned to the relationship between the purpose of a trip and the road categories used for the relocation. The roads are divided in three categories, following the functional road classification of Weijermars et al *(20*), namely through-roads (primary roads), distributor roads (secondary roads) and access roads (local roads). In this paper, thus the road category is the feature of the route choice that will be modeled in function of various explanatory variables, as route choice is a function of multiple factors, not just travel time or distance (*21*).

The first group of variables that is considered concerns trip-related attributes. In literature these attributes are often pinpointed as predominant variables including trip purpose (*22*), trip distances (*12*) and congestion (*4*). Five types of trip purposes are distinguished: work, leisure, shopping, home and other. Congestion is coded as a dummy equaling one for trips made during congested periods (6:00-9:00 and 16:00-19:00) and equaling zero during other periods of the day.

Besides trip-related attributes, other factors such as socio-demographic and geographical characteristics play an important role in the route selection, as discussed by de Palma and Picard (*22*), Bayarma et al (*11*) and Li et al (*23*). Therefore, the personal characteristics age, gender, net personal income, profession and the geographical characteristic province are considered in the analyses.

Table 1 table provides a descriptive overview of the route choices, i.e. the road categories chosen, for the various levels of the explanatory variables. Note that the continuous variables distance and age have been categorized for the tabulation of this table. The table displays for each level of the categorical variables the percentage of trips that are mainly carried out on the different road categories. In addition, the results (p-values) of the chi-square independence test, testing the hypotheses that the route choice is independent of the predictor investigated. In accordance with international literature, the descriptive results in this table point out that trip-related attributes, as well as socio-demographic and geographical characteristics, appear to have an impact on the route choice. Concerning trip purpose, for work-related trips about 15% more trips are made on through roads when compared to trips with other trip purposes. One explanation is the fact that, on average, trip distances for work-related trips are longer than other trips, and in general longer trips are mainly carried out on through roads. This is supported by the figures in Table 1 revealing a 4 times bigger share of through road trips exceeding 20 km compared to small trips of less than 5 km. Congestion appears to have no effect on the road category travelled by. This is in line with Parkany et al (*24*) who state that the majority of people follow the same route during peak and off-peak conditions.

TABLE 1 Road Categories Chosen for the Different Levels of the Predictors

	Total	**Through road**		**Distributor road**		**Access road**		
Category	**# Trips**	**# Trips**	**% Trips**	**# Trips**	**% Trips**	**# Trips**	**% Trips**	**P-value**
Overall	1423	566	39.78%	182	12.79%	675	47.43%	
Trip purpose								<0.001
- Home	423	164	38.77%	42	9.93%	217	51.30%	
- Work	281	146	51.96%	47	16.73%	88	31.32%	
- Shopping	208	77	37.02%	24	11.54%	107	51.44%	
- Leisure	259	95	36.68%	37	14.29%	127	49.03%	
- Other	252	84	33.33%	32	12.70%	136	53.97%	
Distance								<0.001
- 0-5 km	544	106	19.49%	51	9.38%	387	71.14%	
- 5.1-10 km	307	91	29.64%	48	15.64%	168	54.72%	
- 10.1-20 km	297	151	50.84%	45	15.15%	101	34.01%	
- >20 km	275	218	79.27%	38	13.82%	19	6.91%	
Congestion								0.482
- Off-peak	791	307	38.81%	108	13.65%	376	47.53%	
- During peak	632	259	40.98%	74	11.71%	299	47.31%	
Age								0.120
- 18-25	96	49	51.04%	5	5.21%	42	43.75%	
- 26-40	405	166	40.99%	55	13.58%	184	45.43%	
- 41-64	858	328	38.23%	115	13.40%	415	48.37%	
- 65+	64	23	35.94%	7	10.94%	34	53.13%	
Gender								<0.001
- Male	945	347	36.72%	151	15.98%	447	47.30%	
- Female	478	219	45.82%	31	6.49%	228	47.70%	
Profession								0.012
- Blue-collar worker	104	35	33.65%	21	20.19%	48	46.15%	
- White-collar worker	815	335	41.10%	105	12.88%	375	46.01%	
- Independent	69	36	52.17%	7	10.14%	26	37.68%	
- Student	43	22	51.16%	2	4.65%	19	44.19%	
- Not professionally active	301	100	33.22%	34	11.30%	167	55.48%	
- Other	91	38	41.76%	13	14.29%	40	43.96%	
Net personal income								<0.001
- 0-1250 €	177	49	27.68%	16	9.04%	112	63.28%	
- 1250-1750 €	401	175	43.64%	48	11.97%	178	44.39%	
- 1750-2250 €	393	149	37.91%	63	16.03%	181	46.06%	
- 2250-2750 €	132	63	47.73%	8	6.06%	61	46.21%	
- >2750 €	65	29	44.62%	12	18.46%	24	36.92%	
- No answer	255	101	39.61%	35	13.73%	119	46.67%	
Province								<0.001
- Antwerp	380	145	38.16%	50	13.16%	185	48.68%	
- Limburg	325	127	39.08%	80	24.62%	118	36.31%	
- East Flanders	258	126	48.84%	13	5.04%	119	46.12%	
- West Flanders	107	53	49.53%	10	9.35%	44	41.12%	
- Flemish Brabant	353	115	32.58%	29	8.22%	209	59.21%	

P-value corresponds to the p-value of the chi-square independence test.

When the focuses is turned to the socio-demographic characteristics it becomes apparent that younger people travel relatively more by through roads, whereas older have a higher share in routes that predominately travel across access roads. Concerning gender differences, one can notice that the higher share of females in through roads is compensated by a higher share on distributor roads for males. The percentage of routes that mainly travel by access roads is almost the same. With respect to profession the small share of distributor roads for students and the large share of access roads for professionally inactive persons attract attention. With regard to net personal income one can notice a clear difference between the lowest income category and the other income categories: the share of trips mainly carried out on access roads is distinctly higher than other income groups. Finally, also geographical differences seem to play a non-ignorable role.

3 METHODOLOGY

Recall that the focus of this study is to assess the relationship between the primary road category traveled on and the corresponding activity-travel behavior. To estimate this relationship a multinomial logit model (MNL) is developed. In the previous section, an elaborate description of the considered variables was provided. To assess the significance of the various trip-related and non-trip related predictors, a type III analysis of the effects is made, displayed in Table 2. Note that, in line with Parkany et al (*24*), congestion has no significant impact on the modeled route choice decisions. Therefore congestion will not be included in the final model. In accordance with international literature (see e.g. Abdel-Aty and Huang (*21*) and Parkany et al (*24*)), and in line with the descriptive statistics presented in Table 1, next to trip-related attributes (trip purpose and trip distance), also socio-demographic variables and geographical differences play an noticeable role. Important to underline is the importance of the activity-based segmentation: there is a clear relationship between the route choice (road type) and the activities people perform.

TABLE 2 Type III Analysis of Effects

Effect	DF	Wald Chi-Square[1]	P-value[1]	Wald Chi-Square[2]	P-value[2]
Purpose	8	17.590	0.025	16.601	0.035
Distance	2	217.904	<0.001	218.331	<0.001
Congestion	2	1.785	0.410		
Age	2	6.881	0.032	7.033	0.030
Sex	2	26.426	<0.001	26.370	<0.001
Profession	10	20.575	0.024	20.990	0.021
Net personal income	10	24.897	0.006	24.859	0.006
Province	8	81.757	<0.001	82.482	<0.001

[1] MNL model including congestion. [2] MNL model excluding congestion.

The parameter estimates of the MNL model, presented in Table 3, provide more insight in the factors that explain route choice. To detect potential multicollinearity problems the Variance Inflation Factors (VIFs) were calculated. In general, VIFs exceeding 10 indicate the presence of serious multicollinearity undermining the validity of the results (*25*). Other authors consider this boundary too liberal and suggest that the variance inflation factors should not exceed 4 (*26*). The VIFs calculated for the model presented in this paper indicate that there was no problem of multicollinearity.

TABLE 3 Maximum Likelihood Estimates (Access Roads as Reference)

Parameter	Through road Estimate	Through road St. Error	Distributor road Estimate	Distributor road St. Error	VIF
Intercept	-2.355	0.446	-3.259	0.575	n.a.
Purpose					
- Home	-0.330	0.213	-0.879	0.277	1.864
- Work	0.000	n.a.	0.000	n.a.	n.a.
- Leisure	-0.578	0.239	-0.639	0.296	1.670
- Shopping	-0.087	0.248	-0.674	0.326	1.616
- Other	-0.175	0.240	-0.336	0.302	1.687
Distance	0.160	0.011	0.118	0.012	1.077
Age	0.010	0.009	0.031	0.012	2.000
Sex					
- Female	0.497	0.163	-0.714	0.246	1.227
- Male	0.000	n.a.	0.000	n.a.	n.a.
Profession					
- Blue-collar worker	0.476	0.290	0.781	0.344	1.204
- White-collar worker	0.000	n.a.	0.000	n.a.	n.a.
- Independent	0.356	0.349	0.213	0.494	1.116
- Student	0.808	0.439	-0.603	0.849	1.347
- Not professionally active	0.230	0.246	-0.492	0.338	2.168
- Other	0.316	0.321	0.632	0.413	1.238
Net personal income					
- 0-1250 €	-0.379	0.273	0.327	0.375	1.678
- 1250-1750 €	0.000	n.a.	0.000	n.a.	n.a.
- 1750-2250 €	0.003	0.196	0.266	0.253	1.577
- 2250-2750 €	0.335	0.277	-0.582	0.460	1.443
- >2750 €	0.955	0.352	1.431	0.452	1.223
- No answer	-0.030	0.235	0.075	0.303	1.633
Province					
- Antwerp	0.000	n.a.	0.000	n.a.	n.a.
- East Flanders	0.073	0.215	-0.889	0.352	1.500
- West Flanders	0.127	0.288	-0.516	0.420	1.257
- Flemish Brabant	-0.375	0.204	-0.560	0.280	1.656
- Limburg	0.428	0.210	1.358	0.248	1.554

n.a.: standard error not available as the estimate corresponds to the reference category

When the influence of the activity patterns is assessed, it is clear that the likelihood of taking primarily through roads is highest for work trips and lowest for leisure trips. In particular, the odds ratio of taking primarily through roads for work trips compared to leisure trips equals 1.78 (= exp(0-(-0.330))). This can be accounted for by the fact that in Flanders the longest trips made are work trips, whereas leisure activities are generally performed relatively close to the home location (*27*).

With regard to the trip distance, the parameter estimates indicate that the longer the trip distance is, the more likely one travels on higher hierarchy roads, especially through roads. When the trip distance would increase by 1 km, the odds of traveling primarily on through roads increases 17.4 % (the odds are multiplied by 1.174 (=exp(0.160))) and the odds of traveling primarily on distributor roads increases 12.5%. Consequently, the likelihood of primarily driving on access roads decreases the longer the trip distance would be.

Concerning the effect of the socio-demographic variables, one can observe that similar to trip distance, age has an increasing effect on the odds. However, for through roads this increase is not significant. The odds of traveling primarily on distributor roads increase with 3.1% for each additional year to age of the traveler. The influence of gender is not that straightforward. On the one hand, the odds of primarily driving on through roads are 64.4% for females than for males. On the other hand, the odds of driving primarily on distributor roads are 49.0% lower.

With respect to profession one could notice the clear difference between students and the remaining categories. Students have the highest likelihood to drive primarily on through roads and the lowest propensity to drive on distributor routes. One of the reasons explaining the large chance of driving primarily on through roads is the fact that the large majority of these students drives by car towards the location where they participate in educational activities. Given the age of these students (18+), these locations most probably are universities or university colleges, limiting the number of possible activity locations and consequently increasing the average trip distances. In line with the results of the trip distance, thus the likelihood of primarily driving on through roads increases sharply.

Regarding the net personal income one could note that income, in accordance with distance, has an increasing effect on the likelihood of driving mainly on through roads. The odds of traveling by car on through roads are 73.7% (the odds are multiplied by 0.263 (=exp(-0.379-0.955))) lower for the lowest income class when compared to the highest income class. This clear tendency is not confirmed for distributor roads: no clear increasing or decreasing relationship is visible.

Finally, the parameter estimates also show that interprovincial differences exist. The likelihood of primarily driving on through roads is largest for Limburg and smallest for Flemish Brabant. In addition, Limburg drivers also have the largest propensity of driving on distributor routs, implying that they have the lowest propensity of driving mainly on access roads. People living in East-Flanders have the smallest probability of driving on distributor roads.

4 DISCUSSION AND CONCLUSION

In this study the relationships between route choice decisions (i.e. the type of roads driven by), activity patterns and other influencing variables have been assessed. The results confirm the finding by Abdel-Aty and Huang (*21*) that route choice is a function of multiple factors, not just travel time or distance. Crucial for modeling route choices or in general for traffic assignment procedures is the conclusion that activity patterns have a clear influence on the road category primarily driven on. Particularly, it was shown that the likelihood of taking primarily through roads is highest for work trips and lowest for leisure trips. This certainly suggests that traffic assignment procedures should be developed that explicitly take into account an activity-based segmentation. In addition, it was shown that route choices were similar during peak and off-peak periods. This supports the conclusion by Avineri and Prashker (*28*) that car drivers are not necessarily utility maximizers, and that further research is needed to determine whether they are prospect maximizers or whether other behavioral theories provide a more solid behavioral basis. After all, the results in this paper also confirmed that socio-demographic variables such as age, gender, profession and income, and geographical context (i.e. province) play a noticeable role in route choice decisions.

A potential pathway for further investigating route choice decisions might lie in the roots of more psychological underpinnings. As documented by Parkany et al (*24*) attitudes play an important role on travel decisions as they help guide behavior, and a typology of attitudes toward route choice could be used to stratify traffic assignment models. Besides personal attitudes, also a wide variety of other explanatory variables related to route choice. Future data collection efforts concerning route choice could also incorporate additional factors including traveler-related aspects (e.g. life cycle, education, household structure, household car possession, and household driver license possession (*4*)), road characteristics (e.g. speed limits, road with, road length, number of lanes, angularity, intersections, aesthetics (*4*)), traffic characteristics (e.g. traffic safety, reliability of travel times (*6*)), and situational variables (e.g. weather conditions (*29*, *30*), holiday effects (*31*, *32*) and traffic information (*7*)). Moreover, future research should extent to other transport modes such as walking, bicycle use, public transport and carpooling.

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