

Development and assessment of a data collection method for route choice in public transport

Marie K. A. Anderson, M. Sc. in Eng., PhD Student, DTU Transport, mkl@transport.dtu.dk

Abstract

Knowledge about actual route choices for public transport passengers is important when assessing generated choice sets for route choice modelling. An objective measure of relevant routes in actual networks does not exist and assessment of the choice sets is often based on the experience and knowledge of the analyst. Route choices for car traffic have attracted a lot of attention in the research literature, but limited knowledge exists on the route choices of public transport passengers and the need for insight into these choices motivates the work described in the paper.

This paper describes a method to collect data for public transport passengers by using internet and telephone interviews. The route choice questions are formulated and added to the existing Danish Travel Survey (Transportvaneundersøgelsen, TU) and tested in a pilot study at the Technical University of Denmark (DTU). Afterwards, the questions are implemented in the national TU survey and, since February 2009, more than 4,000 route choices in public transportation have been collected.

The method of collecting public route choices proves to be successful since it collects actual route choice data for a large number of travellers and it allows reproducing observed choices in a GIS network for choice set assessment purposes.

1 Introduction

Knowledge about actual route choices for public transport passengers is important when assessing generated choice sets for route choice modelling. An objective measure of relevant routes in actual networks does not exist and assessment of the choice sets is often based on the experience and knowledge of the analyst. The work described in the paper is motivated by the need to get insight into the route choices of passengers in public transport.

Route choices for car traffic have attracted a lot of attention in the research literature, but limited knowledge exists on the route choices of public transport passengers. One of the reasons lies in the difficulty to collect data on actual route choices in public transport networks, since a lot of information has to be provided to describe the routes actually used by travellers. For private transport it is possible to use GPS devices to track routes and then map the data to a physical network (see, e.g., Jan et al. 2000; Schönfelder et al. 2002). For public transport the same method is of little help because relevant information about the lines used is not retrievable with these devices, signals may fall out in tunnels (metro and sections of the urban rail system), and information on the trip purpose, which is another fundamental piece of information for uncovering route choice determinants, is not retrievable.

The accuracy of collected GPS data for use in private route choice analyses has improved in recent years (see Holm 2009), but still the use of this data source for route choice knowledge is questioned (see Bierlaire and Frejinger, 2009).

Since GPS devices could not be used to collect the desired data for this survey, other methods were considered. Bovy and Bradley (1985) used stated preference survey for collection of route choice data. This procedure does not provide the actual routes as desired for this survey. Ramming (2002) asked drivers in the Boston area to name the origin and destination zone of their route and the road segment used. This procedure returned a great number of incomplete route descriptions. Some of these incomplete routes were fixed by using the shortest path between two known points or by using the routes of other respondents travelling between the same points. With this method a great amount of manual work is required to map the data afterwards and the method is not applicable for public transportation since the used lines would not be revealed by listing road segments. Prato (2005) collected data on route choice in a web-based survey where respondents indicate their chosen and other considered routes by selecting the numbered order of passing through junctions on an interactive map of the city centre of Turin. The observations are for drivers and the method is not applicable to the public transportation system since the used lines in public transportation cannot be identified by choosing junctions in a network. Vrtic et al. (2006) asked respondents to provide information on the origin and destination cities of their trip and up to three cities or location they passed through on the way. This provides a great deal of missing information and the exact actual route cannot be reproduced from these pieces of information. This method of asking for specific points of the travel is in some way applicable to public transport if the questionnaire is created to obtain all relevant information so that the exact route can be reproduced.

For public transport route choice, only very few studies have collected data to describe the route choice of the traveller. Hoogendoorn-Lanser (2005) collected data on considered choice sets and actual choices via face-to-face interviews. The survey was carried out for train users in a specific train corridor in the Netherlands. The collected route choice data was not far as detailed as required for this survey with regard to feeder modes, exact bus lines, etc.

Surveys conducted via mail, telephone, web-based etc. are all conventional ways of collecting data on route choice. Often the collected data are concerning the attributes of the traveller and the trip since the actual route is rather difficult to obtain in this way. Mahmassani et al. (1993) and Abdel-Aty et al. (1995) described different approaches to the data collection by means of questionnaires.

The goal of this survey is to examine the route choices of passengers in public transportation. To be able to compare the routes with generated choice sets, the information of the routes should be detailed enough to be able to reproduce the actual chosen route. The data collection should involve a large number of observations that set some requirements. Face-to-face interviews as in Hoogendoorn-Lanser (2005) would be very costly. The following manipulation of the data in order to reproduce routes should also be as small as possible to minimize costs and errors. A questionnaire form was chosen in order to fulfil the objectives of the survey outcome. The questionnaire can be filled out by the respondent via internet or by the interviewer via a telephone interview. The questions concerning route choice of passengers were added to the already existing and ongoing TU survey. In the survey, travel diaries for up to 20,000 people are collected every year. When adding route choice questions to the existing survey, it has to be clarified how the new questions affect the existing part and to be assured that the time consumption and difficulty level of filling out the questionnaire does not increase drastically causing a lower completion rate than before.

In section 2 the method of developing the route choice survey is described. The preliminary requirements to the survey are set up and the fulfilment of the requirements is explained. The TU survey is described and finally the formulations of the route choice questions are presented. In section 3, the applications of the route choice questionnaire in first a pilot study and then the national survey are described and assessments to the implementations are given. Section 4 sums up and concludes on the work done.

2 Method

In the following section, the methods used to create the survey are described. The beforehand requirements are listed and explained and the chosen data collection method is described.

2.1 Requirements

Preliminarily to the creation of the questionnaire, some requirements for the collected data have been set up. The data should be collected for a large amount of people with a rather simple method to keep down costs and a not too time-consuming method to minimize the drop-out rate to get the most representative sample. Even though simple, the collected data should represent the actual chosen route and be reproducible in a GIS network, preferably with a minimum investment of analyst time.

For the current study, it was desired to develop a method to collect the route choice data for a large amount of people. For a small number of collected data, manual work to some level can be accepted, but when collecting thousands of observations the manual work would be very costly and should preferably be kept to a minimum. This means that the respondent should enter as much of the desired data as possible in a form that can be used either without manipulation or with programmed manipulation. If the respondent can enter the data in a GIS network equal to the network the analyst is working, the matching part of the quality check can be skipped. In this survey this option was not available since data are collected for the whole country and the network that the respondents had to work with would be too huge to work with at the desired detail level.

The collection method has to be rather simple to keep costs down and to obtain a high completion rate. When interviews are done face-to-face, the questions can be more complicated if the interviewer is well prepared and can help with the understanding of the questions and how to fill the questionnaire. When interviewing via telephone, the interviewer can also assist in explaining the questions, but detailed descriptions as figures and graphs cannot be used. When the respondents fill in the questions in a printed version or on the internet, the understanding of the questions is completely up to the respondent himself. The questions therefore have to be easily understandable to obtain accurate answers and to avoid losing respondents before completing the survey. In this way it is assured that not a specific part of the population drop out and cause a non-representative sample. On the internet it is possible to create verification procedures for the entered data to point out possible errors to respondents.

A questionnaire survey can be created in a form providing the possibility of collecting route choice for passengers in public transportation. The questionnaire form is rather open and offers possibility of asking for the exact information desired. The formulation of the questions has to be very clear in order to collect the data in a way making it possible to reproduce the exact actual route of the

traveller. This problem is somewhat different between car and public transportation and even though travelling through a public transportation system seems more complex than through a road system, some restraints on the public network make it easier to collect information in a way that the exact route can be restored. For a car driver it is possible to select any given road between two points, but for a public transport user the indication of a specific bus line between two given points the route can easily be reproduced because of the knowledge of the route of the bus line. In public transport, on each trip the passenger can travel with many different transportation modes also including private modes for access/egress.

2.2 The TU survey

The TU survey is an existing and well-established collection of travel data in the form of travel diaries and respondents' and households' socio-economic data, and is consisting of a questionnaire which is either filled out on the internet (at present 20 %) or via telephone (at present 80 %). The survey is ongoing and has more or less been carried out in the same way since 1992 (however, with a break in 2004-5, and telephone based until this break). In the TU survey, respondents are a representative sample of the Danish population between 10 and 84 years who are asked to describe all their trips with both private and public transportation modes on the day before the interview. Data from May 2006 are considered as the "new dataset" since data have been collected continuously since. The survey is ongoing and observations for 62,232 people and 189,297 trips collected from May 2006 to May 2010 are in the dataset.

Respondents provide information on all their trips during the day (e.g., selected modes, time duration, length travelled, trip purpose) and all their socio-demographic characteristics (e.g., gender, age, income, place of residence and workspace). The data are a great source of information and enable revealing many interesting details about travellers' choices in transportation networks.

The existing TU survey links information on actual travel behaviour to a list of background variables making the survey an obvious choice for the addition of the public route choice survey questions.

2.3 Public transport route choice questions

As aforementioned, the questions added to the TU survey were shortly and precisely formulated. The information should be detailed enough to enable the reproduction of the route, but also simple enough for the respondent not to have possibility of misinterpretation. By answering questions about specific points, the route can be reproduced with knowledge of the public transportation network. The public transport route choice question part of the TU survey are presented and explained in the following sub-sections.

2.3.1 Introduction

Before answering the questions concerning public transport route choice, an explanatory text to the following questions is provided to the respondent:

On the next pages you are asked questions about your transportation on [DATE]. Every time you travel on street / road to get to a new activity / purpose, or a new place, we call it a trip. A trip can also be an end in itself, such as jogging or walking the dog.

Remember all errands en route. All errands, activities, and accommodations during the day must be included, also the short ones. It is important that you also enter if you have visited a kiosk, picked up someone, walked the dog, or performed other activities that led you to move from place to place.

Change of transport along the way is part of the same trip. If you use public transport, the same trip can contain many transportation modes. Typically there are at least three: walk, bus or train, and walk again. Walk to / from the bus stop / station is part of the overall trip and must be included along with other vehicles. We therefore ask for where you went, and not for where you boarded the bus. Similarly, if you parked your car and walked the remaining distance to reach the destination, then the trip has two modes: car and walking.

Trip out and to home are (at least) two trips. A trip can never have the same location as start and end point. The trip must be divided at all purposes under way. If the trip is a goal in itself, it must be split up, so that the farthest point along the way is the destination of the trip outbound. Remember to finish with the return trip, which probably has destination in your home.

2.3.2 Trip description

The origin, purpose, etc., are listed before the route choice description.

1. Where did your day start?

- The location the respondent listed as home in an earlier question.
- Another place in Denmark (type and select address from list).
- Another place abroad.
 - The last two options return additional questions on purpose of the trip start location.

2. When did you leave [previous entered address]?

3. After you left [...] what was the first place you went to?

- Same options as in 1.

4. What was the purpose of your stay here?

- 24 choices among others work, school, shopping.

Then all modes used on the trip are entered. The respondent chooses from a drop down list (21 modes, among others car, bike, walk, bus, train). When choosing a mode additional boxes to be filled in appear according to the mode entered.

1. List in the correct order transport modes used

- Walk, Bike, Car, Airplane, etc.
 - Enter length and time used.
- Bus.
 - Waiting time, bus line, length and time used.
- S-train.
 - Waiting time, from-station, S-train line, to-station, length and time used.
- Train, metro.
 - Waiting time, from-station, to-station, length and time used.

When the full list of modes used in the trip is entered, the respondent returns to the questions from above, starting with no. 2 and continuing until all the trips for the specific day are entered.

The list of transport modes can get relatively long, especially when using public transport, but the boxes to fill in are relative easily understood, and along the way many checks of the entered information are offered to the respondent. The respondent selects the *from-* and *to-station* from a drop down list containing stations that are within a certain interval of the address entered and the length travelled so far. Along the way, travelling and waiting times are added to the start time for the respondent to check the arrival time. When the *from-* and *to-stations* are entered, the correct length between the two are calculated and suggested to the respondent. In Figure 1 an example of a public route description is shown. The respondent has travelled with several different public transport modes and walked from the origin and to the destination. The blue boxes are to be filled in by the respondent. This is an example of a complicated trip with many transfers, but still the questionnaire is relatively easy to fill in.

Transport modes in correct order:						
	Transport mode	line	length		time	
1.	Walk		0.5 km		8 min	
				Waiting time:	3 min	
2.	Bus	701	2 km		5 min	
3.	Walk		0.2 km		2 min	
	From-station:	Nykøbing F		Waiting time:	7 min	
4.	Other train		146 km		100 min	We calculated the distance to 146 km from the stated stations
	Transfer at:	København H		Waiting time:	8 min	
5.	S-train	E	13.9 km		20 min	We calculated the distance to 13.9 km from the stated stations
	To-station:	Lyngby		Waiting time:	5 min	
6.	Bus	300s	5 km		10 min	
7.	Walk		0.5 km		5 min	
		Sum:	168.1 km		173 min	

Figure 1: Example of a route description for a public transport trip

When using the above mentioned list of transport modes, the route can be reproduced. Information on the start point of the trip can be used to find the bus stop by searching within a certain buffer (the mentioned length with some margin) where the mentioned bus line stops. When the traveller alights at a train station this point is fixed and the route to the next trains stations as well. When selecting *Other train*, the route is almost definite (not many alternative routes between two train stations are served by *Other trains*). In the end of the trip, the respondent uses bus again and the alighting stop of the mentioned bus line can be found by searching from the destination point.

The procedure of searching for the used bus stop could be avoided if the respondent was asked to provide this piece of information. This option has not been implemented since it would be very hard for the respondent to fill in correctly. Few people know the exact name of the bus stops and therefore free hand writing would involve a great deal of manual analyst work afterwards. After selecting the bus line a list of the bus stops on this bus line could be provided to the respondent but this list could be very long, the creation of the list demands entering of the exactly correct bus line name and still the respondent is perhaps not able to recognize the name of the used bus stop.

Anderson and Rasmussen (2010) explain in details the procedure of matching the data to a route in a GIS network.

3 Applications

3.1 Pilot survey at the Technical University of Denmark

In order to test the described method of collecting route choice data for public transportation, the questionnaire was tested in a pilot study at the Technical University of Denmark during a week in May 2008. The pilot study was carried out amongst employees and students as an Internet based questionnaire. DTU had 4,100 employees and 6,200 students in the fall of 2007, giving a good data foundation if a certain percentage had answered the survey. See Larsen (2008) for more details.

The employees were contacted via email and approximately 65% of the staff received an email. No mailing list or the like of student email addresses could be obtained and therefore the students could only enter the survey via a link on the intranet (where also employees not contacted were informed about the survey). The message on the intranet could potentially be seen by many, but could also more easily be ignored or overlooked than an e-mail sent directly to the respondent. Finally, it was decided to offer a prize to the participants, since it was considered that in particular the students would find greater incentive to participate at the prospect of winning a competition.

The questionnaire available to the DTU respondents was only in Danish, since the existing TU survey was only in Danish. It is estimated that the non Danish speaking share of the employees and students (about 25% and 10% in 2007, respectively) of DTU are sufficiently small to make it possible to get good response rates even without an English version of the questionnaire.

As mentioned earlier, the original TU survey is designed to allow the respondent to choose between being interviewed by telephone or via the Internet. In this study there were no resources to conduct telephone interviews and therefore the questionnaire was only available via the Internet. In 2006, 23% chose to complete the TU survey via the Internet. If these rates are directly transferable, 77% could be expected not to answer the questionnaire.

However, the missing possibility of telephone interviews is expected to give a significantly smaller drop-out rate among DTU staff and students than in the general population. The vast majority of the DTU staff and students are familiar with the Internet and use it in everyday life. In addition, in this study there was no other ways to participate in the survey. It is not known what proportion of the participants in the Danish Travel Survey who would use the Internet version if it was the only option.

The pilot study at DTU collected 545 responses which equals a response rate of 5%. Among students only 3% participated, while among employees 8.5% took part.

Some started the questionnaire without completing it, but there is not enough information to explain this drop-out. The vast majority of the drop-outs (95 %) spent less than the estimated 20 minutes to complete, and therefore probably had no intention of completing it from the start.

1,096 people opened the questionnaire and 545 completed it. 164 people only opened the questionnaire and did not answer a single question, so of the actual respondents 64 % completed the entire study. It was registered the time when the respondent accessed the questionnaire via the link and it could therefore be seen how far the respondent got. It is not known the reason why the

potential respondents showed interest in the study by pressing the link and then gave up before they actually start.

239 persons did not proceed from the introductory page. 127 additional persons gave up after less than 2 minutes. It was reported that the survey was going to take between 10-20 minutes to complete. This was estimated from various tests of the questionnaire. On average 49 minutes were spent on the questionnaire, but this number was significantly affected by the respondents who opened the questionnaire and chose to complete it at a later time and therefore kept it open for several hours. The median ignores the most extreme observations and is therefore providing a more accurate representation of the time compared to the average. The median is calculated on the entire dataset avoiding trying to define a border for outliers. The median is 14.8 minutes, which means that the completion time has been estimated quite accurately.

Data were collected in the ordinary TU survey (without route choice questions) in the same period as the pilot survey. Here, Internet respondents on average spent 79 minutes with median equal to 21.1 minutes, thus there is a slightly smaller time use in the pilot survey than in the ordinary survey. More time spent for the pilot than in the ordinary survey was expected because of the introduction of additional questions and fields to be completed. The lower time may be caused by the fact that the survey was conducted among students and staff at DTU, which are likely to be more Internet competent than the average population.

The pilot study results showed that it was possible to introduce the additional public route choice questions without extending the duration of the investigation significantly. There had previously been reluctance to include route choice questions for fear of how much it would extend the duration of the survey, but these findings in the pilot study showed that this fear was not justified or the problem, at least, was not at the assumed large extent.

3.2 Implementation in the TU survey

Since February 2009, the public route choice questions have been implemented as part of the TU survey; see Christiansen (2009) for more details. From February 2009 to May 2010, more than 25,000 interviews were collected with approximately 78,000 trips, of which 4,400 by public transport for at least a part of the trip.

Each use of a different mode during a trip is defined as a trip part in the TU data. The number of trip parts with bus, S-train, metro and other train are shown in Table 1. The table also illustrates how many respondents have entered information on line use (99 percent of bus passengers, all S-train users) and which train station was travelled via (8 % of bus users, minimum 97 percent of the train users). The low share of train station information for bus user is due to the fact that respondents are not asked this piece of information, but when they travel to and from a train station this piece of information is added to the dataset.

The number of completed public transport trip parts is relatively high and shows that it is possible for the respondents to fill in the route choice questions. The highest difference is for *from-station* for *Metro* and *to-station* for *Other train* (97%). For other train the missing stations are often in foreign countries and the foreign stations do not appear on the drop down list. Another explanation for the missing information could be that the automatic calculation of stations to select from the drop down

list does not present the actual used station because the respondent has entered wrong information in terms of travel length, etc.

Table 1: Number of trip parts using the four public transport modes, number of entered lines, from- and to-stations

Mode	No. of trip parts	Line	From-station	To-station
Bus	3,611	3,576	291	293
S-train	1,122	1,122	1,122	1,103
Metro	885	-	859	866
Other train	491	-	490	476

Both respondents who have travelled with public transport and respondents who have not have had an increase in the amount of time used to fill in the questionnaire via internet after the route choice questions were implemented. Table 2 shows the time use, for the dataset from May 2006-May 2010, split in before and after the route choice questions were added in February 2009. The time used is showed as median value. Some people log on twice to fill the Internet based questionnaire and the time use is registered from the first login to the completion of the survey so in these cases the time use could be several days.

Table 2: Median [min] of the time used to fill in the TU survey for the 2006-2010 dataset

Interview period	All	Public	Other	Internet	Telephone
All (May 06-May 10)	8.5	11.2	8.2	21.6	7.5
Before Feb. 2009	8.3	10.5	8.0	21.8	7.3
After Feb. 2009	8.8	12.2	8.4	21.4	7.8

The increase for all respondents is 0.5 min in average. For public transportation users, the increase is 1.7 minutes. The time use was higher for the public transport users before the new questions were added, but the increase for public transport users is higher in percentage than for non public transport users. The median time used for Internet respondents is almost twice the time used for telephone interviews. The Internet time use has dropped after February 2009, and this can be due to many other changes than the route choice questions (java scripts were added to create faster searches and to correct illogical entries). Time use via telephone use has increased, which could be an effect of the route choice questions.

Table 3: Median [min] of the time used to fill in the TU survey for the 2006-2010 dataset

Interview Period	All	Public	Other	Internet	Telephone
All (May 06-May 10)	8.5	11.2	8.2	21.6	7.5
Oct. 08- Feb. 09	7.8	10.0	7.5	20.4	6.8
Feb. 09-May 09	8.7	12.4	8.3	22.2	7.7

Table 3 shows the difference in time use between the questionnaire version just before and after the implementation of the route choice questions. The version used until February 2009 has a lower time use for all the respondent groups tested. The increases in time between those two versions are from 9 to 24%, the highest for public users and the lowest for internet users. In the comparison between

the new and the whole dataset, time use for entering public trips increases 10%, while time for non public transport users only increases 1%. Internet and telephone both increase 3%.

Table 2 and Table 3 show that there has been an increase in time use for public transport respondents after the implementation of the public route choice questions. Comparing the dataset just before and after the implementation, a greater increase is registered for public users, but the difference rather quickly equalises. The increase can be caused by the fact that the telephone interviewers had to learn how to work with the new questions and, since the highest amount of interviews are completed via telephone, this had a great impact on the results. The time use has not increased too dramatically to be accepted.

4 Summary and conclusions

The question of how to create a survey to collect route choices of public transport passengers was investigated and answered in this study. The requirements for the collection method were ability to collect for many people, simplicity of the choices, easiness to answer correctly, and ability to present the actual chosen by making it reproducible in a GIS network.

Of the different solutions considered a questionnaire form was chosen. The questionnaire was accessible in an internet based form or by an interviewer via a telephone interview. The route choice questions were created with the GIS network in mind and added to the existing Danish Travel Survey. The internet based questionnaire was tested in a pilot study at DTU in May 2008 proving that it was possible to add the questions to the existing survey and get satisfactory answers. From February 2009 onwards, public transport route choice data have been collected in the TU survey providing a dataset of more than 4,000 route choice descriptions.

The pilot study and the results of the implementation of the route choice questions show that the route choice for public transport passengers can be collected via a questionnaire. The questions are rather easy to answer and do not extend significantly the time used for the survey, but still they fulfil the requirements of collecting data enabling reproduction of the route choice on a GIS network (see Anderson and Rasmussen (2010) for details of the matching in a GIS network). When implemented to the TU survey, great data amounts are being collected from all over Denmark and the number of observations is increasing instantly. This provides opportunity for many different uses of the data.

The study has provided insight in the actual route choices that passengers make in this public network and basis for good estimation of route choice models for public transport. At the moment, three studies at DTU Transport are benefiting from the route choice questions. A study is investigating the feeder modes to train stations in the Copenhagen region and this data source provide an, until now, inaccessible amount of information. Other two studies use the data for assessment of generated public route choice sets and the data will also be used for estimation of public route choice models. These ongoing studies prove that the public route choice survey is useful and has been successful.

Acknowledgements: Carsten Jensen and Hjalmar Christiansen, DTU Transport, are thanked for their work on the practical design and implementation of the public route choice questions in the TU survey.

5 References

- Abdel-Aty M.A., Kitamura R., Jovanis P.P., Reddy P., Vaughn K.M. (1995), New Approach to Route Choice Data Collection: Multiphase, Computer-aided Telephone Interview Panel Surveys Using Geographic Information Systems Data base, *Transportation Research Record*, 1493, pp. 159-169
- Anderson M.K., Rasmussen, T.K. (2010) Matching observed public route choice data to a GIS network, Conference paper for Aalborg trafikdage
- Bierlaire M., Frejinger E. (2009), Route Choice Modeling with Network-free Data, *Transportation Research Part C*, 16, pp. 187-198
- Bovy P.H.L., Bradley M.A. (1985), Route Choice Analyzed with Stated-preference Approaches, *Transportation Research Record*, 1307, pp. 11-20
- Holm J. (2009), *GPS data som grundlag for en national rejsehastighedsdatabase*, Conference paper for Aalborg trafikdage
- Hoogendoorn-Lanser S. (2005), *Modelling Travel Behaviour in Multi-modal Networks*, PhD Thesis, TRAIL Research School, Technical University of Delft, the Netherlands.
- Jan O., Horowitz A., Peng Z. (2000), Using GPS data to understand variations in path choice. *Transportation Research Record*, 1725, pp. 37-44
- Christiansen H. (2009), *Vedr. Modernisering af Transportvaneundersøgelsen*, Conference paper for Aalborg trafikdage
- Larsen M.K. (2008) *Indsamling af data for rutevalg i kollektiv transport*, Conference paper for Aalborg trafikdage, Selected proceedings, ISSN 1603-9696
- Mahmassani H.S., Joseph T., Jou R.-C. (1993), Survey approach for study of urban commuter choice dynamics, *Transportation Research Record*, 1412, pp. 80–89
- Prato C.G. (2005), *Latent Factors and Route Choice Behaviour*, PhD Thesis, Turin Polytechnic, Italy
- Ramming S. (2002), *Network knowledge and route choice*, PhD Thesis, Massachusetts Institute of Technology, Cambridge, USA
- Schönfelder S., Axhausen K., Antille N., Bierlaire M. (2002), *Exploring the Potentials of Automatically Collected GPS Data for Travel Behaviour Analysis – A Swedish Data Source*, In: Möltgen J., Wytzisk A. (Eds.), *GI-Technologien für Verkehr und Logistik*, number 13 in IfGIprints. Institut für Geoinformatik, Universität Münster, Münster, pp. 155–179
- Vrtic M., Schüssler N., Erath A., Axhausen K., Frejinger E., Bierlaire M., Stojanovic S., Rudel R., Maggi R. (2006), *Including travelling costs in the modelling of mobility behaviour*, Final report for SVI research program Mobility Pricing: Project B1, on behalf of the Swiss Federal Department of the Environment, Transport, Energy and Communications, IVT ETH Zurich, ROSO EPF Lausanne and USI Lugano