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Household travel survey of intermodal trips – Approach, challenges and comparison

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Abstract

The increasing use of new mobility services like car and bicycle sharing, information and communication technology results in changing use patterns. Multimodal as well as intermodal use of transport modes is increasing in importance. Multi-agent travel demand models are able to describe intermodal trips for supporting transport policy in evaluating planned measures. Such models require comprehensive information on individual (intermodal) travel behaviour. Our work describes the design of a household travel survey focusing on intermodal trips. Additionally, it discusses challenges that emerge in comparing results to traditional household travel surveys, which mainly focus on main mode.

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Keywords: intermodal trip; trip chains; intermodal survey; last mile

1. Introduction

Travel behaviour is changing due to several reasons such as the decreasing use of cars, the reduced car availability especially of young adults or the increasing importance of mobility services. These trends have been observed by different studies (e.g. Institute for Mobility Research, 2013) and household travel surveys (e.g. Zumkeller et al., 2008). Looking at young adults in particular, the question arises about whether they adapt their travel behaviour due to circumstances such as becoming parents. It is clear that environmental consciousness leads

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to more sustainable travel behaviour. Car use is decreasing in metropolitan areas with efficient public transport facilities, car sharing supply and well-developed bicycle infrastructure. Additionally, travel behaviour of people living in metropolitan areas is becoming more and more flexible since mobility sharing options like car-2-go, drive-now or call-a-bike became available.

People have increasing multimodal travel behaviour (Institute for Mobility Research, 2013; Kuhnimhof et al., 2010). They use different modes for their trips over a longer period, such as one week, and may adapt the mode of transport depending on the specific situation. Not only is multimodal travel behaviour increasing, but also intermodal travel behaviour, which refers to the use of more than one mode within one O-D-trip. The project "I-eMM" (Intermodal electric Mobility Management) deals with this intermodal travel behaviour in the Rhine-Neckar region. The planning area covers the city of Mannheim which is metropolitan and three small communities around Mannheim (partly rural cities in the catchment area of Mannheim with and without railway connection). Within the project we aimed to develop electric vehicle concepts such as pedelecs, scooters or small electric cars which are operated in combination with public transport in order to improve access to and egress from public transport. The research focuses on the effects and acceptance of these concepts regarding influences on travel behaviour as well as the integration of these concepts in the operating procedure of public transport companies. Electric driven vehicle concepts should make it easier to reach public transport stations or bus stops and therefore increase the use of public transport. For this reason the project I-eMM surveys intermodal trips in the planning area in order to develop a model which is able to evaluate effects of electric vehicle concepts for defining a sustainable supply and intelligent and intermodal mobility. To develop and evaluate intermodal supply concepts focusing on the improvement of the connection to public transport systems on the last mile, we needed comprehensive information about people's travel behaviour. Therefore we developed a web-based survey which collects information on intermodal trips.

This paper describes the design of the developed questionnaire and the challenges. We also show the main findings of the survey in comparison with existing surveys in order to assess the quality of the results from our survey. The main research question is: "Are there differences between the modal split based on trips and on stages?"

The paper is structured as follows. Section 2 reviews literature on existing intermodal surveys. The approach of surveying intermodal trips and their challenges is described in section 3 and section 4 presents the results of the survey analyses.

2. Literature and research question

Since our work focuses on the development, the challenges and the analysis of a household travel survey which collects data on intermodal trips, our literature focuses on the analysis of existing intermodal travel surveys and the estimation of intermodal travel behaviour.

In most existing national household surveys intermodal behaviour is treated incidentally. Thus, there is less literature to find. However, there are several countries, such as Great Britain or Denmark, which included intermodal trips in their national household surveys. Further, the Swiss National Travel Survey (Bundesamt für Statistik Schweiz, 2012) surveyed intermodal trips in a very comprehensive way. Stages were recorded with a completely novel route-recording method. A stage consists of a portion of a trip completed with the same transport mode (including walking). Anyone riding a bicycle to the railway station, then taking the train and finally walking from the destination station to the workplace thus completes three stages but only one trip. The survey records all of the stages completed by the respondent. The respondents take part in a computer-assisted telephone interview (CATI) where they answer questions about these stages covering choice of transport mode, start and end points, distance travelled, and self-reported times of departure and arrival (Ohnmacht and Kowald, 2014).

Pan et al. (2010) examined the potential to improve travel efficiency by increasing the use of bicycles as a transfer mode for rail transit riders in a case study of Shanghai. To understand what influences people's choice on access and egress trips to rail stations, a survey of rail transit riders on three rail stations was conducted. The analysis of this survey data revealed that walking had the largest mode share for access (51%) and egress (81%) trips followed by bus (29% for access and 13% for egress trips). The bicycle share was low (11% for access and 1% for egress trips), partly due to regulations by government which do not allow the carriage of bicycles in transit and the inconvenience and difficulty of carrying a bicycle on an overcrowded train.

In existing national household travel surveys in Germany like the German Mobility Panel (Zumkeller et al., 2011), Mobility in Germany (infas and DLR, 2010) and the regional household survey of the Rhine-Neckar region (Kagerbauer, 2010), modal split analysis is based on the concept of the "main transport mode". Every trip is represented by (only) one main transport mode according to a method defined by the German Institute of Economic Research (DIW Berlin). Thus, in these surveys intermodal trip information is observed in a very basic way. Participants can report different transport modes for one trip. However, knowledge about the sequence of stages and their duration is missing. To cover this information more precisely we developed an intermodal household survey which collects intermodal trip information on all stages, all modes and the associated duration and length of the stages.

3. Challenges and approach of the intermodal household survey

An intermodal trip consists of more than one stage. Each stage can be undertaken by a distinct transport mode. The main objective of our survey is to analyse all trips with the corresponding stages and transport modes of a specific day and person. Knowledge about the sequence of stages and their duration is very important for the estimation of an intermodal mode choice model. Thus, more comprehensive information, such as distance and time periods of several parts of a trip, is important.

3.1. Challenges

Designing a questionnaire that includes detailed information on intermodal trips has two main challenges. First, the survey should collect duration, distance, mode and sequence of each stage without losing the information on the overall trip. Hence, one main task is to maintain the concept of the "main transport mode" and add information on access and egress stages. This ensures comparability to other existing surveys. Our goal is to get reliable results from a representative sample in the project region. Beyond the use of socio-demographic statistics like age and income distribution for assessing the sample, it is also important to evaluate the reported trip data and compare it to existing surveys. As our survey is the first intermodal trip survey in the project region, the trip data has to be comparable to conventional surveys in Germany which use the concept of "main transport mode".

Second, the complexity of the survey should be minimised in order not to confuse survey participants. The need for further comprehensive information leads to an increasing number of questions that participants have to answer. However, the questionnaire should not be overloaded with too many questions. Consequently, the design of the questionnaire has to be both functional so that comprehensive intermodal trip information can be collected and easy to fill in so that the questionnaire is not overloaded.

3.2. Survey method

Traditional household surveys which aim to collect information about people's travel behaviour use trip diaries. The participants are asked to fill out the trip diaries. Usually such trip diaries are paper based (PAPI) and sent out by mail. Intermodal trip collection needs more comprehensive information – each stage of an intermodal trip has to be reported like a conventional trip. Due to this increasing need for information and the increasing time expenditure for participants reporting intermodal trips, it is hard to incorporate an intermodal household survey with PAPI methods without confusing the participant with too many questions or possibilities to fill in. Hence, our intermodal survey is web-based. It is designed in a sequential way with a smart filter management. The respondents only answer questions which fit with their intermodal travel behaviour. The drawback of using web-based survey methods is the risk of getting an overrepresentation of younger persons. Since our goal is to get reliable data for a representative sample in the project region of the Mannheim area, we wanted to avoid such a biased age distribution in the sample. In accordance with the work of Kagerbauer et al. (2013), the combination of computer-assisted telephone interview (CATI) and computer-assisted web interview (CAWI) seems to be the most promising method to prevent nonresponse issues in older age groups in the population. As young people are more likely to participate in a CAWI survey and older people in a CATI survey, the results of both CATI and CAWI together are comparable with those of a PAPI survey. The sample in this study is drawn from the official register of residents. Participants were given two different options to participate in the survey: either answering the questions in a computer-assisted telephone interview (CATI) or in a computer-assisted web interview (CAWI). This approach helps to achieve a sample which is less biased and representative for the planning area after weighting.

3.3. Survey design

To overcome the challenges described above our survey is web-based (for both CAWI and CATI methods) and constructed in a sequential way with a smart filter management. It uses the concept of “main transport mode”, i.e. we ask for the main mode first. Afterwards, we gather time and mode specific information on the access and egress stages in sequence.

Besides the socio-demographic information which is asked at the end of the interview, a trip diary is implemented. Each participant in the survey reports every trip of a day including departure time, origin and destination, trip purpose and every mode used on each stage. After asking for the main mode information first, we gather time and mode specific information on the access and egress stages one after another. The choice set is adapted in a way that only modes with a lower rank than the main mode can be chosen as access or egress modes. To keep the handling easy and to ensure correct answers from the respondents, questions were kept simple. For example, the questions for the main modes are simple questions like “Did you use the train on your trip?”, “Did you use the car on your trip?” and so on for all main modes. Hence participants do not need to know about the definition of main modes and they just have to answer “yes” or “no”. It is important to survey the sequence of the main transport mode queries from the highest to the lowest rank. These chronological questions ensure the collection of the main mode, and all possible stages with their modes and their duration for the whole trip.

As shown in Figure 1 every main mode has its own access and egress query which queries all stages (parts) of the trip step by step. Additionally, participants are asked for different information depending on the main transport mode used. For example, if they choose bus as main mode they will be asked for the start and destination bus station. If they choose car passenger as main mode different scenarios will be conceivable. The trip could consist of exactly one stage when the person is picked up at the starting point and taken to the destination point. The trip will turn into an intermodal trip if the person first has to walk to a parking place to enter the car as a passenger. Every main mode has individual sequences of questions to consider all possibilities of intermodal and monomodal trips. The basic sequence of questions is described as follows. First, the starting point is specified, then individual information about the access is queried. After defining the intermodal transfer point, such as a public transport station, we collect information about the duration of the ride with the main mode. Finally the egress stage(s) are queried.

As a consequence the complexity of the survey increases – more than 150 questions are implemented to get information on one intermodal trip due to the different possibilities described above. However, in spite of this number of questions participants do not notice the complexity. They are led through the questionnaire by a smart filter management so that only those questions appear which are relevant for their specific trip. A participant has to answer up to 15 questions on average.

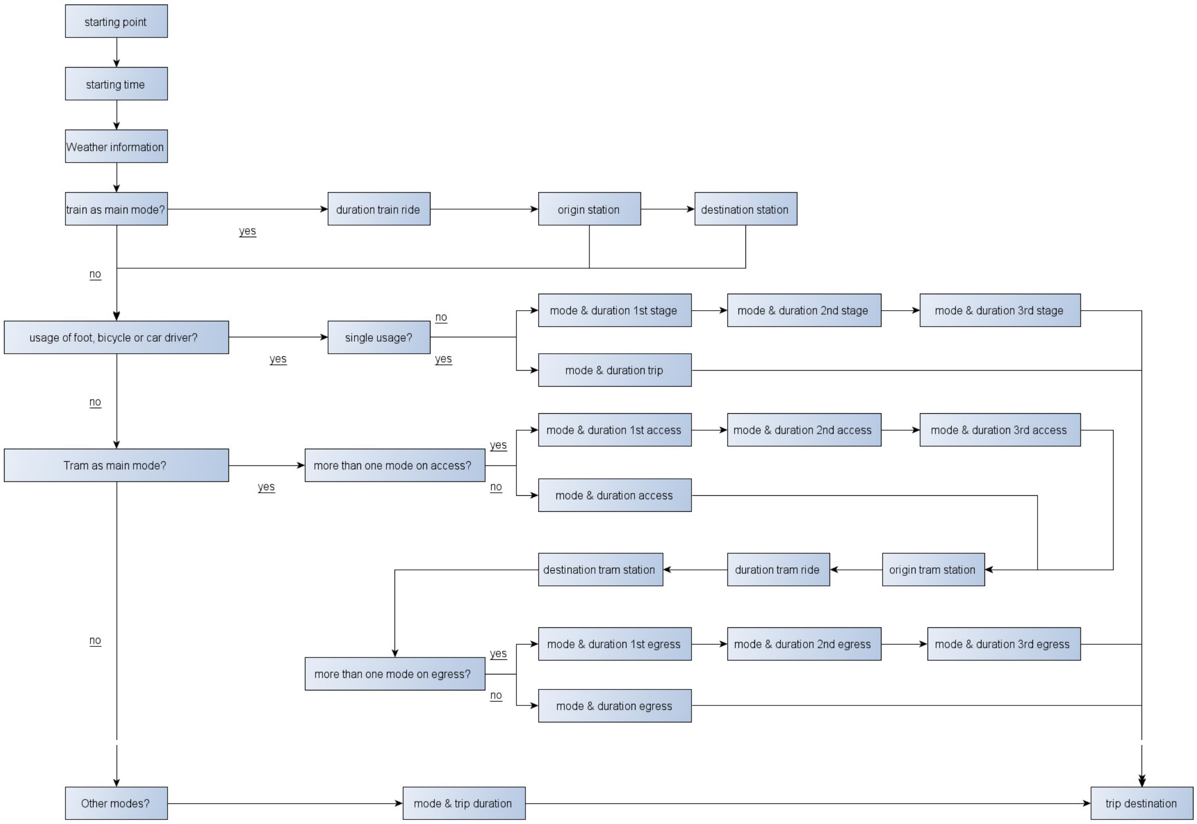

Figure 1. Intermodal survey logic for one intermodal trip (excerpt only for selected main modes).

4. Results

Within the project I-eMM we carried out the intermodal household travel survey in the Mannheim area. We recruited 2,167 people drawn from the official register by random sampling methods and 164 of these people answered the questionnaire completely, leading to the response rates shown in Table 1. In comparison, the survey (CATI+CAWI) carried out in the Rhine-Neckar region in 2007 had quite similar response rates: 8.1% (useful questionnaires/sample size), 16.7% (households willing to participate/sample size) and 51.8% (useful questionnaires/ households willing to participate). This leads to the conclusion that the willingness to participate is stable over the years.

Table 1. Response rates of the intermodal travel survey in the Mannheim area 2013

Response rates	Intermodal Travel Survey Mannheim 2013
Ratio of persons successfully surveyed [%]	7.57%
(= useful questionnaires / sample size)	
Ratio of persons willing to participate [%]	12.18%
(= persons willing to participate / sample size)	
Ratio of persons successfully surveyed [%]	62.12%
(= useful questionnaires / persons willing to participate)	

To classify our results we analyse the key travel behaviour figures from other surveys in similar regions – a household travel survey in the metropolitan region of Rhine-Neckar from 2007 (MRN 2007), which was conducted in the same area with a bigger scope and the German Mobility Panel from 2012 (MOP 2012). The mobility key figures are trips per day, kilometres per day and the time spent for trips in minutes during one day. The results are summarised in Table 2. It shows that the participants of the intermodal survey make fewer trips (3.2 trips per day) than in MRN 2007 and MOP 2012. One reason for that may be the spatial conditions. The intermodal survey's participants live in a quite small and very urban area with a very good infrastructure whereas the other surveys also include participants living in larger rural areas. In these rural areas people have to travel more often and further. The length of the trips is summarised in the key figure of kilometres per person and day. The analysis of the travelled distance shows almost the same value of 39 or 41 kilometres. Normally, we would expect a lower value in the intermodal survey. However, due to the existence of a few trips with a long length, the travelled distance has a higher value than expected.

Table 2. Comparison between the intermodal survey and existing surveys.

	Intermodal Survey	MRN 2007	MOP 2012
Trips per day	3.2	3.6	3.36
Kilometres per day	39	39	41
Time per day [minutes]	80	84	82
Modal split			
Walking	18%	21%	21%
Bicycle	11%	11%	13%
Private Transport	53%	58%	54%
Public Transport	18%	10%	12%

In total the results of our survey are comparable to results of other household travel surveys. In the following section, we show selected findings for intermodal travel behaviour calculated from our intermodal travel survey.

22 percent of all trips are intermodal trips

As defined above an intermodal trip consists of more than one stage with a distinct transport mode, whereas, trips that consist of only one stage are monomodal. Figure 2 shows the number of stages per trip. The results show that 78% of all trips are monomodal trips and 22% of all trips are intermodal which consist of two up to five stages. Of intermodal trips, most have three stages followed by trips with two or four stages.

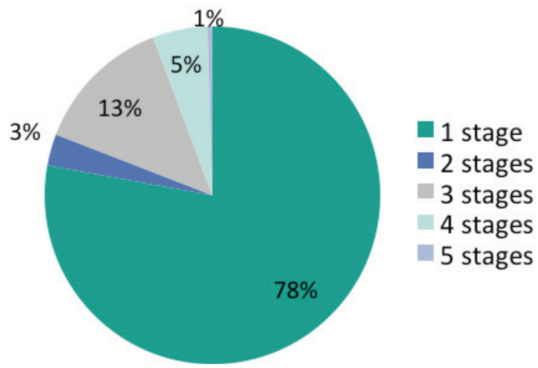

Figure 2. Share of stages by trips.

A typical intermodal trip is a public transport trip with three stages which often is as follows: an access stage to the public transport station, the public transport ride and an egress stage from the station to the destination of the trip. This is emphasised by the findings of Figure 3. It illustrates that almost 80% of trips with public transport as main mode are intermodal trips consisting of three stages. Another 20% of public transport trips consist of four stages. On these trips more than one mode is used on the access or egress stage. Further, there are only a few public transport trips with five stages. In addition, we establish that there are no public transport trips that consist of less than three stages, because it is normally impossible to have a public transport ride without getting to a station. Figure 3 also illustrates that more than 90% of trips with private transport or bicycle as main mode are monomodal and only a few trips consist of two stages. An example of an intermodal private transport trip is accessing the car by walking, executing the ride by car and parking close to the destination so that an egress walk trip is unnecessary. In our survey the definition of an access trip to a private car was not set as we wanted to see when people report their access and when they do not report it. When people report access by walking, this stage usually takes more than two minutes and has a length of more than 100 metres. Since we do not enforce the reporting of the access to a car, intermodal trips are in this case reported less frequently. The same holds true for intermodal trips in combination with the main mode bicycle. However, walking trips are by definition always monomodal trips.

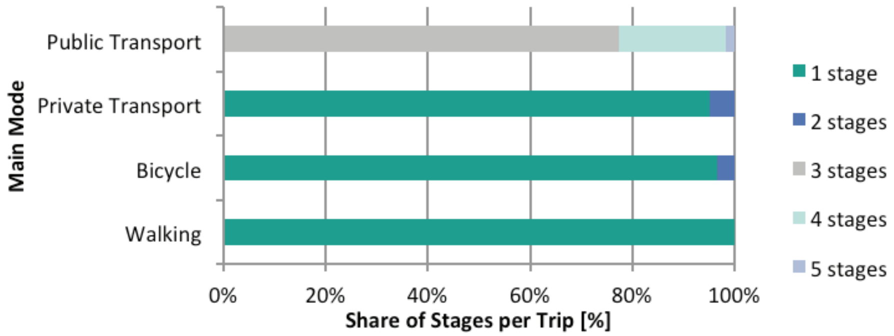

Figure 3. Share of stages per trip by main mode.

Intermodal trips are longer than monomodal trips

By comparing intermodal and monomodal trips we analyse differences in the length of the trips. Most intermodal trips have a length of 4.5 kilometres (Q1) to 12.5 kilometres (Q3) and a median of 8.5 kilometres. Monomodal trips range mainly from 2 kilometres (Q1) to 9 kilometres (Q3) with a median of 4.5 kilometres. The mean values of both intermodal and monomodal trips are higher than the median. This is caused by the existence of few reported trips with a long length. Figure 4 shows the boxplot of length distribution of intermodal and monomodal trips.

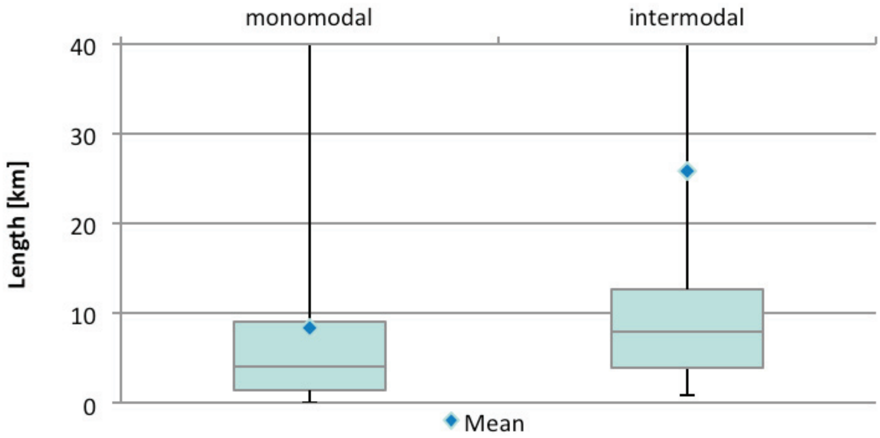

Figure 4. Length of intermodal and monomodal trips in comparison.

Increasing share of walking, decreasing share of private and public transport

Another interesting analysis of our intermodal survey results is the difference in modal split (traffic volume) on the basis of trips and on the basis of stages. In conventional surveys the modal split is based on trips. However, using this definition, important information on intermodal trips is lost. Thus, we state that a modal split based on stages contains more comprehensive information and should be considered. Figure 5 illustrates the modal split on the basis of stages and on the basis of trips. Two differences are obvious. First, the share of walking trips increases from 18% to 36%. Second, the share of private transport decreases from 53% to 37%. Walking is a typical mode for access or egress stages. More than 90% of these stages are made by walking. All these trips are not considered in the concept of the main mode. This leads to an increasing number of short walking trips, at least two for every public transport trip. The decreasing private and public transport share is just a consequence of this observation. While the number of these trips remains the same, the share decreases. For bicycles the number of trips increases since about 10% of access and egress trips are made by bicycle. But due to the high increase in the walking trips, the proportion of bicycle trips remains the same.

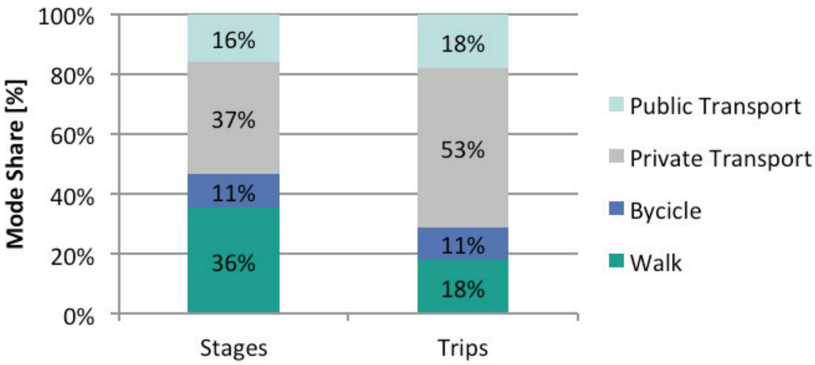

Figure 5. Mode split (traffic volume) on the basis of stages and trips.

Figure 6 shows that the modal split on the basis of stages and on the basis of trips does not differ much based on the travelled distance. Walking trip distance and private transport trip distance increase about one percentage point (walking from 3% to 4%, private transport from 53% to 54%). As the length of every trip with public transport decreases by the length of their egress and access stages, the share of distance travelled by public transport loses two percentage points (from 40% to 38%). So, in spite of quite large variations in the number of trips, the modal split on the basis of travelled distance only shows less change.

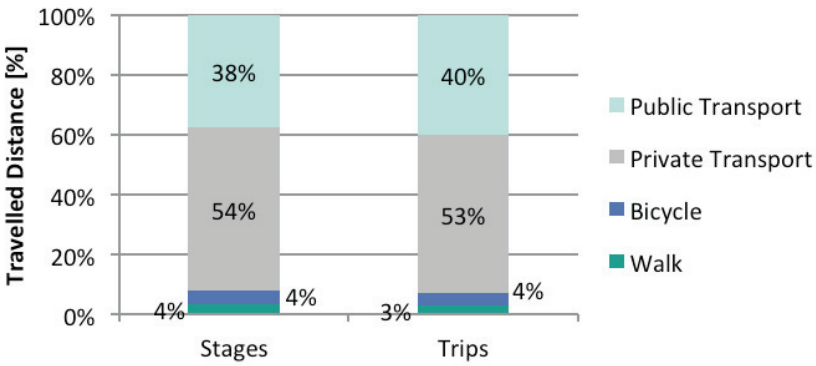

Figure 6. Mode split (travelled distance) on the basis of stages and trips.

Model implementation of intermodal trips

As the aim of the project I-eMM was to develop and evaluate intermodal e-sharing services from the customer perspective, we considered both the supply with suitable vehicle supply concepts and the demand focusing on intermodal trips as well as the acceptance of the developed sharing services on intermodal trips. We integrated the sharing systems into an agent-based travel demand model which models intermodal trips on the basis of this survey (Schröder et al., 2014). The model results allow us to give a realistic recommendation and evaluations of intermodal sharing offers for the planning area. The recommendation includes information about the most suitable intermodal sharing concepts and their vehicle requirements.

5. Conclusion

Travel behaviour in cities may change in the future – multimodal as well as intermodal use of different transport modes is becoming more and more important. To improve intermodal travel in cities comprehensive information on individual intermodal travel behaviour is required. We succeeded in developing a web-based questionnaire that surveys intermodal trips in a comprehensive way. As a result we gathered information on the overall trips (start and end location, trip purpose, main mode, duration) and also on the egress and access stages (duration, length, sequences of modes, transfer points). Our survey design ensured the comparability to results of existing surveys basing on the concept of the main transport mode. Our results showed that 22% of all trips are executed with more than one mode. By comparing the modal split on the basis of trips and stages we show that walking and cycling are underrepresented in conventional mode shares. The intermodal trip information can also be the basis for an intermodal mode choice model that allows more accurate representation of a person’s travel behaviour in agent-based simulation models. With such a model we are able to support transport policy in evaluating measures to improve transport conditions on access and egress stages.

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