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## Developing and Evaluating Intermodal E-Sharing Services – a Multi-Method Approach

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### Abstract

Different studies assume that travel behavior and mobility patterns of people may change within the next years: multimodal and intermodal usage of transport modes are getting more and more important. We expect a great potential for sharing services especially on intermodal trips. We aim at developing and evaluating intermodal electric mobility management concepts from the customer perspective. Since conventional approaches and singular methods are not appropriate, we adopted a multi-method approach consisting of five parts: (1) supply concepts are developed, (2) vehicle requirements for intermodal sharing are identified, (3) intermodal trip information is collected, (4) an agent based model and a macroscopic demand model are developed further in order to represent intermodal trips and e-vehicles and to evaluate several supply concepts, and (5) the impact and acceptance of modern and flexible mobility services like carsharing, bikesharing or new electric vehicle concepts (e.g. segways or light cars) is assessed and evaluated. The proposed methodology can be used for the development of customer oriented and attractive intermodal sharing services. Hence, the model results are essential for the evaluation and economic appraisal of e-sharing services from the supplier perspective. The proposed methodology can be applied to other cities and regions.

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## 1. Introduction

Different studies assume that travel behavior of individuals may change within the next years (Kuhnimhof, Wirtz, & Manz, 2012; Chlond, Wirtz, Streit, Weiss, & Vortisch, 2014; Kagerbauer & Vortisch, *Mobilität heute und morgen?*, 2013). Multimodal and intermodal usage of transport modes is getting more and more important. People have a multimodal travel behavior when they switch their main modes of transport for different trips in a longer period (e.g. in the course of one week). We define an intermodal trip as the usage of several transport modes during one trip, e.g. a trip with public transport in combination with bike or private car (park-and-ride). Innovative concepts of flexible vehicle sharing services are also conceivable. These services might improve the connection between egress and access stages of public transport. These stages might be an attractive use case for electric vehicles, such as pedelecs or battery electric cars (BEV) since these “first miles”/“last miles” are within the range limit of these vehicles. In this paper we develop a multi-method approach for evolving and evaluating innovative sharing concepts using electric vehicles from the customer perspective.

The remainder of the paper is structured as follows. In section 2 literature on intermodal sharing concepts is reviewed. The multi-method approach is described in section 3 and its results are presented in section 4.

## 2. Literature Review

Many cities all over the world try to shape mobility services in order to fulfill the changing mobility needs of their inhabitants.

Bikesharing services are applied in various cities all over the world, for example in Paris, Montreal, Washington D.C. and Gothenburg. Bikesharing stations in Barcelona are located near metro stations in order to promote especially intermodal transport in combination with bikesharing and public transport (Midgley, 2009).

Other cities foster special carsharing services for short trips within the city, for example the Stadtteilmobil Project in Essen, Germany (Stadtmobil Rhein-Ruhr, 2014).

Furthermore, regional public transport providers start to react on changing mobility needs of their customers. The “Rheinbahn Düsseldorf” transportation authority offers for example the “Mobil in Düsseldorf” monthly ticket. Holders of this ticket can use all local public transportation services in the urban Düsseldorf area, as well as bikesharing (240 minutes per day) and carsharing (90 minutes per month). Comparable services are in use in other German cities such as Hannover, Freiburg and Bremen (Wolter, 2012).

To our knowledge there are no fully integrated intermodal mobility services that allow booking the whole intermodal trip as a combination of public transport and innovative concepts of electric mobility and flexible vehicle sharing services at once. We aim in integration such a service in the Mannheim metropolitan area (city of Mannheim and neighbouring municipalities Heddeshheim, Ilvesheim and Viernheim).

In order to do so, we need to evaluate the potential of those new services from the customer perspective. Therefore, the important questions are: do potential customers accept flexible systems for their intermodal trips? Which requirements have potential customers on both, the vehicles and on the supply concepts? How can we assess the user acceptance and thus how to incorporate these concepts in existing transport models?

## 3. Methodology

Conventional approaches and singular methods are not appropriate for developing and evaluating intermodal e-sharing services from the customer perspective. Their major drawback is that they do not map complex and intermodal travel behavior. Moreover, a sophisticated, multi-method approach must be developed in order to overcome the weaknesses of singular methods.

Our multi-method approach for developing and evaluating intermodal sharing services is illustrated in Figure 1.

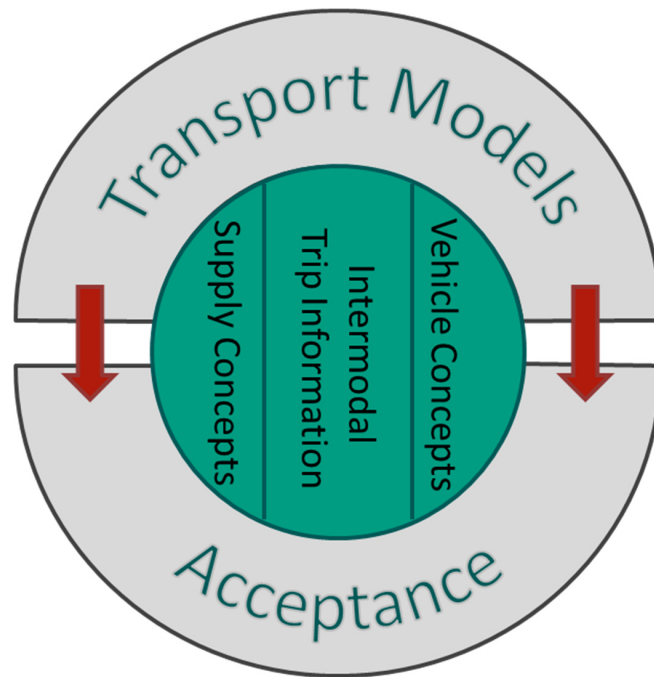


Figure 1 Multi-method approach for developing and evaluation of intermodal sharing services

This approach consists of five parts: (1) supply concepts are developed, (2) vehicle requirements for intermodal sharing are identified, (3) intermodal trip information is collected, (4) an agent based model and a macroscopic demand model are developed further by representing intermodal sharing offers in the models and (5) the acceptance of various electric vehicle sharing concepts is evaluated.

### 3.1. Development of Supply Concepts

Developing successful and customer oriented concepts for intermodal e-mobility services in combination with public transport is a core task of the project for the following reasons: a) Necessary business processes will be identified only for those concepts proving as the most promising. b) The concepts will eventually be integrated into comprehensive business models combining both seamless transportation chains for users and a highly efficient transport management for operators. c) Concepts for intermodal e-mobility services also need a strong coordination with customer information services and advanced booking and accounting systems.

The methodological approach for developing appropriate service concepts starts with an identification of relevant requirements on intermodal e-mobility services from the customers view. In that special regard, the project does not just aim at service concepts providing their efficiency at present. The project is rather looking for new mobility solutions which can be run successfully under an altering framework (with respect to customer behavior / mobility patterns, transport policy, legal framework). The project focus lies on e-mobility services in combination with public transport services to cover the “last mile” of customer’s journey. This encompasses the wide range of mobility options before accessing and after egressing public transport modes.

The methodology bases on a step-by-step approach to identify an appropriate combination of public transport modes and e-mobility services allowing for customer needs and customer acceptance. At the first stage, potential components of e-mobility services have to be identified and designed, and eventually combined to draft service concepts. The evaluation of these concepts has a special regard to customer’s acceptance by using the results of a stated preference survey. At the second stage, the components of most promising e-mobility service concepts are

further improved and specified in detail before undergoing a detailed transport model based evaluation process. Expected demand volumes of planning options in the future are estimated by a microscopic transport demand model and a macroscopic assignment model.

Another relevant aspect in this context is the localisation of connection points between public transport and e-mobility services (intermodal hubs) providing significantly improved access and egress conditions. A practice-oriented multi criteria proceeding is developed to support the process of identifying both suitable locations for intermodal hubs and their specific supply with appropriate e-mobility vehicles.

### 3.2. Identification of Vehicle Requirements for Intermodal Sharing

The aim of the identification of vehicle requirements is to create a system of objectives relative to the requirements of a vehicle, which can be established in intermodal carsharing. The system of objectives comprises the mental vision of the planned features of a product and all necessary restrictions, their dependencies and constraints. In this case the objectives describe the required future state of the product, its components and its context, but not the solution (Albers & Braun, 2011). To build the system of objectives, following procedure was adopted.

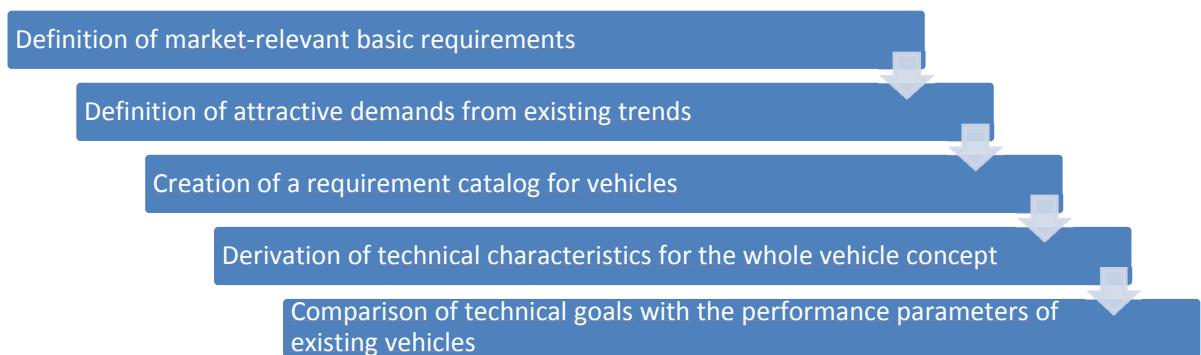


Figure 2 Procedure for building the system of objectives

A differentiation between potential user groups may depend on the individual mobility needs. In this context, market segmentation studies have already been investigated (Korthauer, 2011; Pfaffenbichler, 2009). The next step was to compare the information obtained about the future clientele/customer with a trend analysis (Fink & Siebe, 2011). On the long term the trend analysis by (Lindemann 2009) was used in the strategic product and process planning to determine the future trends. Winterhoff et al. (2009) highlight three mega-trends:

- Neo-Ecology: Social Responsibility for the Environment (Corporate Social Responsibility)
- Individualization: Attempt to dissociate from the mass, non-compliance and against the stream/current.
- Mobility: Trend towards composed modular and individual mobility; Best possible integration of the vehicle in the mobility chain.

The two methods market segmentation and trend analysis result in a vehicle-specific requirements catalog. This catalog has been divided into technically, economically and environmentally/socially dimensions. Using the House of Quality (HoQ), the collected customer requirements could translated into technical product characteristics of the overall vehicle concept.

The balance between customer requirements and quality characteristics is illustrated in the matrix of HoQ. The better a quality characteristics turns over an explicit customer demand, the higher it is weighted. As seen in the example in Figure 3 a noise-reduction has a strong influence on the subjective comfort of the driver. This results in a specific weight value for each quality characteristic.

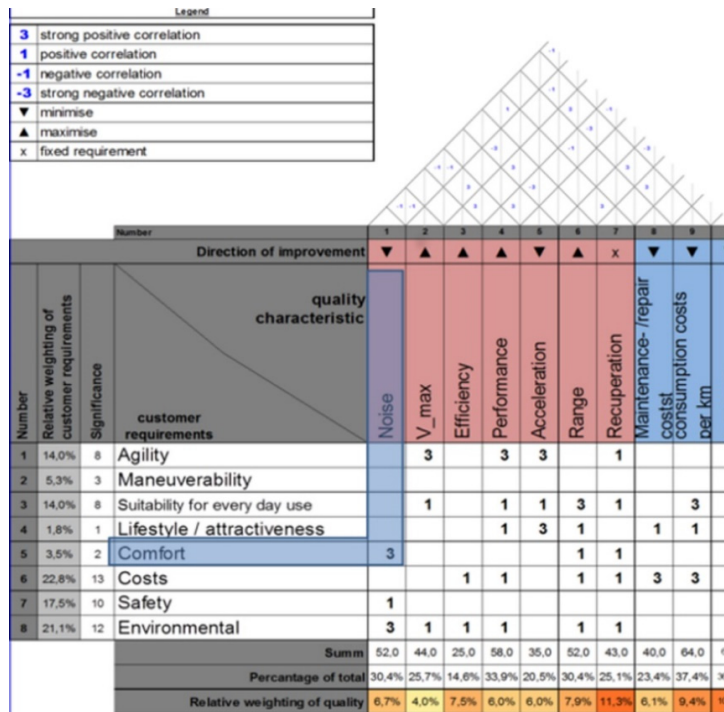


Figure 3 House of Quality (HoQ)

### 3.3. Surveying Intermodal Trip Information and Acceptance Evaluation of Electric Vehicle Sharing Concepts

To develop and evaluate intermodal supply concepts focusing on the improving of the connection to public transport systems on the last mile we need comprehensive information of people’s travel behavior. Information on intermodal trips is especially required.

An intermodal trip consists of more than one stage. Each stage can be operated with a distinct transport mode and has a peculiar duration. A person shifts its transport mode at least once within one intermodal trip. Intermodal trip information is already queried to some extent in most existing travel diary surveys. However, because of several reasons this type of information cannot be used properly. In the existing survey of the Rhein-Neckar region (Kagerbauer, 2010) the knowledge about the sequence of stages and their duration is missing. The Swiss National Travel Survey (NTS) in the year 2010 (Bundesamt für Statistik Schweiz, 2012) reveals detailed intermodal trip information. Since the spatial dimension of Switzerland differs significantly from our project region the intermodal travel information gathered from the Swiss NTS cannot be easily implemented in our model.

In order to collect intermodal trip information and evaluate the acceptance of e-sharing services on intermodal trips we carried out a survey that contains both, a revealed preference (RP) survey and a stated preference (SP) survey. The RP survey analyzes the revealed travel behavior including different stages, the different modes and the transfer points. These data are used to develop and estimate an intermodal mode choice model of an existing agent based mode choice model. In the SP survey the participants can choose between several hypothetical but realistic mode choice situations based on their reported trips. The participants have the opportunity to choose and evaluate sharing services with specific variables (time, cost) on a reported stage, e.g. from a public transport station to their home location. The answers are used to analyze the acceptance of different mobility services with electric vehicles assuming the existence of these offers. With the SP survey we intend to find answers to the following questions: Are people willing to shift from their common transport mode to an alternative sharing service? Which person groups will use such intermodal

sharing concepts? Are there typical relations where e-sharing services are especially valuable? How much money are people willing to pay for such services?

### 3.4. Representing Intermodal Trips in Transport Models

In general transport demand modelling differentiates between two essential types of modelling: microscopic agent based models and macroscopic models. Microscopic agent based models simulate the individual travel behavior of every person in the study area and illustrate his or her trip chains with origin and destination, trip purpose, mode usage, duration and length. Macroscopic transportation models calculate the amount of all origin destination (OD) relations of person groups. To evaluate e-sharing supply we use the results of both models. The agent based model provides the representation of intermodal trips of all people with their individual trip chains and the trip stages. The macroscopic model reveals the total amount of egress and access stages from public transport as well as the assignment with the traffic volume on the road and public transport network.

Within this project two traffic demand models are in use – the macroscopic demand model VISUM from PTV and the microscopic agent based travel demand model “mobiTopp” (Mallig, Kagerbauer, & Vortisch, 2013) from KIT.

The agent based transport model mobiTopp represents all trips of every person in the study area. mobiTopp contains the first three steps of the four-step algorithm of transportation modeling: trip generation, destination choice and mode choice. Agents are generated to represent the sociodemographic characteristics of the real population in the study area. The collected input data result from regional household surveys (Zumkeller, Chlond, & Kagerbauer, Regional Panel Against the Background of the German Mobility Panel - An Integrated Approach, 2008) as well as information from the German Mobility Panel (Zumkeller, et al., 2012). The activity patterns of the German Mobility Panel are input for the trip generation module. Based on the networks for all modes and the impedances (mainly time and cost) the destination choice (gravity model) determines all origins and destinations of the trips including start and end time duration and distances. The mode choice model (multinomial logit model) defines the used modes of these trips (Kagerbauer, 2010). The mode choice is determined by many factors such as car availability, the impedances between zones (trip time and trip cost) and also sociodemographic factors. In the existing model each trip is represented by one main mode even if other modes are in use. In order to model intermodal trips the mode choice model has to be improved to get all used modes on all stages within one trip. The procedure is shown in section 4.4.

The supply of public and individual transport systems in an integrated network is modeled by the macroscopic demand model VISUM. According to the four steps of travel demand modeling the software calculates the impedances between zones by assigning the travel demand on the current road network as well as the public transportation network considering lines, line routes and also the timetables. The VISUM software also represents intermodal trips by assignment. The impedances of e-vehicles between OD relations are modelled as egress and access trips in addition to existing public transportation network with connection points as well as direct links. Thanks to the assignment algorithms the mode choice of the OD matrices is calculated. The procedure is also shown in section 4.4.

For assessing the impact of the proposed intermodal sharing services we use both the agent based and the macroscopic models to compare the results. Both models evaluate two states – the present state including the existing transportation supply by representing intermodal trips and a future state considering also the developed innovative intermodal e-sharing offers.

## 4. Results

The proposed multi-method approach results in a recommendation of intermodal e-sharing services. The recommendation includes information about the most suitable intermodal sharing concepts and their vehicle requirements on the base of a transport model evaluation process. These models also allow evaluating the acceptance of the supply concepts. Figure 4 gives a detailed overview of the single methods and results included in our approach. Moreover, the interactions between the adaptations, the transport models and the acceptance analysis are shown.

Within this section, the results of the multi-method approach are discussed.



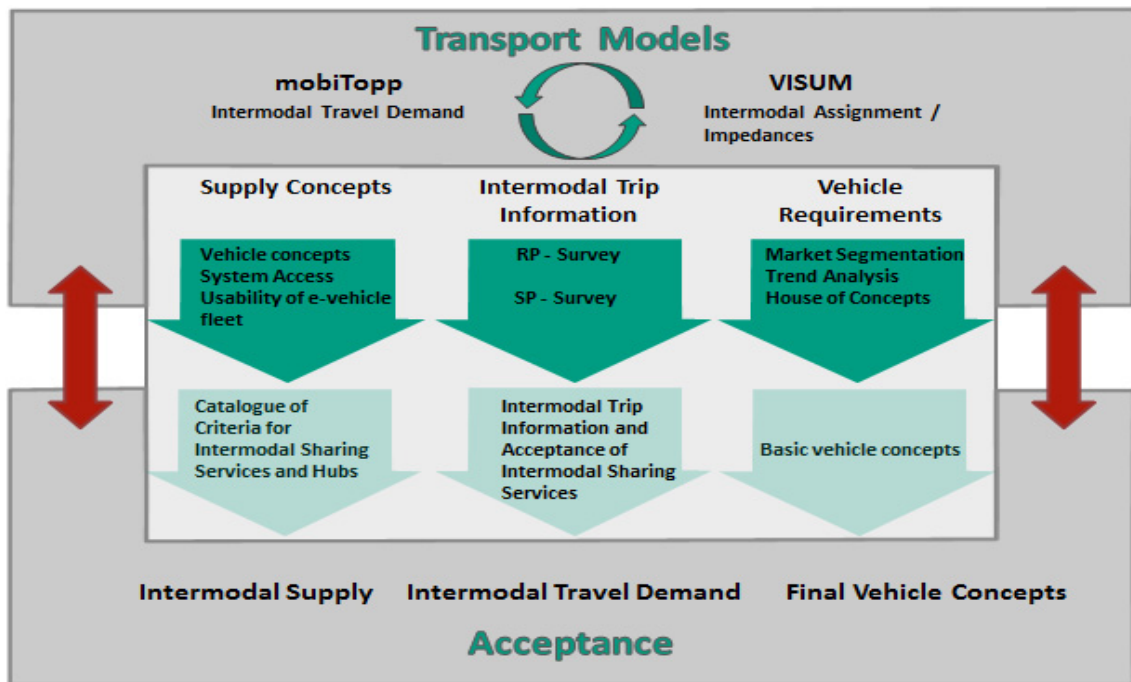


Figure 4 Multi-method Approach for developing and evaluation of intermodal sharing services in detail

#### 4.1. Development of Supply Concepts

Six different requirements have been identified as relevant for a supply concept of intermodal transport service in combination with public transport. The characteristics of components are as follows:

##### Vehicle concept and optional combination of transport modes

“Speed” and “comfort” are the most relevant criteria for e-mobility services. Both criteria determine the different types of electrically powered vehicles. The subordinated criteria “space requirements”(to host the e-vehicle fleet at the rental station) and “operational costs” can be derived from vehicle size, comfort, equipment and energy consumption. The limited distance range of electric vehicles is not taken into account in this project due to relatively short distances in the study area. Resulting from these considerations, three basic categories have been created to represent different types of electric vehicles as components in a comprehensive intermodal supply concept: Vehicle category 1 „slow“ (e.g. segway, pedelec, e-bike), vehicle category 2 „quick“ (e.g. scooter vehicles), and vehicle category 3 „fast“ (e.g. e-car).

##### System access to e-vehicle fleet

Beyond the fixed intermodal hubs (where both e-vehicles and public transport are available), e-vehicles can be provided at a dense or poorly equipped grid of permanent rental stations (with optional recharging facilities), or as free floating services (with recharging facilities solely at the connecting points).

##### Usability of e-vehicle fleet

The terms of usage regulate the flexibility of the e-vehicle fleet for customers. Thus, e-vehicles are available for trips between all rental stations and/or connection points with public transport without any restrictions. Another option could be that the access stage or the excess stage in public transport modes is mandatory for the usage of e-vehicles, i.e. at least one of the rental stations along the customer’s route must be an intermodal hub.

Another restriction in usage can be limitations of the maximum trip lengths (regardless of the limited range of e-powered vehicles). Thus, the maximum trip length can be either generally limited, e.g. to avoid competition to public transport services running in parallel or to optimize the allocation of vehicle supply. It is also possible to link the maximum trip length to the speed category of e-vehicles.

Further restrictions may occur from limitations in e-vehicles types at rental stations at the start or the final destination in housing areas.

### **Setup and transfer times**

Time consumption for the rental and drop-off procedures and the transferring time between e-vehicles and public transport modes depends on the attractiveness of intermodal services and is influencing customer's behavior. Here, the close interaction between the supply concept and the business process is obvious.

### **User costs**

User costs result from the price or fare system of the supply concept. A strong interaction to the developing process of business model is inherent. A market-proofed price model and the price elasticity of customers need to be considered.

### **Information / Communication (ICT)**

ICT services as another component of intermodal e-mobility services influence the awareness of customers on the supply concept, its access and handling in practice. For the evaluation in the transport demand model, an optimal ICT service is assumed.

The supply concept components listed above will be included in planning options with varied characteristics tuned with input data from the stated preference survey.

Another important aspect is the selection of a realistic number of bus, tram or train stops which are appropriate to function as intermodal hubs. This selection bases on the assumption that intermodal services will be perceived as a transport alternative by potential customers only if it provides advantages for them, e.g. getting faster and/or more comfortable to a destination. This is given if a) the multimodal hub is "reachable by e-vehicles of different types" and b) "public transport services at the hub are frequent".

Based on these considerations, a smart multi-criteria selection procedure was developed to identify appropriate intermodal hubs in the study area fulfilling the following criteria:

- Intermodal hubs are serviced by rail based public transport (regional/suburban train or tram), no simple bus stop.
- Demand potential in the catchment area of the hub is sufficient (minimum pop. of 1,000 residents and/or workplaces); the shape of a specific catchment areas results from the boundaries to the neighboring catchment areas.
- Minimum service in public transport is available (number of services per hour), separated by transport modes and traffic hours.
- Intermodal hubs are connected to the road network, and, more generally, reachability for all of the three assigned speed categories for e-vehicles is given.
- The availability of space for the implementation of the e-vehicle rental station is given close to the hub or within its vicinity.

The application of the multi-criteria selection procedure results in a total potential of 141 railway and tram stops proving to be appropriate to host intermodal services with e-vehicles.

#### *4.2. Identification of Vehicle Requirements*

Based on the weighted quality characteristics/criteria in 3.2, an evaluation of different vehicle module characteristics was executed Figure 5 shows a morphological box with its possible vehicle module characteristics.



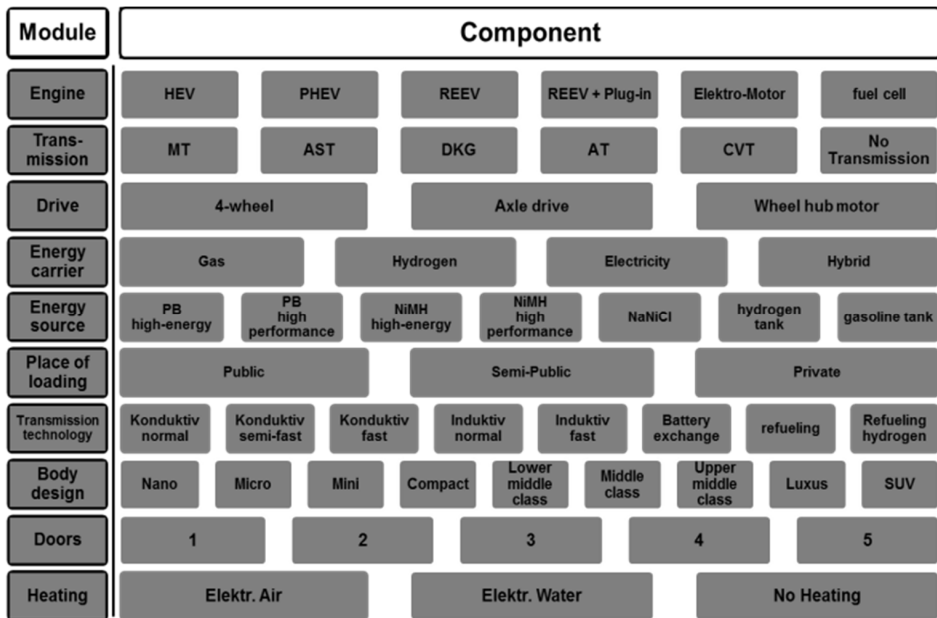


Figure 5 Morphological Box of Vehicle Components

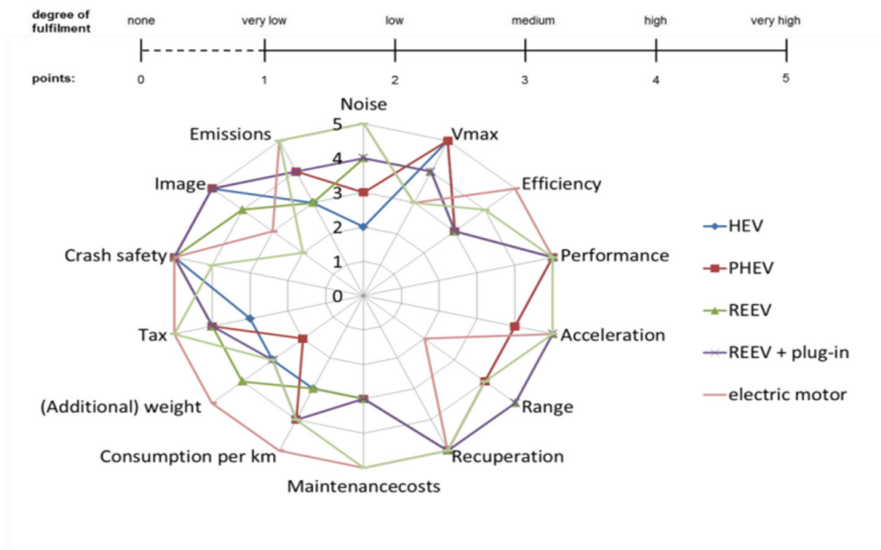


Figure 6 Evaluation of different Vehicle Components

The resulting weighted constellation identified a classic electric vehicle with a wheel hub drive, fed by a lithium-ion battery. The spotted vehicle “Mini” has three doors and will be mainly charged tethered in the private sector.

As part of the next step, the set of possible users has been separated into five groups of customers: Families, commuters, students, pensioners and ecologically minded people. That is because of the heavy diversification of customer requirements for the vehicle. By varying the weights at the assembly level, particular module groups could be highlighted. The same principle can be applied to the module and component level by varying the considering

weights of the HoQ or the evaluations of the criterion table. There is a possibility to give the customer for example a more cost-intensive or fashion-forward character by changing the parameters of the customer requirements. In addition to that scenarios, a significant increase of the eco-idea could be sensitized and translated into the customer requirements. After the adjustment of planned and available vehicles with the weighted quality characteristics three different classes of e-vehicles were chosen as input for the simulation: Two-wheelers with low comfort & speed level (pedelec, segway), motorcycle-similar vehicles with medium comfort & speed level (e-scooter, e-lightcar) and battery electric cars.



Figure 7 Relevant Classes of e-vehicles

#### 4.3. Intermodal Trip Information and Acceptance of Intermodal Sharing Systems

To collect intermodal trip information a survey was carried out in the Mannheim area with a sample size of about 150 persons. The survey contains both, RP survey to collect intermodal trips and SP survey to analyse the acceptance of the developed supply concept on the reported trips.

Designing a questionnaire that includes detailed information of intermodal trips entails two challenges. First, the survey should collect duration, sequence and modes of each stage without losing the information on the overall trips. Second, the complexity of the survey should be minimized, in order not to confuse the survey participant. Our survey is web-based and is constructed in a sequential way. It utilizes the concept of “main transport modes”, i.e. we ask first for the main stage and mode. Afterwards, we gather time and mode specific information of the egress and access stages in a sequence.

Various combinations of modes that can be used during an intermodal trip are feasible. This issue raises the complexity of the survey design inherently. Although more than 150 questions are implemented to get the information of one intermodal trip, the survey participants do not notice the complexity. They are led through the questionnaire by a smart filter management. Additionally, pictures were added for visualization.

As a result, we gather comprehensive information on intermodal trips, e.g. locations of origin and destination of trips, the number of corresponding stages, the modes used on these stages as well as the trip and stage durations. Additionally, the sociodemographic characteristics of the participant are surveyed. We use this data to calibrate and validate the intermodal mode choice model described in 4.4.

To determine the acceptance of sharing services on intermodal trips we conduct a SP survey subsequent to the RP survey. In the SP survey the participants can choose between several hypothetical but realistic modes based on their reported trip stages. There are four opportunities that need to be evaluated – besides the reported modes the three developed vehicle classes with estimated time and price values can be chosen.

The price and time values give us information on price and time sensitivity and elasticity. The price and time calculation bases on the information of the reported trips and is done separately for every vehicle concept using assumptions on travel time and price difference.

We transfer the revealed travel time of the used mode into distances by using travel time and travel speed. We implement factors of directness that shorten or lengthen a distance in dependency of the used modes in order to

consider that the different modes of transport do normally not use the same routes. Finally, the resulting distances are retransferred into travel times.

We specify prices for each transport mode in order to get information on the price elasticity. We calculate the prices based on the travel time or travel distance under the following assumptions: (1) bike and walking are free, (2) car cost amount 0.3 € per km, (3) public transport costs are derived from the fare system of the RNV (the local/municipal transport service), and (4) the prices for the e-sharing systems bases on own calculations considering the purchase price, an assumed average driving performance, maintenance costs and financing costs, considering 0.37 € per minute for e-carsharing, 0.18 € per minute for e-scooter, and 0.12 € per minute for e-bikes. We mention that these price assumptions could differ from the prices resulting out of the whole evaluation process.

#### *4.4. Development of an Agent based and a Macroscopic Demand Model*

To evaluate the developed supply concepts in terms of the demand volumes to be expected in the future a microscopic transport model and a macroscopic assignment model are used. Each model has to be developed further in a way that intermodal trips can be represented and that the results are transferable. Therefore, we need the following adaptations, advancements and developments.

##### **Common database**

To compare and to transfer the results both models have to be adjusted. Therefore a consistent framework condition is mandatory. On the one hand the sociodemographic factors of the inhabitants per zone as well as income and on the other hand the zone structure has to be adjusted.

First of all a planning area has to be defined. We chose the area of Mannheim and their surrounded neighbor municipalities Viernheim, Heddesheim and Ilvesheim. The selected planning area covers three spatial area types. The city of Mannheim as an urban region with very good public transport supply, the communities of Viernheim and Heddesheim as a suburban region with fair public transport and the community of Ilvesheim as a suburban region with moderate public transport services (just a few busses and no rail bound public transport services).

For the task of intermodal trip representation, the structure of traffic area zones in the transport model needs to have a suitable size. If the zones are too large, important information get lost during the assignment process. If the zones are too small, the allocation of spatial structure data may be arbitrarily and the handling of the model will be difficult.

It was therefore decided to shape the size of the zones according to the access of surrounding tram and trains stops by foot with a walking distance of three minutes at the maximum. Zones which were too large according to the criterion have been divided in a useful way. As a result, the number of zones rose from 80 up to 120 zones.

Additionally, both models were fed with data on spatial structure, e.g. residents and employees per zone, distribution of average household income and other sociodemographic characteristics of residents.

##### **Representing Intermodal Trips in the Macroscopic Model**

As a start solution, the macroscopic public transport model provided by the project partner RNV proved to be most suitable for an upgrading in accordance with the project needs.

The implementation of intermodal e-mobility services started with the determination and localisation of the fixed infrastructure for e-vehicles (intermodal rental stations). At a second stage, the number of intermodal hubs was limited to a reasonable size by a multi-criteria selection procedure (see 4.1). Next, all selected hub stations for e-mobility services were linked together and the specific range of e-mobility services available at each hub was defined (according to spatial availability). Finally, the model was thoroughly tested and calibrated.

A grid of “simple” rental stations for e-mobility services without a hub function will complete the station network, in particular in the residential areas. The total number of simple rental stations depends on available options for the system access to the e-vehicle fleet (see 4.1). These “simple” rental stations will be implemented into the model with the same methodology as described above for the hub stations.

### Representing Intermodal Trips in the Agent Based Model

For representing intermodal trips in the agent based model we developed a two-step mode choice model. In the first step we determine the main mode by using a discrete choice model. Depending on the chosen main mode the second step determines possible stages and their transfer points.

A stage is defined as a part of a trip with one mode. A transfer point is defined as a node where persons are able to change their mode. In reality these points are represented by public transport stations (shift from or to public transport), park-and-ride facilities (shift from or to private car) as well as carsharing stations.

The first step, the main mode choice, is based on the existing mode choice model of mobiTopp. However, our developed sharing services are not yet implemented. Thus, we extend the mode choice by the missing modes of the three classes of e-vehicles that are predestinated for intermodal sharing services. The main modes are ranked into an ordinal scale. The mode with the highest rank on every stage of a trip represents the main mode on the trip, e.g. an intermodal trip in which the modes walking, public transport and riding a bicycle are considered, is represented by public transport as the main mode. Figure 8 illustrates the used modes in the first step of the model and the associated ranks.

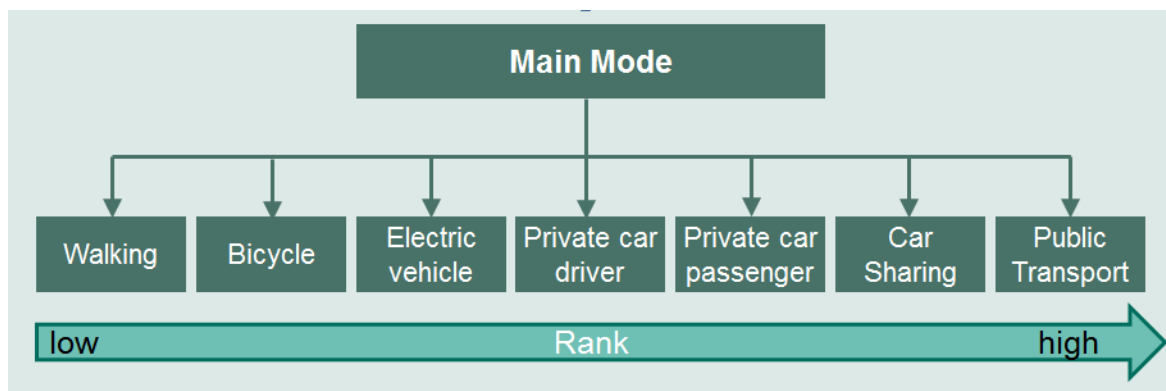


Figure 8 Main modes and the associated ranks

For each mode we define a utility function which considers variables like travel time, cost and the availability of the modes. After that, a multinomial logit model determines the probabilities of selection.

In the second step we add intermodal combinations for the chosen main mode. We also use a utility function for every combination and a multinomial logit model to get the probabilities here. Due to the large number of possible mode and stage combinations complexity of determining the probability rises rapidly.

Next, we determine all possible opportunities of mode combinations considering access and egress stages. According to the definition of the main mode on these stages only the modes with a lower rank than the main mode are possible to use. To reduce complexity without losing much information we limit the maximum number of stages during one intermodal trip on four. At least one of these stages is covered by the main mode.

Second we determine the impedances between origin and destination for every intermodal combination. Therefore we use the results of the macroscopic assignment model which calculates the impedances of intermodal trips considering travel time and travel cost on the current public and private transportation network. For trips in combination with public transport even the timetable is considered which is very important in order to get reliable results.

With these impedances the utility as well as the probabilities can be determined. As a result we get OD matrices for every combination of modes that show the amount of the used combination – the intermodal travel demand. Putting these matrices back in the assignment model we also get the intermodal traffic volume on the current network. Thus, the acceptance of intermodal sharing services can be determined. With this information we can also evaluate our choice of suitable intermodal hubs with the catalogue of criteria described in 4.1. Adding the results of the SP survey we can refine the vehicle concepts with all necessary vehicle characteristics.

## 5. Conclusion and Outlook

Travel behavior in cities may change within the next years – multimodal as well as intermodal usage of different transport modes is getting more and more important. The transport conditions can be improved by implementing intermodal sharing services especially on access and egress stages of public transport. Due to the low distances on these stages such services provide a great opportunity for electric mobility.

To develop and evaluate such intermodal e-sharing services from the customer perspective conventional approaches and singular methods are not sufficient since they consider only individual aspects of the planning process. We integrated several singular approaches into an integrated multi-method approach.

The proposed methodology enables the development of customer oriented and attractive intermodal sharing services for the Mannheim metropolitan area. Thereby we consider both the supply side with suitable vehicle systems and adequate supply concepts and the demand side focusing on the representation of intermodal trips and the acceptance of the developed sharing services on intermodal trips. We integrated the developed sharing systems into a macroscopic and an agent based transport model. 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. Hence, the model results are essential for the economic appraisal of e-sharing services from the supplier perspective. Although we developed the presented methodology for the Mannheim metropolitan area, our approach can also be applied to other cities and regions. To sum up, our multi-method approach for developing and evaluating intermodal e-sharing services may help to improve the planning process and to implement such services in various other cities and agglomeration areas.

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