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Differences in cognition of public transport systems: Image and behavior towards urban public transport

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KURZFASSUNG

Für die Bestimmung der Verkehrsmittelwahl werden in der Verkehrplanung primär messbare Faktoren wie Reisezeiten, Kosten, Verfügbarkeiten von öffentlichen Verkehrsangeboten, Autobesitz und Parkplatzverfügbarkeiten berücksichtigt. Darüber hinaus werden in der Literatur – mit Fokus auf den öffenlichen Verkehr – schienenbasierte Verkehrsmittel gegenüber Bussystemen als attraktiver beschrieben, auch wenn die messbaren Faktoren eines Angebotes identisch sind. Dieses Phänomen der höheren Attraktivität und eine daraus resultierende höhere Nachfrage unter gleichen Angebotsbedingungen von Bahn und Bus wird als Schienenbonus bezeichnet. Vor dem Hintergrund eines Schienenbonus stellt sich die Frage, wie verschiedene öffentliche Verkehrssysteme wahrgenommen und bewertet werden und welche Zuschreibungen zu diesen Systemen gemacht werden.

Die dieser Dissertation zugrundeliegende Forschungsfrage zielt auf den Zusammenhang von Systemattributen von Bus und Tram und deren Wahrnehmung durch verschiedene Nutzergruppen. Neben der Wahrnehmung von Bus und Tram steht auch die Reaktion darauf, im Sinne einer Verkehrsmittelnachfrage, im Fokus. Dazu wurden die relevanten Systemattribute identifiziert und für ausgewählte Fallbeispiele in der Schweiz quantifiziert. Des Weiteren wurden psychologische Ansätze zur Unterschuchung eines Schienenbonus für die städtischen Verkehrssysteme Bus und Tram herangezogen. Dies ermöglicht die Herleitung des Images von Bus und Tram in der Schweiz. Abschliessend wurde das Verkehrsmittelwahlverhalten hinsichtlich eines möglichen Schienenbonus analysiert.

Der Vergleich der Systemattribute von Bus und Tram zeigt, dass sich Zuschreibungen zu diesen Systemen hauptsächliche bezüglich zweier Aspekte unterscheiden. Erstens wird ein Tram als zuverlässiger beurteilt, da es Vortrittsberechtigt ist. Denn für die beiden Verkehrssysteme gelten unterschiedliche Verkehrsgesetze. Für das Tram gilt die Eisenbahnverordnung, welches einem Tram Vortritt gegenüber allen anderen Verkehrsteilnehmern einräumt. Dies führt dazu, dass der Eigentrassierungsanteil für ein Tram deutlich höher ausfällt als der Anteil an Busspuren. Zweitens wird das Tram von der Bevölkerung deutlich stärker als Umweltfreundlich bewertet als ein Bus. Die Analyse zeigt jedoch, dass dies nicht per se der Fall ist und Bussysteme bezüglich Energieverbrauch und Emissionen durchaus mit Tramsystemen vergleichbar sind.

Der Schienenbonus wird auf Unterschiede in der Wahrnehmung von Bus und Tram zurückgeführt. Für die Untersuchung der Wahrnehmung wurde das Schema-Konzept angewendet. Ein Schema bildet das "Bild im Kopf" ab, welches eine Person von einer Sache oder einem

Anlass hat. Die entsprechende Studie hat ergeben, dass sich 74% der Befragten bei einer hypothetischen Wahl zwischen einem identischen Bus- und Tramangebot für ein Tram entscheiden würden. Das hergeleitete Schema für die Tramentscheidung basiert zu 40% auf positiven Zuschreibungen des Fahrwegs (Zuverlässigkeit, Vortritt). Im Gegensatz dazu wird die Busentscheidung mehrheitlich mit Aspekten des Fahrzeugs (35%) und psychologischen Faktoren (36%) wie Emotionen begründet. Zudem hat sich gezeigt, dass Erfahrungen und Vertrautheit mit einem Tram dessen Wahl begünstigen. Bei einem Bus konnte dieser Effekt nicht festgestellt werden.

In der detaillierten Untersuchung des Images von Bus und Tram wurde das semantische Differential angewendet. Diese Methode ermöglicht es, Differenzen in der Bewertung von Zuschreibungen zu Bus und Tram darzustellen. Das resultierende Image für Bus und Tram in der Schweiz ist verblüffend ähnlich. Ein Bus schneidet bei Softfaktoren (*bedeutend, wertvoll, benutzerfreundlich*) am Besten ab. Das Tram erhält die beste Beurteilung bei den Faktoren *Umweltfreundlichkeit* und *Zuverlässigkei/Freie Fahrt*. Die Unterschiede in der Bewertung zwischen Bus und Tram vergrössern sich mit zunehmender Nutzung des öffentlichen Verkehrs.

Um den Einfluss der Erfahrung mit Bus- und Tramangeboten und der Gewohnheit zu untersuchen, wurde das Image von Bus und Tram von Bewohnern von drei Städten verglichen. Das Image eines Buses ist dabei über alle drei Städte vergleichbar. Dahingegen variiert das Image eines Trams stark. Einwohner von Tramstädten haben ein positiveres Image von einem Tram als Einwohner der Busstadt. Das Bus-Image dieser Einwohner ist positiver als deren Tram-Image.

Der Vergleich des Verkehrsmittelwahlverhaltens für den Arbeitsweg zeigt keine höhere Nachfrage von Tram gegenüber Bus auf. Dieser Vergleich wurde auf der Basis eines identischen Angebotes (Fahrplantakt, Reisezeit) angestellt. Es wird vermutet, dass andere Einflussfaktoren als das Verkehrssystem (Schienenbonus) ein höheres Gewicht bei der Verkehrsmittelwahl im städtischen Raum haben.

Die Vermutung, dass verschiedene öffentliche Verkehrsmittel unterschiedliche Nachfragewirkungen erzielen, kann mit dieser Arbeit für den Fall Bus und Tram in der Schweiz nicht bestätigt werden. Die aus hypothetischen Situationen ermittelten Schemata von Bus und Tram zeigen einen hohen Einfluss sozialer Normen auf. Das Image von Bus und Tram welches auf der Bewertung von Attributen basiert, weist dahingegen nur geringe Unterschiede auf. Die Attibute die für Bus und Tram am unterschiedlichsten bewertet wurden beziehen sich auf *Umweltfreunlichkeit* und *Zuverlässigkeit/Freie Fahrt*. Diese Aspekte weisen sich jedoch als nicht systemspezifisch heraus. Die Unterschiede in der Präferenz von Bus und Tram und in der Bewertung von Systemattributen konnten bei effektivem Verkehrsmittelwahlverhalten nicht nachgewiesen werden.

Unter der Voraussetzung, dass Bus und Tram der gleichen Gesetzgebung unterliegen – entsprechende Gleichbehandlung bezüglich Vortritt, Eigentrassierung und Priorisierung an Knoten geniessen – ist zu erwarten, dass ein Bussystem unter gleichen Angebotsbedingungen die gleiche Nachfragewirkung erzielen kann wie ein Tram. Berücksichtigt man das unterschiedliche Fassungsvermögen der Fahrzeuge, ist die Nachfrage lediglich durch die Kapazität (Fahrzeuggrösse und die Taktfrequenz) und nicht durch das Verkehrsmittel an sich (Bus oder Tram) bestimmt.

ABSTRACT

It is recognized that hard factors such as travel time, cost, availability of public transport services and car ownership, and parking situations have a major impact when people consider the choice between using an automobile or public transport. Moreover, there is evidence from the literature that rail-based public transport is often considered superior to bus systems even in cases where quantitative hard factors are equal. This attraction of passengers is known as a psychological rail factor and it is used to express a higher attraction in terms of higher ridership of rail-based public transport in contrast to bus services. This raises the question of how public transport characteristics are perceived and valued, and which attributions are made towards different transport modes.

The underlying research question of this dissertation targets the relationship between system attributes of bus and tram and the related stakeholder's perception of and reaction to these system attributes. Therefore relevant system attributes of bus and tram are identified and quantified for selected case cities in Switzerland. Further, psychological concepts to explore attributions of public transport users and potential public transport users on these two public transport systems are applied. Based on this, the images of bus and tram are deduced for the example of Switzerland. Finally, mode choice behavior is analyzed with reference to the availability of bus and tram in order to detect a rail factor in effective mode choice behavior.

The comparison of attributes of bus and tram revealed that these two systems mainly differ on two aspects. First, due to the length of the vehicle, a tram has a higher capacity compared to a bus. However, relative capacities are comparable for tram and bus, with 4.1 to 4.5 places per meter length of a vehicle. Moreover, aspects of loading and crowding are comparable for selected bus and tramlines. Second, bus and tram are treated differently regarding traffic law. In contrast to a bus, a tram has right of way against all other traffic participants. Wherever possible there is a dedicated way for tramlines and as a consequence mixed-traffic conditions occur far less for tram- than for buslines. Finally, although a tram is often considered to be more environmentally friendly than a bus, this is not the case per se. Environmental issues such as energy consumption, pollution and noise emissions do not allow for conclusions about which is the superior system.

As a rail factor is assumed to be influenced by different perceptions of attributes, perceptions are explored based on the schemata concept. Schemata refer to a mental picture that someone has about a concept. The underlying study revealed a preference for a tram of 74% of the respondents in a hypothetical setting where bus and tram services are equal. 40% of the schema of a tram is loaded with positive attributions towards the guideway mainly expressed by reliability and right of way. In contrast to that, the schema of a bus is mainly constituted of attributions towards vehicle characteristics (35%) and psychological factors (36%). It was found that familiarity and experience tend to influence the attributions towards a tram; however, no similar effects are established for the schema of a bus.

The in-depth analysis of the image of bus and tram applied the measurement of the semantic differential to identify differences in ratings of attributes of bus and tram. It was found that the general image of bus and tram is surprisingly similar. Whereas a bus got the best scores on soft factors (*importance, value* and *ease-of-use)*, a tram got high ratings on *environmental friendliness* and *reliability/free flow*. Differences in the image of bus and tram increase with higher frequency of public transport use. To identify the impact of experience, images are compared according to the place of residence of the respondents. The image of a bus is consistent across all three cities considered in the study. In contrast, the image of a tram varies strongly. Moreover, inhabitants of tram cities do have a more positive image of a tram than of a bus, whereas inhabitants of the bus-served city reveal better ratings for a bus than for a tram.

The comparison of revealed mode choice behavior in bus and tram corridors established no significant differences for mode choice for commuting trips based on equal public transport service characteristics. It is assumed that other aspects than the public transport system itself have a higher weight for mode choice decisions.

The assumption that different public transport systems cause different effects on public transport demand is not supported by the conducted research for bus and tram in Switzerland. In a nutshell, schemata based on preferences reflect the respondent's justification of their choice, which is strongly influenced by social norms. Images expressed as quantified attributions have shown that the difference between ratings of bus and tram are smaller than expected from the schemata. Attributions that differ most are related to environmental impacts and traffic flow/reliability. Nevertheless, quantified data of energy consumption and emissions are similar for bus and tram, depending on the type of vehicle, traction and average loading of the vehicles. Finally, established preferences cannot be justified by revealed mode choice behavior.

Under the precondition that buses and trams are treated equally regarding traffic law, which requires measures such as right of way, dedicated lanes and priority at intersections, a bus system can theoretically attract the same ridership numbers as a tram system given the same service conditions. Thus, ridership numbers are limited by the capacity of vehicles and by the frequency of service.

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1 Introduction

1.1 Motivation

The ongoing urbanization process brings great challenges along with it. With respect to transportation, these include handling rising mobility needs while retaining or improving quality of life. In densely populated areas, public transport serves as a backbone for the transport system because of its high capacity and its less negative impact on the environment compared to car traffic.

Within the last three decades many efforts have been undertaken to investigate how a shift from car usage to public transport could be achieved. Reinforcing measures favoring public transport, improvements of public transport services and also punishment aspects towards car usage have been introduced and tested successfully in order to shift the modal split.

It is recognized that hard factors such as travel time, cost, availability of public transport services and car ownership, and parking situations have a major impact when people consider the choice between using an automobile or public transport. Moreover, there is evidence from the literature that rail-based public transport is often considered superior to bus systems even in cases where quantitative hard factors are equal. This attraction of passengers is known as a psychological rail factor and it is used to express a higher attraction in terms of higher ridership of rail-based public transport in contrast to bus services.

The idea of a rail factor is consistent with statements that the image of a transport system has an impact on demand. According to Hensher et al. (2005), the image of a transport system that *"may ultimately be an important influence on preference formation, especially for new means of transport"* (p63) is a relevant component in mode choice. Furthermore, research shows that public transport users often perceive transport characteristics differently than planners expect. This raises the question of how public transport characteristics are perceived and valued, and which attributions are made towards different transport modes.

Regarding a rail factor, little empirical evidence exists that might explain reasons for this phenomenon. Why should individuals change their mode choice or trip frequency when replacing a bus with a tram? The investigation of these questions allows for insights into how individual transport behavior is affected by images and under which circumstances a change of the bus system towards a rail-based system leads to the desired and expected change in mode share.

With regard to urban public transport, making the right choice for an appropriate public transport system between tram (or light rail public transport, LRT) and high-quality bus systems, requires a proper knowledge of the effects of these systems on various stakeholders' decisions and reactions.

1.2 Preliminary statements

From the literature it is assumed that the two systems, bus and tram, are perceived differently, even when the same (technical) quality of service is provided. Vuchic (2005), for instance, summarizes the more significant characteristics of LRT compared to bus rapid transit (BRT) as having a "*much stronger image, passenger attraction and positive impacts on the city*" (Vuchic 2005, p588). One consequence is that the impact on transport demand and spatial development should differ between tram and bus.

Considering recent tram projects it was detected that a change from bus to tram is expected to have remarkable effects on ridership and on spatial development (which affects demand potential). These effects cannot be explained with common planning criteria, which are based on usual service attributes. Tramlines are assumed to gain higher ridership than buslines under same service conditions.

Demand forecasts are based on models that consider objective factors, such as travel times and distance to the stops. These system characteristics are well known for different transport systems. For rail-based systems planners often apply an additional rail factor. This term summarizes positive attributions, e.g. comfort, reflected by the higher valuation of rail-based systems. The rail factor is used to explain the difference between calculated demand forecast, based on common system characteristics and service characteristics, and observed higher demand revealed after a system upgrade. That means that a replacement of a bus system with a tram system – under the precondition that the service characteristics remain the same – leads to a remarkable change in demand. Many public transport operators report increased ridership after having introduced a new tram system or a new tramline.

It seems that both public transport systems, bus and tram, are valued unconsciously in a different way. The first assumption is that several system attributes are valued differently which leads to these transport systems having different impacts. For instance, it might be assumed that a tram is attributed to be faster and more reliable in city centres due to its right of way.

Based on conclusions drawn from relevant studies, two preliminary statements are made, which serve as a starting point of the research. First, demand for public transport is expected to be higher for tram services than for equal bus services; demand increases accordingly in cases where the public transport system changes from bus to tram, all other service characteristics remaining the same. Second, if so, this effect is influenced by different cognitive reactions to these public transport systems. The cause of this effect can be explained by the perception and reaction of individuals on single system attributes (e.g. right of way of a tram makes a system more reliable, which is an important factor for users).

The analysis of how preferences of rail-based systems can be explained with regard to different stakeholders constitutes the main body of this dissertation. Furthermore, it is of great interest to identify positively valued attributions to a tram system and to outline how they can be transferred successfully onto bus systems.

1.3 Purpose of the study

While cost factors of transport systems are well known, perceived impacts of urban public transport have not yet been properly investigated. We summarize under perceived impacts the effects of bus and tram systems on relevant decisions that affect transport demand and mode choice, modal split, and thus expected revenues.

Understanding the effects of urban public transport systems on the perception and reaction of relevant stakeholders is essential in order to improve the decision-making foundation for future improvements of public transport. Therefore, differences in perceptions of bus and tram are explored by using the example of Switzerland in order to judge the benefits of each system.

The question of different perceived values of bus and tram that possibly cause different travel behavior, hence a rail factor, is important for several reasons. First, transportation in general and transport infrastructure in particular significantly affects the economy. Given the considerable expense of transport systems, it is important that the impact of these costs is evaluated properly. Regarding travel demand and targeted mode shares, the evaluation should be more profound than on a theoretical estimated "rail factor". Second, the results of the research provide useful fundamentals for decision-makers and transport planners. Furthermore, it is of great interest to small- and medium-sized cities to define factors that are valued as positive for tram systems and to discuss their transferability onto bus systems. Briefly, this dissertation contributes to the following aspects:

- The application and discussion of methods from various adherents that allow for explanations of the observed phenomenon of a rail factor. Appropriate methods to measure the perception of transport systems and system attributes (e.g. vehicle attributes) are outlined;

- Expanding knowledge about different stakeholder's expectations of the effects of public transport by investigating the state-of-the-art in practice. Furthermore this knowledge provides new arguments to aid decision-making in public transport investments.

Finally, the synthesis discusses whether the supposed benefits of tram systems are in line with the expectations and reactions of the stakeholders involved. The conclusions considers how these interrelationships can be used in terms of a clever application of the benefits of different urban public transport systems to achieve appropriate solutions with respect to different stakeholders.

1.4 Structure of the dissertation

The introductory chapter gives a short overview over the motivation and purpose of the dissertation. The different chapters are prefaced with the associated sources as elements of the dissertation have been published or accepted for publication:

- Scherer, M. (2010) Is light rail more attractive to users than bus transit? Arguments based on cognition and rational choice, Transportation Research Record, 2144, 11-19.
- Scherer, M. and U. Weidmann (2011) Differences in travel behavior and demand potential of tram- and bus-based neighbourhoods. Evidence from a cluster analysis, Transportation Research Record, 2217, 1-10.
- Scherer, M. and K. Dziekan (2012) Bus or Rail: An approach to explain the psychological rail factor, Journal of Public Transportation, 15 (1), 75-93.

Moreover, papers presented at conferences, working papers and field reports of the different studies conducted in the context of this dissertation constitute another text source.

The remainder of the dissertation is structured as follows: Chapter 2 serves as the setting of the scene of the dissertation in the area of urban public transportation and mode choice. First, the underlying definitions of bus and tram as used in this dissertation are presented. Then, public system attributes for urban public transport are introduced and discussed for the cases of bus and tram. As different impacts of these two systems on demand are assumed, quantified data on demand for bus and tram are summarized for Swiss examples. Demand forecast and revealed demand for newly implemented bus and tramlines are reviewed for international cases. This is followed by a literature analysis on impact factors on mode choice including psychological explanations.

Afterwards, the framework for the dissertation is outlined in chapter 3. This includes the presentation of the target groups, the introduction of the rail factor as main effect to be investigated and the formulation of the research question. Deduced from the findings of the literature review, hypotheses are drawn and the four steps of the approach for the investigation are introduced.

Appropriate methods are required in order to approach the research question. In chapter 4 different methods and concepts from the economical and psychological field are summarized and discussed for their suitability for exploring the rail factor.

Chapter 5 comprises the first step of the investigation. Public transport attributes are quantified for the example of Switzerland. Therefore data from case studies of three Swiss cities is compiled and compared for bus and tram. This is the objective basis for the following discussion about different effects of bus and tram.

In contrast to revealed data analyzed in chapter 5, preferences and perceptions towards bus and tram for a hypothetical identical setting are analyzed in chapter 6. The underlying study is based on a survey among Swiss residents and has the objective of identifying reasons for differences in the perception of bus and tram. Therefore the psychological concept of the schema theory is applied.

In chapter 7 the subsequent in-depth study to explore the image of bus and tram is presented. Differences in attributions towards bus and tram are measured with the semantic differential what allows for direct comparison of ratings of attributions for bus and tram. Furthermore, ratings of various stakeholder groups are distinguished in order to analyze ratings of groups with different mode choice behavior and different public transport opportunities.

Chapter 8 covers the question of whether bus and tram cause different mode choice behavior, and hence whether public transport use is generally higher for tram services. Therefore mode choice behavior for work trips is analyzed against the quality of public transport service provided at place of residence distinguished by bus and tram service.

In chapter 9 the findings of the four steps are summarized and discussed. This final chapter includes the conclusions on different effects of bus and tram based on revealed data of bus and tram attributions, psychological investigations of bus and tram images and on revealed mode choice behavior related to the availability of bus and tram service. Finally, further research questions are formulated.

2 CHARACTERISTICS OF URBAN PUBLIC TRANSPORT BUS AND TRAM

"A public transport system's ability to attract passengers and to influence land use development and quality of urban life should be included [in mode evaluation]"
Vuchic (2005) p527

In this chapter an overview of the underlying understanding of bus and tram is given. Furthermore findings from a broad literature study regarding differences in ridership attraction of bus and tram are presented and discussed in the light of methods and concepts that have been applied.

This chapter is partly based on the following documents:

Scherer, M. (2010) Is light rail more attractive to users than bus transit? Arguments based on cognition and rational choice, Transportation Research Record, 2144, 11-19.

Scherer, M. (2010b) Tram or Bus: Analysis of revealed preference data, working paper, Institute of Transport Planning and Systems (IVT), ETH Zurich, Zurich.

2.1 Definitions

2.1.1 Tram and light rail

Several definitions of tram and light rail exist that partly differ in technological aspects. However, in the dissertation at hand the term light rail and tram is used synonymously, because the understanding of tram in the study areas in Switzerland fits best with the definition of light rail as defined by the Transportation Research Board (TRB). According to the thesaurus of the TRB, light rail transit refers to *an urban transportation system that uses electrically powered lightweight rail cars operating singly or in short trains on fixed duo-rail guideways; may be grade separated, and loads passengers from low-to medium-height platforms*. In contrast to this definition, the term tram is rather related to the vehicle and understood as older version of the modern light rail vehicles, since the TRB defines a tram as *electric rail vehicles used for transporting passengers in urban areas and typically operating on city streets, the more modern version of which is the Light Rail Vehicle (LRV). Also referred to as Streetcars*. Since tram vehicles are replaced continuously when needed, there are many new and modern vehicles that correspond to the definition of light rail vehicles. Furthermore, no connotative distinction between light rail and tram exists in Switzerland. All electrified urban transportation systems operating in short trains (maximum length approximately 45m) on duo-rail guideways on street levels are identified as a tram. The definition of light rail of the American Public Transportation Association (APTA) as presented in Kuby et al. (2004, p229) suits as well to the conditions of tram in Switzerland. They define light rail transit as:

Lightweight passenger rail cars that operate singly (or in short, usually two-car, trains) on fixed rails in right of way that is not separated from other traffic for much of the way. Light rail vehicles are driven electrically with power being drawn from an overhead electric line via a trolley or a pantograph. Also known as "streetcar," "tramway," [or] "trolley car."

In the dissertation at hand all these definitions refer to the understanding of a tram.

2.1.2 Bus and bus with high level of service

The term bus refers usually to all forms that are operated with this kind of vehicle. This definition is too wide for this study because a comparability of bus and tram is not possible with this broad range of bus qualities. To avoid confusion, the definition of bus is here applied to buses with a high level of service (BHLS) respectively to the definition of bus rapid transit (BRT) from the Transportation Research Board (TRB):

Bus service operating on exclusive transitways, (…) or ordinary streets that combines intelligent transportation systems technology, priority for transit, cleaner and quieter vehicles, rapid and convenient fare collection, and integration with land use policy.

The main reason for the choice of this definition is that bus transportation in Swiss cities generally fullfill these conditions of a BRT, sometimes also known as BRT light. Bus lanes are present wherever feasible and many other forms of priority are standard features for urban public transportation in Switzerland. The term bus refers here to both (electrified) trolleybuses and motorized buses. Since public transport demand is high in urban areas, bus lines considered in this dissertation are at least operated with articulated buses or double-articulated buses, which means that they provide a high capacity that is comparable with a (short) tram composition.

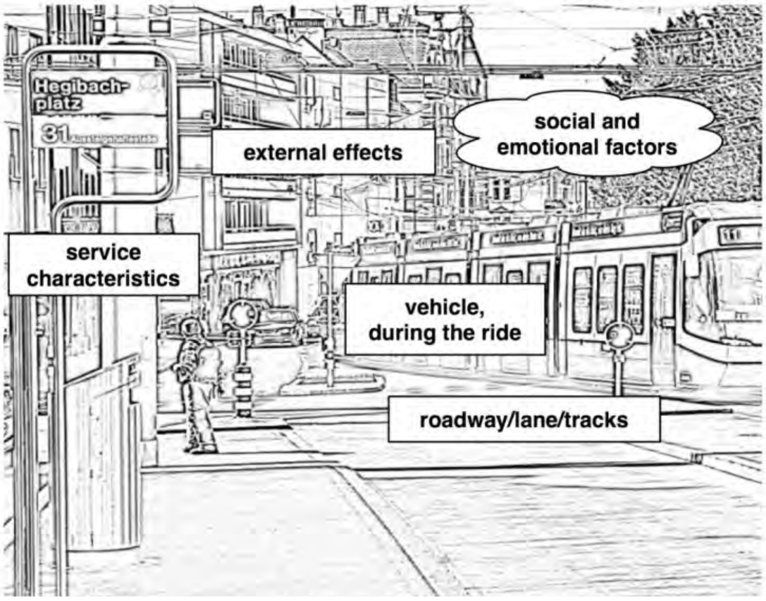
2.2 General attributes of urban public transport

2.2.1 Overview

In this section the main attributes of urban public transport systems are presented to allow for a comprehensive picture of the systems of interest. They can be classified roughly into five different categories (see *Figure 1*). The attributes for tram and bus are classified from a users point of view. This comprises aspects of public transport systems that are generally perceived by users.

1. Vehicle: Attributes that are related to the vehicle itself, its indoor conditions and vehicle aspects that affect the ride.
2. Roadway/Guideway: Aspects and associations towards the roadway/guideway including lanes or tracks, right of way conditions, and riding conditions when directly related to the guideway.
3. Service characteristics: This includes all service aspects that are required to allow passengers to use public transport.
4. Social and emotional factors: Positive and negative feelings and beliefs associated with public transport that are mainly subjective and based on experiences.
5. External effects that influence the image of public transport such as street views, environmental attributes, or attributions to certain locations.

Figure 1 Categories of public transport attributes



In the following, the specific aspects are presented in detail with respective background information.

2.2.2 Vehicle

Vehicles for bus and tram exist in various dimensions. The width of a tram vehicle is between 2.2m and 2.4m and the width of most buses 2.5m adjusted to usual street widths. The length of buses is restricted to about 25m (double-articulated buses) whereas trams can be composed of several modules due to the guidance of tracks and therefore can reach a length of up to 45m. These aspects influence firstly the capacity of the two systems, and secondly the requirement for stop length. Restriction on vehicle length is mainly based on problems of the integration of tracks in the urban development, and regarding a bus, the vehicle path limits the length of the vehicle.

As presented in the list in *Figure 2*, many further aspects are attributed to a public transport vehicle. Considering the vehicle itself, there are few objective differences between bus and tram vehicles. Both systems allow for low-floor vehicles, electrified traction if operated as trolleybus, modern vehicle design, comfortable seating (seat comfort that contributes to ride comfort), and low immissions in the vehicle. Three differences have to be mentioned regarding the vehicle: Firstly, in contrast to trams some parts in a bus vehicle require steps to get on a seat due to the larger sizes of bus wheels. Hence a tram rather allows for a continuous low floor distribution of seats. Secondly, a longer tram vehicle may require longer ways towards a seat that is available, which is more convenient in a tram with less lateral movements due to its guided way compared to a bus. Lastly, the longer vehicle, i.e. the partitioned tram vehicle, does not allow for direct contact with the driver, which affects security feelings of passengers.

Considering the list in *Figure 2*, there are many aspects of a vehicle that are influenced by local and subjective conditions. Nevertheless, they are expected to be important to different stakeholder groups. Handicapped persons, for instance, are in need of modern low-floor vehicle types that allows for easy boarding. Considering the mix of vehicles provided by a local public transport operator, these requirements are satisfied differently. However, this varies across cities and public transport operators.

Figure 2 Attributes of vehicles

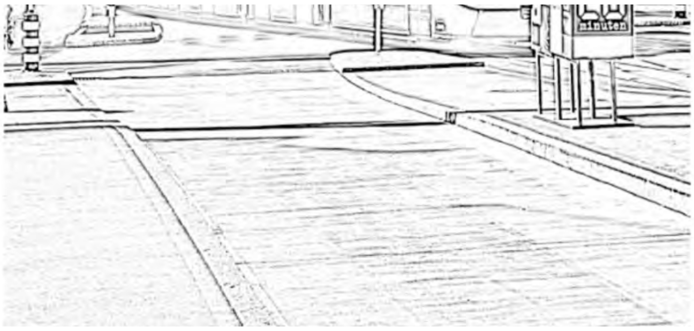
2.2.3 Driveway

The driveway of bus and tram can be characterized by the attributes in the list in *Figure 3*. The main characteristic is whether a driveway is constituted of a dedicated lane (track or bus lane), which has the advantage for operating mostly without disrupting other (car) traffic. Furthermore the aspect of having right of way is not strictly related to a dedicated lane but can be achieved by various measures when planning the layout of the street, such as appropriate classification of streets or traffic light priorization.

Attributions towards the guideway include flexibility to react to traffic and street conditions. A bus, for instance, can react more flexibly to street conditions compared to a track-bounded tram service. Other attributes include aspects that individuals relate to dedicated lanes and right of way such as higher reliability, punctuality and free traffic flow. The latter are often related to tracks, what corresponds to a subjective feeling and is therefore hardly measurable.

The aspect of a barrier effect and the effect of a driveway on the cityscape/streetscape are rarely discussed with reference to bus and tram. Nevertheless the consumption of public space for transportation in general and for dedicated lanes in particular is an important issue in urban planning and has to be mentioned. In cases where local conditions do not allow for multiple lanes, mixed traffic is often the consequence. In this case bus and tram are usually treated equally with priorization on traffic lights wherever possible. Theoretically, comparable construction characteristics are feasible for both public transport systems.

Figure 3 Attributes of driveway



2.2.4 Service characteristics

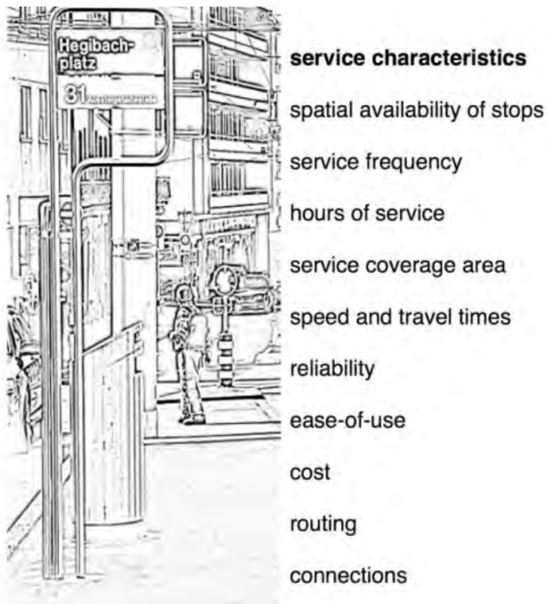
Service characteristics summarize all aspects that are necessary for customers to use public transport service. This includes basic information for passengers about the public transport offer such as (compare *Figure 4*):

- Stop locations
- Timetables
- Routing in general and connections to specific destinations in particular
- Pricing

Regarding bus and tram, there are generally no differences in service aspects between these two systems since the organization of services is not dependent of the respective system. However, since equipment of stops such as shelters and benches often depends on the average amount of passengers boarding at a stop, there are differences in equipment standards of bus and tram stops.

Additionally to objective service attributes there are subjective attributions that individuals make towards the attributes. One prominent example is the reference to higher reliability of trams that is either related to timetables or the driveway, as mentioned in the previous subsection. Although traffic conditions such as daily congestion is considered in timetables, a higher reliability is mainly achieved due to dedicated driveways and priorization of public transport at crossroads.

Figure 4 Attributes of service characteristics



2.2.5 Emotional and social aspects

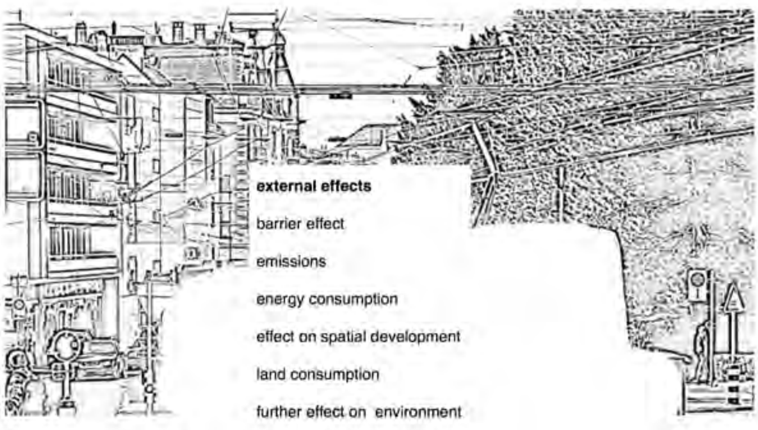
Analyzing customer surveys and qualitative studies (e.g. Megel 2001, Cain et al. 2009, Guiver 2007) reveals that there is a need for a category that summarizes emotional aspects towards public transport modes. This category is dedicated to non-classifiable arguments. It allows individuals who are not able to formulate and concretize a reason for their preference but do have a preference because of their "gut feeling" to express this feeling with attributes of emotions. This category includes formulations and emotional valuations such as *better, like more, better knowledge, experience, and convenience* in a broad term. These aspects are highly subjective but relevant when investigating preferences for bus and tram.

2.2.6 External effects

External effects comprise all aspects that are not directly related to a vehicle or to the guideway (*Figure 5*). Aspects mentioned most within this category are environmental impacts such as noise and emissions to the air from public transport operations, because users directly perceive these aspects. Although other non-visible effects such as life-cycle aspects of public transport vehicles and infrastructure, including construction, maintenance and disposal are hardly noticed by transport users, they belong as well to the external effects.

Considering the broad range of environmental factors, individuals are not able to judge all detailed components (such as CO_2, SO_x, NO_x, PM_{10}, other energy consumption etc.). With regard to environmental data, the main problem is the basis on which a judgment for comparison is made. This makes it difficult to draw general conclusions about environmental friendliness of bus and tram, and hence to compare these two systems.

Figure 5 External attributes of urban public transport



Furthermore, in the category of external effects are expectations of other positive or negative effects from bus and tram on aspects such as spatial development, land values, transport demand, and social segregation and gentrification. This subgroup of effects will not be discussed in detail in this dissertation because the focus lies on the public transport demand caused by the transport system itself, thus considering neighboring effects of transport systems would exceed the scope of the dissertation. However, there are assumptions drawn from the literature that expectations towards bus and tram differ regarding possible external effects. The difficulty with this subgroup of effects is the causality between public transport system and effect. Especially in urban areas there are many other impacts on the spatial development etc., which makes it difficult to evaluate the contribution of a bus or a tram.

2.3 Ridership attraction

2.3.1 Introduction

An assumed difference in passenger attraction of bus and tram under equal service characteristics constitutes the starting point of this work. This phenomenon is known as rail factor or rail bonus. Vuchic (2005) and other authors propose to include a public transport system's ability to attract passengers for mode evaluation. Since the supposed higher ability of rail-based systems to attract demand is a repeated argument in favor of investing in rail-based public transport systems it is of particular interest to highlight the aspect of differences in demand considering tram and bus.

In the following section findings about demand, demand forecasts and ridership attraction are summarized for both public transport systems. Focusing on the supposed higher ridership attraction of rail-based systems, two main themes discuss the attraction of rail-based public transport in the literature. One is based on quantitative data, including modeling and data analysis, while the other focuses on qualitative explanations of reasons for a preference of rail over bus.

2.3.2 Demand

Demand for urban public transport is influenced on one hand by service characteristics and on the other by structural data, such as number of residents, number of jobs and the relation between origin and destination, which constitutes the travel demand potential. Additionally, individual preferences and spatial characteristics also influence demand for public transport. Demand is expressed as number of passenger boardings or combined with the average length of a ride as passengerkilometer (pkm).

The presented data from two case cities Zurich and Berne depend on the length and design of a transport net and the average demand is partly influenced by capacity restrictions of vehicles.

Bus

Demand numbers for bus service in Table 1 distinguish between data for diesel buses and trolleybuses that operate in the city area. The average demand (boardings) per bus vehicle kilometer (vkm) is about 8 passengers in Berne and Zurich. Demand is significantly higher for trolleybuses compared to dieselbuses on a vkm basis. The main reasons for this result is that trolleybuses operate on main routes with high demand compared to dieselbuses that operate in the city centre and at the urban fringe with less demand. Further, the category of diesel buses includes various sizes of vehicles with lower capacities compared to trolleybuses that are articulated or double-articulated vehicles. Considering pkm per vkm, the values lie between 13 and 22.

The average travel distance of bus passengers is 2.2km in Berne and 2.1km in Zurich. Whereas travel distances for diesel buses and trolleybuses differ significantly in Berne (2.7km and 1.3km) they are similar for both bus types in Zurich (2.1km and 2.2km).

Table 1 Demand on Bus (trolleybus) lines in Berne and Zurich per year

City		vkm	boardings	pkm	boardings/ vkm	pkm/vkm
	bus	5'804'000	38'520'000	102'090'000	6.6	17.6
Berne	trolleybus	1'439'000	21'762'000	29'376'000	15.1	20.4
	both	7'243'000	60'282'000	131'466'000	8.3	18.2
	bus	6'160'000	37'800'000	78'800'000	6.1	12.8
Zurich	trolleybus	5'400'000	54'300'000	118'300'000	10.1	21.9
	both	11'560'000	92'100'000	197'100'000	8.0	17.1

Source: Geschäftsbericht Bernmobil 2010, VBZ 2011 (Data 2010)

Tram

The average demand per offered vkm is 17 passengers in Berne and 12 passengers in Zurich respectively 29 and 21 pkm per vkm (see Table 2). The average travel distance of a tram ride accounts for 1.7km in Berne and 1.8km in Zurich.

Table 2 Demand on tram lines in Berne and Zurich per year

City	vkm	boardings	pkm	boardings /vkm	pkm/vkm
Berne	1'923'000	32'815'000	55'365'000	17.1	28.8
Zurich	16'860'000	199'000'000	352'500'000	11.8	20.9

Source: Geschäftsbericht Bernmobil 2010, VBZ 2011 (Data 2010)

Comparison

The comparison of demand and performance of bus and tram (Table 1 and Table 2) reveals that trolleybuses and trams show a comparable share of boardings per vkm (trolleybus: 10-15 and tram: 12-17) and comparable values of pkm per vkm in Zurich (trolleybus: 22, tram: 21) whereas this ratio is higher for tram in Berne. Considering average trip length, bus trips are slightly longer than average tram trips. The average difference accounts for 1-2 public transport stops.

In Swiss cities, trolleybuses and trams usually follow routes with high demand because the vehicle capacities can cope with expected passenger numbers. Moreover, they have comparable service characteristics, comparable operational areas, and both systems operate on a high level of service. Thus, it is of special interest to compare these two systems. As noted before, they also show similar demand characteristics when comparing on a performance basis. However, considering that tram vehicles have higher capacities it might be surprising that demand for tram is within the range of demand for trolleybuses.

2.3.3 Forecast

Bus

Forecast for future ridership for bus service is elementary when implementing new bus lines or when bus service is going to be improved. Bus rapid transit systems (BRT) in the Americas and other continents play a prominent role in the discussion about new bus-based systems because of their high success in gaining passengers. In Europe, similar improvements of bus services are known as buses with high level of service (BHLS). Many successful examples show that improvements of existing bus service characteristics such as acceleration due to better stop distributions or dedicated bus lanes and investments in new modern high capacity vehicles lead to increased ridership over several years of between 20-134%, not only on the specific line but also on the public transport systems in general (compare Table 3). Heddebaut et al. (2010) establish that ridership gains of BHLS are above the numbers expected due to improvements of specific attributes such as shorter travel times, higher frequencies and other quality improvements. They conclude, *"the holistic approach appears to achieve ridership gains which are more than the sum of the part"* (Heddebaut et al. 2010, p313).

The success factors of the BHLS systems that lead to the increase of ridership are summarized as follows:

- Increase in service supply (e.g. vehicle-km)
- Improvements in operating speed and reduction of journey times
- Reduction of headway (increase of frequency)
- Changes to the network or route structure
- Adjustments in the tariff structure

- Corporate design and strong marketing

Table 3 Characteristics of selected BHLS and ridership gains after their implementation.

City	System identity	Share of dedicated lanes	Network re-structuring in the corridor	Ridership (P/day)	Ridership change
Amsterdam	Zuid-Tangent	80%	Significant	40’000	+47%
Dublin	Quality Bus Corridor	70%	Minor	34’000	+125%
Gothenburg	TrunkBus	45%	Significant	24’000	+73%
Hamburg	Metrobus	27%	Minor	60’000	+20%
Helsinki	Jokeri Line	21%	No	25’000	+100%
Madrid	Bus-VAO	100%	Minor	33’000	+70-100%
Nantes	BusWay	86%	Significant	24’600	+55%
Paris	TVM	95%	Significant	65’800	+134%
Prato	LAM	36%	Major	n/a	+57%
Stockholm	Blue Line	30%	No	36’500	+27%

Source: Heddebaut et al. 2010 (Table 1 and Table 2)

Tram

New tramlines usually replace existing bus services on routes with high demand or they are newly implemented along routes with strong spatial development activities. Predicted ridership is not available for Switzerland because there are hardly any new-implemented tramlines.

With regard to ridership on recently implemented tram systems in French cities, Groneck (2007) ascertains significant differences between measured and predicted ridership of up to 143% (see Table 4). Deviations of predicted and effective ridership vary between –63,000 and +45,000 passengers per day on a tramline. Furthermore, Mackett and Edwards (1998) found that expected forecasts for US cases were not met in many cases and forecasts for UK systems seemed to be mixed. A broad investigation of success factors and reasons for failure of new rail systems was conducted by Babalick-Sutcliffe (2002). Regarding forecast and effective ridership numbers it can be concluded that forecast models seem to be inaccurate, and consequently that the success of a tram implementation that is accompanied with a remarkable increase in public service quality (capacity, frequency, vehicle conditions) compared to the previous existing bus services, was misestimated.

Table 4 Predicted and effective ridership of new tramlines

City	Network density per population[1]	Line	Forecast (P/day)	Effective ridership (P/day)	Deviation (P/day)	
Nantes, F	1.32	1	80'000	85'000	+5'000	+6%
		3	25'000	27'500	+2'500	+10%
Strassbourg, F	1.00	A	75'000	96'400	+21'400	+28%
		B	80'000	108'000	+28'000	+35%
Paris, F	0.10	T1	51'000	87'600	+36'600	+72%
		T2	25'000	60'700	+35'700	+143%
Montpellier, F	0.66	1	65'000	110'000	+45'000	+69%
Orléans, F	1.55	1	44'000	41'000	-3'000	-7%
Lyon, F	0.44	T1	49'000	63'000	+14'000	+29%
		T2	50'000	67'500	+17'500	+35%
Manchester, GB	0.79	Bury, Altrincham	35'700	44'500	+8'800	+25%
South Yorkshire, GB	-	Yellow, Blue, Purple lines	70'700	18'700	-52'000	-74%
Tyne and Wear, GB	2.10	Parts of Yellow and Green lines	219'000	208'900	-10'100	-5%
Vancouver, CAN	-	Part of Expo line	100'000	136'000	+36'000	+36%
Pittsburgh, PA, US	0.63	-	90'500	31'100	-59'400	-66%
Buffalo, NY, US	0.30	-	92'000	29'000	-63'000	-68%
Portland, OR, US	1.21	Blue line	42'500	24'000	-18'500	-43%
Sacramento, CA, US	0.28	Parts of Blue and Gold lines	20'500	12'000	-8'500	-42%
St. Louis, IL/MO, US	0.75	Part of Red line	17'000	44'400	+27'400	+161%

Source: Information from Groneck 2007 and Balcombe et al. 2004 on new light rail systems since 1985,
[1]Hass-Klau et al. 2003 p28f (defined as track length (km)/ 10'000 city population).

The mentioned ridership numbers of newly implemented light rail lines do not consider changes on the supplementing bus network. Some sources criticize the success of new light rail because on the other side, ridership on bus routes suffered and in some examples total ridership on the public transport systems decreased after the implementation of a new light rail (Hensher and Waters 1994, Hensher 1999, Richmond 2001, Hensher and Golob 2008). This effect has been found in the US but similar studies for Europe are not at hand.

Comparison

In their extensive investigation of light rail and bus systems, Hass-Klau et al. (2003) found that both systems are able to attract former car users. Although it is assumed that transfers of car users to buses on busways or buslanes is lower than on light rail, the example of Dublin shows that a transfer percentage of 16% can be achieved with a busway. Overall, the main gain of passengers came from former public transport users who either switched from buses or increased their public transport use.

2.3.4 Differences in ridership attraction

Overview

Several studies claim a higher ridership attraction of a new rail-based service compared to a previously existing bus service (see Table 5). Table 5 gives an overview of the different geographical study areas and the findings regarding ridership attraction. The contributions from the 1990s in particular (Hüsler 1996, Arnold and Lohrmann 1997, Berschin 1998) claim a remarkable increase of ridership after the implementation of a new rail-based system. These findings are based on before-and-after analyses of ridership numbers. The strongest effect of ridership attraction was found for rural or regional transportation with an increase in demand of 30%.

Even higher are modeled results by Zöllner (2002) that are based on an analysis of demand functions on 12 regional rail routes. His studies are situated in low-density areas, where the demand for public transport is low and the discussion arose as to whether to replace existing regional rail with buses. Considering demand in rural areas several authors claim a remarkable reduction of passengers when replacing train with bus services of up to -45% (Zöllner 2002). However, these findings are not transferable to urban areas with bus and tram operating on the same level of service with equal service characteristics and with different conditions for car traffic compared to rural areas. Additionally, the reverse assumption that public transport demand will significantly increase when replacing a bus with a rail-system (under same service conditions) in rural areas lacks evidence.

Newer studies tend to be based on more sophisticated analysis methods, including behavioral approaches (e.g. Megel 2001, and Cain et al. 2009) and multinomial logit models (Axhausen et al. 2001, Ben-Akiva and Morikawa 2002). Results deduced from these studies minimize the existence of a rail factor under specific circumstances.

Table 5 Overview of studies on differences in ridership attraction of rail compared to bus

Source	Geographical area		Findings	Method and concept
	rural	urban		
Hüsler 1996		x	+25% ridership	Before-and-after comparison of ridership data
Arnold and Lohrmann 1997		x	+15% ridership	
Berschin 1998	x		+30% ridership	
Zöllner 2002	x		-45% ridership replacing regional train with bus	Comparison of demand functions
Axhausen et al. 2001		x	Small preference for LRT	SP mode choice experiment
Ben-Akiva and Morikawa 2002		x	No clear preference	RP and SP data analysis
Megel 2001	x		Preference for rail	Interviews, schema theory
Currie 2005		x	Similar values for BRT and rail modes	Comparison of value of trip attributes (mode specific factors) from literature review
Cain et al. 2009		x	No difference between BRT and LRT perception	Focus group discussions

Quantitative methods

Although some authors listed in Table 5 claim a substantial rail factor, others found in their before-and-after comparisons of demand no clear evidence for a higher rail preference (e.g. Kottenhoff and Lindh 1996, Kasch and Vogts 2002). However, it has proved very difficult to evaluate and determine the rail factor precisely because the implementation of a new public transport system is usually accompanied by an improvement of quality of service such as higher frequencies, new vehicles, changes in stop distributions and augmented marketing campaigns (Kasch and Vogts 2002). Effects of these changes in public transport service are often not considered sufficiently in before-and-after comparison of demand. Kasch and Vogts (2002), for instance, found in their analysis of 16 routes where bus service was replaced by tram an average increase in ridership of 83%. However, this is not a pure result of the replacement of the existing bus service, because the systems change was accompanied by the following improvements:

- Higher frequency
- New stop infrastructure
- New low floor vehicles
- Increase of capacity
- Marketing campaigns
- Increase of stop distances by about 5%
- Higher travel speed and a decrease of average travel times by 82%
- 100% dedicated lanes and priority at traffic lights for the new tram
- Some restrictions for car traffic
- Partial cancellation of parallel bus services.

Under these circumstances it is not possible to deduce a rail factor because all these aspects contribute to a better public transport service quality.

Regarding a change in regional public transport service in terms of replacement of rail with bus service as it occurred in the 1980ies in some parts of Germany, Langenheim and Schliephake (1986) found differing results. One example is that although passengers claimed to prefer rail over bus in about 60% of the cases, revealed bus usage accounted for almost 60% of the demand on the relation to be investigated. This means that passengers did not act according to their claimed preference.

Considering analyses based on utility theory, the existence of a rail factor diminishes. Whereas Axhausen et al. (2001) found that there might be a weak preference for LRT compared to bus service based on their SP survey, Ben-Akiva and Morikawa (2002) detected no evident preference for rail travel over bus in their analysis of two case studies in the Boston area. They used revealed preference (RP) survey data with extensive data on level of service attributes to estimate utilities of mode choice. Holding the service variables constant, the relative attraction of each public transport mode was measured by a dummy variable. They assume that the attraction for a metro originates in its advantages along with other attributes that were not quantified, and conclude that the preference for the metro vanishes when express buses operate on exclusive lanes. Other factors than the generally used level of service factors, such as in-vehicle travel time, out-of-vehicle travel time, travel cost and number of transfers, are considered to be important in mode choice for rail and bus. According to Ben-Akiva and Morikawa (2002) the following factors are especially important:

- Reliability, due to the right of way or some other kind of priority measures
- Information availability, including visibility of routes and stations
- Comfort in terms of ride comfort and ease-of-use
- Safety and security
- Availability

Since these factors are difficult to quantify or do not vary between origins and destinations (O-D), they are not included in general choice models.

Currie (2005) found some evidence that BRT is generally able to perform similar to light rail in the perception of passengers, given comparable service characteristics. His findings are based on comparison of mode specific factors that captures the user-perceived attractiveness of a public transport mode compared to another. His literature review revealed that BRT and LRT show similar ranges of average demand compared to common on-street bus services.

Schulz and Meinhold (2003) conducted a conjoint-analysis in order to detect differences in willingness to pay for either bus or train in regional transportation. They estimated a multi-nomial logit model (MNL) and found a slightly higher willingness to pay for rail-based system over the whole dataset. However, public transport users are overrepresented in this data, which leads to biases. Furthermore, Schulz and Meinhold (2003) ascertain that the effect of higher preference towards rail-based systems decreases for user segments that include car-users, young people and people with high knowledge about the public transport.

Qualitative methods

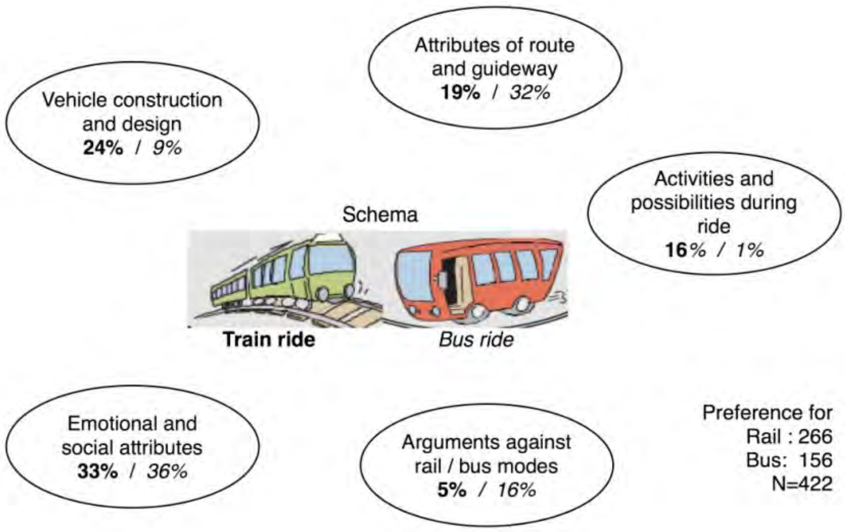
To date, only a few studies have applied qualitative methods to explore an assumed rail factor. Megel (2001) investigated rural train versus bus preferences in Germany and Cain et al. (2009) conducted a study on the image and perception of BRT in Los Angeles.

Searching for the rail factor, Megel (2001) explored relevant system attributes of bus and rail using a cognitive approach. Based on cognitive maps that are represented as schemata or scripts, she developed schemata for rural public transportation. A schema is defined as *"a cognitive structure that represents knowledge about a concept or type of stimulus, including its attributes and the relations among those attributes"* (Fiske and Taylor 1991, p98) and is comparable to the image of a concept. This set of interrelated cognitions allows an individual to quickly make sense of a situation or an event on the basis of limited information.

Her findings about the schema “train ride” emphasize the importance of emotional and social attributes, such as relaxation, silence, experiences, and positive or negative feelings, which formed 33% of the explanations for the preference for trains, followed by 24% for attributes dealing with the vehicle (construction and design) and 19% of the arguments considering the attributes of guideways and various other attributes (*Figure 6*).

In contrast to the schema “train ride”, the schema “bus ride” is based on 36% emotional and social attributes and 32% attributes concerning the route or roadway of the bus, followed by arguments against rail modes. Less than 10% of the decision arguments dealt with vehicle attributes. Surprisingly, less than 2% of the arguments for rail concerned travel times and only 5% mentioned the right of way. With respect to bus attributes, travel times had about the same small number of notations.

Figure 6 Schemata “regional public transport” for bus and train



Source: Megel 2001. Percentages for rail preferences are ***bold****, those for bus are italic*

Although image studies ascertain a better image and higher preference of rail-based systems compared to bus-based systems, it is not known yet to what extent this preference reflects real mode choice behavior. Megel's study is not directly related to demand, but investigations of the perception of attributes that influence demand provide useful insights into how individuals value service and system characteristics.

Cain et al. (2009) used focus group discussions to quantify the importance of image and perception of different public transport lines in Los Angeles. They found that full bus rapid transit (BRT) is perceived by everyone as superior to regular bus services in the Los Angeles region. In contrast, although other high quality bus services (non BRT) were also highly regarded by their users, the general public's view was influenced by the same negative perceptions as regular buses. A comparison of performance variables considered in the research for specific public transport lines showed that the same modes received different ratings on mostly intangible factors (attributes that are abstract, subjective and thus difficult to measure, e.g. safety, impact of other riders and comfort). These intangible factors have a significant influence on modal perception. Hence, modal perception is affected by the different neighborhoods, which leads to the conclusion that mode attributions depend on specific experiences or images.

As a consequence, Cain et al. (2009) conclude that the perceived image of BRT by the general public can compete with the image of light rail. Especially when people are familiar with one public transport mode, their support for this mode is revealed to be greater than for an unfamiliar mode.

2.4 Impacts on mode choice

Besides qualitative studies conducted to explore preferences between different public transport systems, approaches and findings that target mode choice behavior in general are of interest. Many aspects, such as intentions, beliefs, habits and images, influence mode choice behavior. Subsequently, different qualitative aspects on mode choice are presented.

2.4.1 Intention and beliefs as a predictor of mode choice behavior

Mode choice and travel behavior are investigated with various qualitative approaches. Considering mode choice between car and bicycle, Bamberg and Schmidt (1992) applied the theory of planned behavior (TPB, compare 4.3.1). They found in their study of car and bicycle use among students that more than 60% of the variance of the variable "intention to use the car" and more than 72% of the variance of the variable "intention to use the bicycle" was explained by the characteristics of one of the three model variables that constitute TPB ("subjective norm," "attitude toward behavior," and "perceived behavioral control. In another longitudinal study, Bamberg and Schmidt (1998) found that increased bus use was brought about partly by changes in the underlying beliefs about bus use.

Heath and Gifford (2002) applied the TPB in their study about public transport use in the frame of a universal bus-pass program in order to identify the potential to reduce car use and to determine psychological factors associated with the change in mode choice. Therefore they examined bus use before and after the implementation of the universal bus-pass. Regarding the relationship of intention (as a result of TPB determinants) and behavior, the variable "intention to use bus," asked on a five point scale, turned out to be by far the most significant predictor of effective bus use. This variable explained 63% of the variance in actual bus use (out of 72%). These values are in the range of Bamberg and Schmidt's studies, but are however, relatively high compared to reviewed studies by Conner and Armitage (1998) that have average explanatory power of 34% of the variance of behavior. Heath and Gifford (2002) conclude that TPB is especially useful in predicting pro-environmental behavior.

Changes in beliefs are one target to be explained with the TPB. Beale and Bonsall (2007) conducted a study to examine whether providing specific marketing material can reduce common misperceptions of bus use. The aim was to increase bus use with specific changes in beliefs about bus services. They established a slight positive effect on bus use of habitual and occasional bus users and no or a negative effect on people who never use the bus. As a conclusion, the marketing material supported bus users in their attitudes since individuals react positively to marketing containing arguments that are in line with their personal beliefs. In contrast, marketing information favoring bus services could be interpreted as "anti-car" messages and hence, evoke negative feelings in car users towards bus because car users may feel criticized for their behavior.

Quantitative studies confirmed that people are more likely to react to new transportation solutions at a time when their personal lifestyle is changing. However, according to Harms (2003) the influence of attitude and perceived behavioral control grows in relation to the influence of habit during periods of situational change. She analyzed the motivation of participants of car sharing organizations in Switzerland. Other sources of applied TPB on transportation are Karash et al. (2008) for an overview and Kaiser et al. (1999) for enhancements of the TPB with environmental attitudes based on two Swiss transport associations.

2.4.2 Attitudes form habits

Habits in terms of frequent use of a transport mode (especially car use) are partly attributable to how attitudes, beliefs, and choices are correlated. Gärling et al. (2001) and Verplanken et al. (1997) have found that attitudes or preferences guide initial mode choice for most activities of an individual but in cases where these choices become habitual, mode choice is difficult to influence. That is, positive attitudes toward car use lead to frequent choices to do so, and lead to automatized driving choice. Depending on the type of reduction required, habitual trips might not be reduced at all.

2.4.3 Images of transport systems

The image of a transport system is on one hand constituted of system attributes. Furthermore an image is influenced by local conditions, different cultures and beliefs. For the case of the United States and Canada, Wirthlin Worldwide and FCJandN (2000) ascertain geographical differences in perception of public transport in different regions of the United States and Canada. Regarding the image of public transport in Germany some experts consider the image of public transport in Germany to be weak and not attractive (Lasch 2005 in Gegner 2007) while others rate the image to be good (Petersen 2005 in Gegner 2007).

Gegner (2007) analyzed the public image of public transport in Germany. Based on a hermeneutical picture analysis of images in relevant German print media he distinguished between different public transport modes. His findings about the image of bus and tram vary. The image of a bus is the most related with crime and is attributed as transport mode for "losers." A picture of a bus is used in the media only for urban areas when a special vehicle is displayed. Usually, buses are associated with rural areas. The image of a tram is more neutral. The tram turns out to represent a "boring" transport mode that is neither perceived as nice nor as ugly or dangerous. It is a transport mode representing big cities (in Germany). Nostalgic and futurist images are both associated especially with this transport mode.

Referring to the success of many newly implemented tram systems in France this is partly justified with image reasons. New tram implementations are explicitly based on ambitions to improve the image of public transport while reconstructing the streetscape and implementing exclusively designed tram vehicles (Groneck 2007). This should evoke stronger identification of residents with "their" new tram.

Other researchers found that some attributes towards public transport such as travel time are classified simultaneously as advantages and disadvantages depending on the right of way (i.e. separate bus lane or tracks) (Beirão and Cabral 2007, Guiver 2007). With regard to different attributions to bus and light rail, light rail is generally perceived as more reliable, comfortable, faster and more spacious than buses. Furthermore, light rail is more often rated higher concerning intangible factors, a finding that emerges from positive attributions such as "new, enjoyable, and attractive" (Beirão and Cabral 2007).

Guiver (2007) found in a discourse analysis of focus group discussions on bus and car travel, that local buses were often seen as sub-standard when compared with bus services in other cities. Even more interesting is the finding that people activated worst-case scenarios when talking about bus travel. This negative setting presumably leads to generalizations about attributions towards bus travel. Both the activated scenario and the selective attributions towards bus travel support the assumption that mode choices are being made partly on personal experiences and common cultural representations of modes. This means that planners need to consider different pre-conceived beliefs as well as ways of thinking and processing information when they design public transport systems (Beale and Bonsall 2007).

2.5 Purpose for implementation of new systems

A comprehensive analysis by Edwards and Mackett (1996) on reasons for implementations of new urban public systems revealed that decision-makers either address transport issues or economic and development issues. Transport issues include the goal to reduce traffic congestion. Decisions-makers expect that a new, fast, and comfortable public transport system such as a tram will offer a lower disutility to users and hence will attract former car users. The expected effect is that parts of car users switch their mode of transport. As a consequence, there should be less traffic on the road, travel speed increases and congestion decreases.

Capacity was cited as a critical factor for mode selection in many case cities of the cited study. Regarding predicted peak capacity requirements for British systems (Edwards and Mackett 1996), most public transport systems such as buses, light rail and metro were suitable to cope with the estimated demand. Nevertheless, buses and light rail were in the scope of the decision of most cases and finally light rail was usually chosen. The following factors were ascertained in the cases of the study to justify the choice of light rail (Edwards and Mackett 1996, p230ff):

- Local factors (past experience, existing rail services, context)
- Capacity
- Cost: in some examples capital costs or operating costs ruled out the use of buses although bus-based solutions were generally cheaper than light rail solutions, especially if there was no existing rail infrastructure. Other reasons included tracksharing, or reduction of operating cost or differenced in subsidies.
- Image and public perception: The positive image of a rail-based system was often used to justify the choice of light rail. It is also expected, that these systems rather stimulate development. However, there is not much evidence that this effect exists (Hall and Hass-Klau 1985) except if the system provides a significant improvement in quality.
- Political consensus: It was found that it is easier to get a political consensus across political parties for a rail-based system than for a bus-based.

- Legislation and funding: Regarding differences in legislation (e.g. regulation by local authorities) or funding schemes, there may be different treatments for bus-based and rail-based systems that influence the decision in favor for light rail.

Edwards and Mackett (1996) summarized their findings about how decision-makers justified the choice of a light rail according to Table 6. However, most of the assumed contributions of light rail to urban development are not proven, consequently the expected effects have not been substantiated. Mackett and Edwards conclude from their study of about 50 cities and systems, that *"the impacts do not meet the expectations to any great extent"* (Mackett and Edwards 1998, p237). Hensher and Waters (1994) claim that both systems, bus priority systems and light rail transit, have a marginal impact on overall mode split, *"unless substantial steps are taken to discourage single occupant motor vehicles"* (Hensher and Waters 1994, p140).

Table 6 Criteria influencing the choice between light rail and buses

For light rail	For bus
Image: -perceived as able to attract drivers from cars -perceived as able to stimulate development -seen as requiring priority in city centre -fixed infrastructure implies permanence Funding available (…) Does not cause on-street pollution Can interact physically with heavy rail Can run on-street and on existing rail track	Lower cost increases amount of network built for a given sum of money Flexible routes
Against light rail	**Against bus**
High cost restricts amount of network built for a given sum of money Inflexible route	Image: perceived as unable to attract drivers from cars - perceived as unable to stimulate development -not seen to require priority in city centre -not seen as permanent service Difficult to obtain funding Causes on-street air pollution Cannot physically interact with heavy rail

Source: Edwards and Mackett 1996, Table 7, based on interviews with decision-makers

Newer studies focusing on cost overruns and demand overcasting found also biases between expectations of newly implemented tramlines and real outcomes. Additionally, Cohen-Blankshtain and Feitelson (2011) found in their study about the role of goals in decision-making on light rail routing only a weak relationship between challenges faced by the city, the goals set for the LRT and the characteristics of the LRT line to be built. This is mainly influenced by the political decisions to meet funding reasons. Furthermore they found that existing right of way (ROW) is preferred if possible to implementing new ROW sections or other restrictive measures.

In contrast to tramways, reasons for implementations of BRT or BHLS systems are different. Mostly, the need to fill the gap between tram and conventional bus services in terms of performance, cost and capacity are the main reasons for BHLS implementation. In particular, economical advantages and the flexibility to react to rising demand along routes that do not have a ridership potential that would justify a tram favor bus systems. Nevertheless the fundamental component for a successful BHLS is an at least partly exclusive on-street lane in order that buses and their passengers are not stuck in congestion.

2.6 Discussion

2.6.1 Quantitative impacts of a rail factor

Two conclusions can be drawn from the experiences of demand forecast: First, demand is often higher for new tramlines than for previously existing bus services and, second; the future demand was not estimated with appropriate accuracy. Regarding travel demand forecast of new light rail systems, French estimates were generally too pessimistic compared to estimates of US cities. Whether negative or positive, a deviation of several thousand passengers requires enormous adjustments in rolling stock, personnel, costs, etc., or produces an incalculable loss in revenues. For the operational planning of public transport operators, reliable demand predictions are very important.

Although before-and-after comparisons of ridership data often show an increase of passengers the conclusion that this is because of the change of the systems from bus to a rail bounded public transport system is not valid. Thus, not only the system changed but also many service attributes were improved which makes it difficult to apportion the benefit of the system change itself.

Considering a mode shift from car towards public transport, the expectations have not been met in many cases of newly implemented light rail systems (Mackett and Edwards 1998).

Hass-Klau et al. (2003) conclude that the level of transfer depends on the existing level of public transport use. This means that cities with a high modal share of public transport (such as e.g. many Swiss cities) are less likely to attract many former car users than cities with a low modal share of public transport. Furthermore, it is assumed that complementary measures such as road pricing and expensive parking charges have as well a remarkable effect on car use. The availability of public transport service and public transport use in Switzerland is relatively high and hence, according to the findings of Hass-Klau et al. (2003), a switch from car use to public transport use might be smaller than expected from experiences in other cities.

2.6.2 Qualitative explanations

The studies that investigated a higher preference for rail bounded public transport found that bus and rail are attributed differently. These attributions impact the image of public transport systems. It is assumed that images influence behavior and attributions towards public transport systems are a main driver for a rail factor.

However, attributions are influenced by local conditions, behavioral habits and beliefs about public transport systems. As a consequence, the image of public transport modes and possible reactions towards transport modes varies across geographical areas depending on the systems and public transport services provided and depending on the experience of the general public. Furthermore conditions of alternative transport modes, especially car traffic, influence the perception of public transport systems. In congested areas, for instance, a public transport mode that is not affected by car traffic due to dedicated lanes is attributed positively.

In a nutshell, attributions that constitute the image of a transport system are based on different perceptions of system attributes. Differences in attributions towards bus and rail bounded public transport are possible explanations for a rail factor. Nevertheless, attributions towards these systems have to be deduced separately for specific regions because they are influenced by local conditions. Regarding an assumed rail factor, not only attributions are likely to differ but also reactions to public transport systems are expected to vary.

2.6.3 Conclusions

Many of the estimations found in the literature dealing with the term "rail factor" are based more on the experiences of planners or transport operators and on expectations of decision-makers than on detailed empirical analysis of the reasons for this preference (compare chapter 2.5). Furthermore, in estimations based on before-and-after data of public transport demand, it is difficult to apportion the share of increased demand caused by the transport mode itself because not only did the system usually change, but also the relevant service characteristics are improved, such as travel times and stop distributions. Hence, results of before-and-after studies tend to be strongly dependent on local conditions and they cannot be transferred easily. Finally, situations where the public transport system changes from bus to tram or vice versa, with all other characteristics remaining constant, are hard to find.

With regard to the different methods of investigating a rail factor, before-and-after-analyses do not contribute satisfactorily to further explanations of the higher attraction of rail compared to bus, because possible reasons cannot be drawn from the data available. In contrast, methods and concepts from psychology seem to be productive. Approaches that consider cognition of users and other stakeholders as applied by Megel (2001), are appealing for the explanation of perceived impact. For a better understanding of how the motives of stakeholders are influenced, rational choice approaches currently in use will have to be extended/expanded.

The established methodological shift from pure data analysis towards increasing behavioral considerations in order to find explanations for various stakeholders' reactions is in line with the efforts to evaluate level of services from a user's perspective (e.g. TRB 2008, Scherer et al. 2010d). However, explanations for an urban rail factor are rare, and in particular no findings exist for areas where the level of public transport service and public transport usage are high.

3 Research framework and hypotheses

3.1 Framework

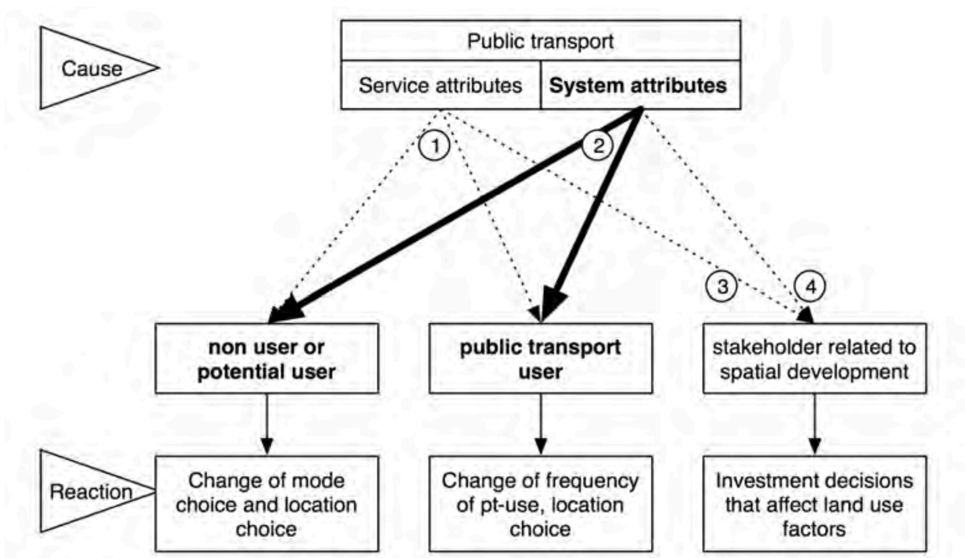
3.1.1 Target groups

Effects of public transport are manifold and difficult to measure properly. With regard to affected fields, several relevant affected stakeholder groups are distinguished. The direct beneficiaries of public transport can be divided into roughly three groups: First, users who profit from affordable and reliable transport options; second, non-users of public transport who benefit in terms of improved capacities on streets when the modal split for public transport increases; and third the general public who registers a higher quality of life due to reduced negative impacts from car traffic, such as air pollution or land consumption for transport.

Transport systems not only affect these beneficiaries, they also have a significant impact on urban development decisions in two ways. Public authorities consider investments in transport systems as a tool to manage and control urban development in terms of coordinating land use and traffic volume by providing appropriate capacities. In addition, due to their accessibility specific locations are more attractive to private investors than others.

User behavior is affected by public transport determinants of service and of system attributes. As a consequence, ridership numbers express reactions of users and potential users on these attributes (numbers 1 and 2 in *Figure 7*). Therefore, demand and demand forecast and how (potential) users perceive different public transport systems are of main interest.

Figure 7 Impact of public transport



Stakeholders in spatial development do have different access to transport system effects, but their decisions also affect transport behavior and demand. There are two groups that mainly influence spatial development: Public institutions that draft land use regulations and promote specific development goals and private real estate developers with their economic interests. Both groups account for effects of transport systems that they expect to target their interests. Their decision-making process is mainly based on expectations and experiences with transport system effects (numbers 3 and 4 in *Figure 7*) and accordingly, on their supposition that bus and tram are perceived in different ways in terms of a higher valuation of tram access. This leads, e.g., to an increase in land prices.

Reactions on service attributes such as travel times, costs and availability of public transport service (1) are already well investigated, and do not contribute to the distinction between two similar transport systems (bus and tram) in a satisfactory way. This is because the service attributes of these two systems are equal under the supposition of high quality standards.

Focusing on the effects of attributes of these transport systems (2) is expected to allow for new insights for an assumed rail factor. By investigating the differences in the effect of various urban public transport systems on users, non-users, and potential users, a better understanding of the benefits of these systems is gained in order to improve the knowledge base for transport planning and for policies that support decision-makers.

3.1.2 Effects of public transport: rail factor

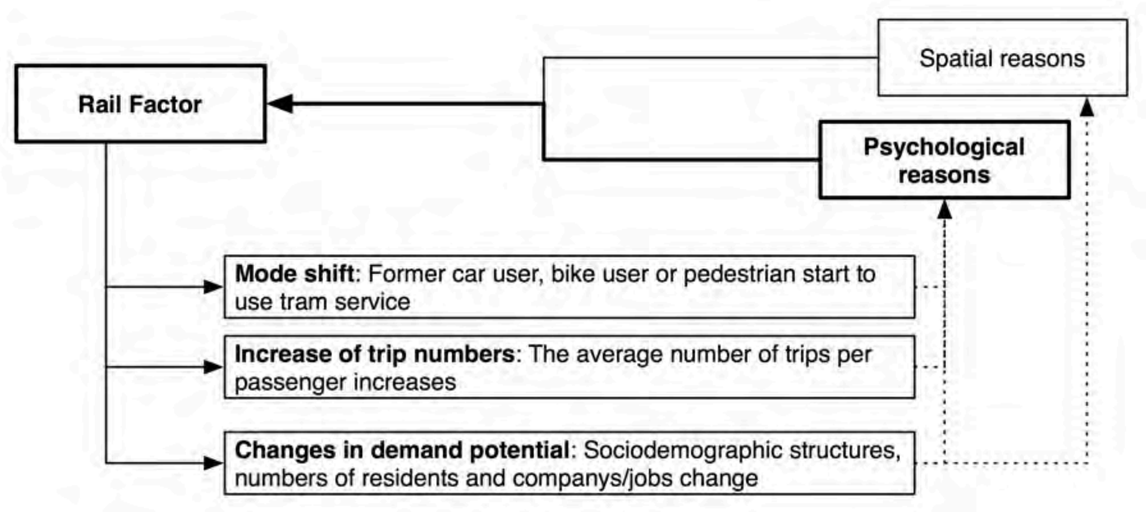
As a system specific effect, the rail factor is in the focus of the dissertation. The rail factor comprehends a claimed increase in demand when replacing a bus system with a rail-bounded system all other service characteristics (travel times, stop distribution etc.) remaining the same. Since a replacement of a bus system with a tram system is usually accompanied by various changes of the service (e.g. frequency), streetscapes and land use, the pure effect of the tram system itself on demand is difficult to quantify.

Theoretically, causes of a hypothesized rail factor have three sources (compare *Figure 8*). First, a mode shift of individuals that formerly used other modes of transport leads to additional demand. These new users may react on a newly implemented rail-bounded public transport system in terms of changing their travel behavior. Second, it might be that a new tram system affords public transport users the opportunity to use the service more often. Third, a tram system may attract residents and employees with a higher affinity to public transport. Furthermore changes in spatial development and land use can also influence changes in demand potential. It is expected that all these factors influence a rail factor.

Whereas demand for a public transport service changes with the implementation of the service, changes in spatial development require more time and start already with investment decisions for new public transport infrastructures. Spatial development in terms of changes in residential numbers or number of jobs affects public transport service as well, however on a different timeframe.

The explanation of reasons for changes in travel behavior caused by a replacement of the public transport system is of man interest in the underlying research.

Figure 8 Causes of a rail factor



The following approaches have been applied in other studies to analyze and determine a rail factor or psychological differences that affect mode choice and travel behavior:

1. Schema theory (Megel 2001)
2. Memory representation (Dziekan 2008a)
3. Instrumental, symbolic and affective motives (for car use) (Steg 2005)
4. Image of different public transport systems (Cain et al. 2009)

3.1.3 Research question

The underlying research question of this dissertation targets *the relationship between system attributes of bus and tram and the related stakeholder's perception and reaction on these system attributes.*

Therefore the following knowledge is essential:

1. System attributes of bus and tram. What are the relevant system attributes and where are differences in attributes of bus and tram?
2. How are these system attributes perceived by various stakeholders? The target groups of main interest are public transport users and potential public transport users what comprehend residents in general.
3. How do different target groups react to the evaluated system attributes of bus and tram? Are there differences in travel behavior towards bus and tram?

Answers to these questions allow a closer approach to the research question of whether and how bus and tram cause different reactions concerning travel behavior.

3.2 Hypotheses

Derived from the literature research, the subsequent hypotheses are drawn. The leading hypothesis seeks to find whether a rail factor exists for the case of urban public transport. Therefore an approach to define and establish a rail factor is required. The starting point constitutes a theoretical rail factor:

1. *In a hypothetical case where in an urban area both systems are available and consist of the same service characteristics, there is a stronger commitment to choose trams than bus services.*

Different preferences are interpreted as influenced by different perceptions of these two systems. That means that the socio-cognitive model expressed as image differ significantly for tram and buses.

2. *Bus and tram are perceived differently which leads to different images of these two urban public transport systems.*

2.1 System characteristics are valued differently for bus and for tram

2.2 The image of a tram is more positive than the image of a bus.

This socio-cognitive knowledge and its valuation can be explained by applying the schema theory. With regard to the schema theory, a schema of urban public transport and several sub schemata, including a sub schema tram and at least one or more sub schemata for bus (trolleybus, maybe BRT), exist in people's minds. The analysis of pictures in mind is used to investigate these hypotheses.

Assuming that differences in the image of bus and tram affect travel behavior this should be observable in different travel behavior of residents living in bus and tram corridors. Thus, a rail factor expresses a higher public transport use of individuals who live close to a tram stop compared to residents living in the catchment area of a bus stop with similar public transport service.

3. Public transport use is higher in neighborhoods served by tram than in neighborhoods served by bus.

3.1 The image of a tram is more positive for residents living close to tram services than for residents living close to bus services.

3.2 The image of bus is more positive for residents living in bus corridors than for residents living tram corridors.

Connecting the valuation of system attributes with real travel behavior leads finally to conclusions about a revealed rail factor.

3.3 Approach

The investigation of an urban rail factor is based on 4 steps (see *Figure 9*). First of all, system attributes as introduced in section 2.2 are quantified for bus and tram according to Swiss conditions. The basis therefore is data from various transport operators and the writer's own calculations for specific case studies. This allows for first references on attributes with differences between bus and tram.

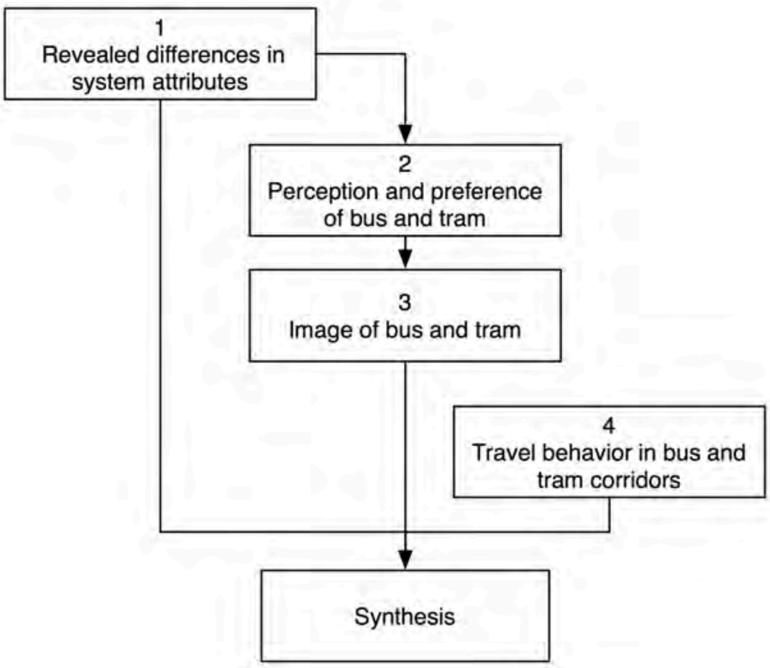
Second, perceptions of bus and tram systems and preferences for these systems are explored in the light of the hypothetical case that bus and tram services are identical. In this study categories of reasons for preferences are examined applying content analysis. From these categories, schemata of bus and tram are deduced. The findings are then compared to the results of Megel's investigation of a rail factor (Megel 2001) for regional public transport that also applied the schemata approach. Furthermore, the examination of reasons for preference is used as input for the subsequent study of images of bus and tram.

The third step consists of the analysis of the image of both systems; tram and bus, as perceived by residents of case study cities. Based on the schemata developed in the second step, the image of public transport systems is analyzed applying the method of semantic differential (Osgood et al. 1957). This method allows detecting differences in the valuation of public transport attributions for bus and tram.

The fourth step consists of data analysis of revealed preference data. The hypothesized effect of bus and tram systems on revealed travel behavior is tested with analysis of spatial information of travel behavior for work trips applying GIS software. The underlying assumption is that travel behavior in terms of public transport use differs between residents of tram corridors on those of bus corridors with comparable public transport service.

The synthesis combines the findings of the four steps. The images of bus and tram deduced from psychological approaches (step 2 and 3) are compared with findings of revealed behavior. Furthermore, the contrast between beliefs established in steps 2 and 3 and revealed attributes is elaborated. Finally, answers to the research question and hypotheses are summarized and discussed for a generalization of the findings for other case cities.

Figure 9 Approach



4 Review of concepts and methodological approaches

"Economics and psychology have radically different views of the decision-making process.
First, the primary focus of psychologists is to understand the nature of the decision elements,
how they are established and modified by experience, and how they determine behavior.
The primary focus of economists is on the mapping from information inputs to choice."
Ben-Akiva et al. (1999) p188

Common approaches in transport planning are mainly based on normative approaches that consider decisions on an economical level applying rational-choice models. Another stream to explain mobility behavior is based on psychological approaches. The advantages and limitations of various approaches are discussed. Relevant aspects of human cognition that help understanding human decision making are introduced and discussed with respect to urban public transportation.

This chapter is partly based on the following articles:

Scherer, M. (2010) Is light rail more attractive to users than bus transit? Arguments based on cognition and rational choice, Transportation Research Record, 2144, 11-19.

Scherer, M., K. Dziekan and C. Ahrend (2011a) Exploring the Rail Factor with Schemata of Bus and Rail: Two Studies from Germany and Switzerland, Paper presented at the 90th Annual Meeting of the Transportation Research Board, Washington, D.C., January, 2011.

Scherer, M. and K. Dziekan (2012) Bus or Rail: An approach to explain the psychological rail factor, Journal of Public Transportation, 15 (1), 75-93.

4.1 Introduction

Different methods and methodological approaches are reviewed and discussed regarding their applicability to the research question introduced in the previous chapter. Therefore applied approaches for mode choice in general and for a deduction of a hypothesized rail factor are analyzed. Three fields of concepts are considered.

- Economic approaches: Demand models in general and mode choice models in particular are mostly based on economic considerations. It is of interest whether common concepts based on economical approaches contribute to the explanation of a rail factor.
- Behavioral approaches: This group of approaches originates from psychology and allows for a different perspective than economical approaches. Behavioral approaches seek for motivations for a certain behavior, such as attitudes or habits. As introduced in chapter 2, mode choice explanations can refer to behavioral approaches. Therefore previously mentioned theories and concepts are presented and discussed.
- Cognitive approaches: Cognition refers to how a concept is perceived and stored in mind. Since cognitive shortcuts are used for everyday decisions, it is assumed that different perceptions of bus and tram can influence mode choice decisions. Hence, it is relevant to understand how cognitive approaches contribute to a rail factor.

Methods and concepts that fulfill the following conditions are needed. First, to analyze a rail factor it is required that impacts of bus and tram can be distinguished. Furthermore, the method has to allow for explanations for assumed differences in behavior towards bus and tram. Third, local conditions as an impact factor on a rail factor have to be considered appropriately.

4.2 Economic approaches

4.2.1 Utility theory

Introduction

The classic transport demand model is based on four steps: trip generation, trip distribution, mode choice, and route assignment. Considering a replacement of bus service with an equal tram service, it is assumed that destination choice and route choice of individuals remain stable. As a consequence, an expected increase in ridership is a reflection of mode choice what is generally modeled by discrete choice analysis (e.g., Ben-Akiva and Lerman 1985, Ortuzar and

Willumsen 1994). Discrete choice models generally allow modeling behavior given that preferences of decision makers towards relevant attributes that target their alternatives are known.

The assumption behind discrete choice analysis is that a decision maker selects the alternative with the highest utility U from a given choice set. The model consists of parameterized utility functions in terms of measurable independent variables (deterministic components) V_{in} and unknown parameters (random components) ε_{in}.

$$U_{in} = V_{in} + \varepsilon_{in} \tag{1.1}$$

with i being the alternative i of a given choice set and n the respective respondent to chose the alternative.

The systematic component V_{in} is composed of variables x_i that characterizes the alternative i. In transport planning, these are often variables describing the trip such as travel times and costs, and may also include sociodemographic variables such as income, gender, and car ownership. The β coefficient reflects the weight of the variable regarding V_{in}. The random component ε_{in} has a mean of 0.

$$V_{in} = c + \beta_1 \times x_1 + \beta_2 \times x_2 + \ldots \beta_n \times x_n \tag{1.2}$$

Many improvements have been proposed and tested in order to account for specific shortcomings of the utility framework (see Schüssler 2010 for an overview on similarity in modeling).

Utility functions do not allow predicting the chosen alternative by all individuals. Therefore the concept of random utility was implemented. Given that an individual has a choice set C_n with j numbers of alternatives, random utility states that the probability that an alternative i is chosen by the decision maker n as:

$$P_n(i) = \Pr(U_{in} \geq U_{jn}, \forall j \in C_n) \tag{1.3}$$

Whereas the utility U of each alternative can be divided into a deterministic and a random component:

$$\begin{aligned} P_n(i) &= \Pr(U_{in} \geq U_{jn}) \\ P_n(i) &= \Pr(V_{in} + \varepsilon_{in} \geq V_{jn} + \varepsilon_{jn}) \\ P_n(i) &= \Pr(\varepsilon_{jn} \leq V_{in} - V_{jn} + \varepsilon_{in}) \end{aligned} \tag{1.4}$$

The most common model for more than two alternatives is the multinomial logit model (MNL). This is based on the assumption that all random components ε_{in} are:

- Independently distributed, which implies that there are no common unobserved factors affecting the utilities of alternatives.
- Identically distributed in terms that the same variation in unobserved factors are expected across all modes. This is especially sensitive since e.g. the aspect of comfort understood as crowding varies much more for trains than for cars and as a consequence the assumption of identical distribution is disturbed.
- Gumbel distributed with a location parameter η and a scale parameter μ >0.

Then the probability that alternative i is chosen by the individual n results in:

$$P_n(i) = \frac{e^{\mu V_{in}}}{\sum_{j \in C_n} e^{\mu V_{jn}}} \tag{1.5}$$

The underlying concept of random utility maximization of a transport alternative depends on the variables and their respective coefficients used in mode choice models. Applying different mode specific constants c can catch differences between public transport services in the deterministic component (1.2). These mode specific constants allow considering the effect that is not covered by the attributes applied in the deterministic term. However, the mode specific constant may capture various effects such as location specifications and taste variations what cannot be controlled for.

The MNL is a commonly used model for mode choice with a given choice set consisting of distinct alternatives and attributes that vary in their value depending on the alternative. Regarding the choice between bus and tram alternatives under equal service conditions the MNL structure is not an optimal model to detect differences in future demand when replacing one public transport mode with the other. Considering a rail factor for tram in terms of higher preference for tram under same deterministic components as those of a bus would result in a shift of probabilities from situation 1 to situation 2 in the following example.

1)	2)
$P(car) = 0.6$	$P(car) < 0.6$
$P(PublicTransport_{Bus}) = 0.4$	$P(PublicTransport_{Tram}) > 0.4$

Since the attributes of the deterministic component of the utility function are the same for bus and tram, this result is not expected by applying MNL. Even in cases where individual tastes are estimated for the specific choice between bus and tram the MNL approach does not allow an explanation of the phenomenon of expected higher preference for a tram in a satisfactory extent.

The red bus and blue bus paradox

Having a choice set with two alternatives with no remarkable differences is known as an *independent irrelevant alternative* property (IIA property). The most prominent example for this problem is the red bus/blue bus paradox. The IIA property holds that the ratio of choice probabilities of any two alternatives is unaffected by systematic utilities of any other alternative (Ben-Akiva and Lerman 1985) in the case of a MNL as follows:

$$\frac{P_n(i)}{P_n(l)} = \frac{e^{V_{in}} \Big/ \sum_{j \in C_n} e^{V_{jn}}}{e^{V_{ln}} \Big/ \sum_{j \in C_n} e^{V_{jn}}} = \frac{e^{V_{in}}}{e^{V_{ln}}} = e^{V_{in} - V_{ln}} \tag{1.6}$$

Under the assumption that the random components are independent this would result in $V_{in}=V_{ln}$. For the example of the blue bus and red bus paradox three alternatives are defined: car (1), blue bus (2) and red bus (3). Given V_n to be the deterministic component for any of the three alternatives and initially assuming that $V_{car} = V_{bus}=0.5$, the consequence of the independence of alternatives $V_{1n}=V_{2n}=V_{3n}$ leads to an overestimation of V_{bus}. If the two bus alternatives are perfectly correlated, then the utilities are expected to be the same, which requires a correction of systematic utilities for the two bus alternatives to be used in a logit model. Thus the choice axiom is generally restricted to distinct alternatives.

Ben-Akiva and Lerman (1985) note that there is a misinterpretation of the IIA property by assuming that it applies to the population as a whole. Identifying different homogenous groups (distinct market segments) with different choice probabilities towards alternatives allows for better results. As a consequence the suitability of logit being an appropriate model has to be decided for any particular choice depending on the particular specification of the deterministic component of the utility function.

Against the background of the IIA-property, the choice between bus and tram could be modeled if certain assumptions are fulfilled. First, the list of variables of the deterministic component has to be extended with variables that allow for distinction between bus and tram. However, these variables are expected to be difficult to measure since they are mostly based on soft factors (see Ben-Akiva and Morikawa 2002). Second, the estimates may be improved by including additional socioeconomic attributes to form market segments and to estimate tastes of different homogenous groups instead of modeling the population as a whole. As a consequence, regarding these difficulties, the MNL is expected to be of low value to give an insight into the phenomenon of higher tram preference compared to bus. Concepts that relax the IIA assumption, such as nested logit models and heteroscedastic models, are not considered in the context of this work.

Limitations of the utility theory

As mentioned earlier, the utility theory has its restrictions and limitations. Utility theory is commonly based on the following assumptions, which are critical for the targeted research questions:

- **Perfect decision maker:** Decision makers act rationally and possess perfect information (*homo economicus*) to maximize their personal utility. However, derived from the evidence that the maintenance of coherent beliefs, and consistent and transitive preferences is too demanding for limited minds (Simon 1956, Tversky and Kahneman 1974) it is supposed that maximizing utilities for a future outcome is even more difficult (Kahneman 1997). Therefore the underlying assumption of rationality has to be revised for specific choice situations because people usually do not possess or need full information to make a decision.
- **Personal utility function:** The definition of personal utility maximization is problematic because the understanding of personal utility is highly variable. In economic models the maximization often considers costs whereas some individuals are more interested in e.g. minimizing their travel times. Since individual choices are affected by current emotional states and the context of choice (Kahneman and Thaler 2006), accordingly, the maximum utility may rather be described as satisfying goals (compare e.g. the theory of bounded rationality by Simon 1956).
- **Choice set generation and attributes:** A choice set of alternatives is constituted of a set of attributes x that are measurable. This implies that an alternative comprehends all attributes that are relevant for the decision maker's choice. Since it is not possible to consider all relevant attributes for any decision maker and to capture individual tastes and beliefs towards these attributes in the MNL, these models tend to be too general to explain a potential rail factor.

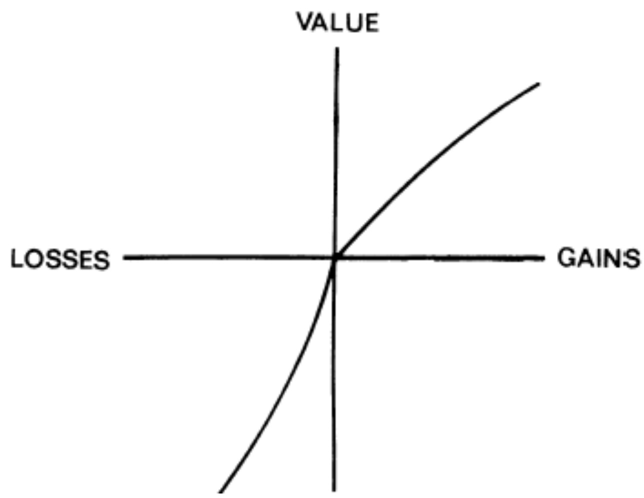
Based on these assumptions utility theory is seen to have limited explanatory power for the underlying research question that seeks for an explanation of a rail factor. Nevertheless it is an appropriate model for mode choices on an aggregated level with distinct alternatives such as the choice between car and public transport options. However, as a generalized model, it is difficult to capture the differences between bus and tram options.

4.2.2 Prospect theory

Introduction

Derived from several classes of choice problems where the classical utility theory failed to predict behavior, Kahneman and Tversky (1979) proposed the prospect theory to adjust decision-making under risk. The prospect theory considers that individuals are in general risk averse in the domain of gains and rather risk seeking in the domain of losses. This can be expressed in a concave utility function for gains, respectively for positive utilities and values and in a convex curve for negative values. The utility function also considers that losses loom larger than gains, which results in a steeper curve in the domain of losses compared to gains. Furthermore prospect theory allows for considerations of reference points of individuals where the value of losses and gains equals 0 (compare *Figure 10*). A reference point accounts for different initial positions of individuals.

Figure 10 Utility function for the prospect theory



Source: Kahneman and Tversky 1979, p279

In contrast to common utility theory the value function is regarded as the carrier of changes in wealth or welfare rather than final states, which is compatible with basic principles of perception and judgment. According to Kahneman and Tversky (1979, p277) *our perceptual apparatus is rather attuned to the evaluation of changes or differences than to the evaluation of absolute magnitudes*. Considering the utility function, value is a function of two arguments: Firstly, the reference point and secondly the magnitude of change (negative or positive) from this reference point. Additionally, the value function is multiplied by a decision weight, which expresses the impact of events on the desirability of the prospects. The characteristic of the weighting function is derived from experiments and considers that individuals generally overweight events that have a small probability and underweight events that have high probabilities.

Theoretical application to bus and tram

Depending on the point of view, the prospect theory allows for different conclusions regarding preference and reaction towards bus and tram. For a public transport user, there is only a small gain when replacing the bus service with an equivalent tram service. As it is expected that the main requirement of this user group is a high level of service and hence service conditions theoretically do not differ between these two services according to the definition of a rail factor, the perceived differences are expected to be small. Considering *Figure 10*, small changes in gains result in even smaller changes of the value for a certain person due to the concave utility function.

Another group of traffic participants is car users. How are they affected by a change of bus to tram? Whereas buses can be treated as other traffic such as other cars or lorries, a tram is different due to the rails. This difference is highly perceivable by car users. When introducing a tram, car users can be affected with a loss of space when a tram gets its own dedicated tracks. This may be perceived rather as loss for car users and looms larger than gains, according to the prospect theory. As a consequence car users are expected to be stronger opponents of tram implementations and rather prefer bus systems than other traffic participants.

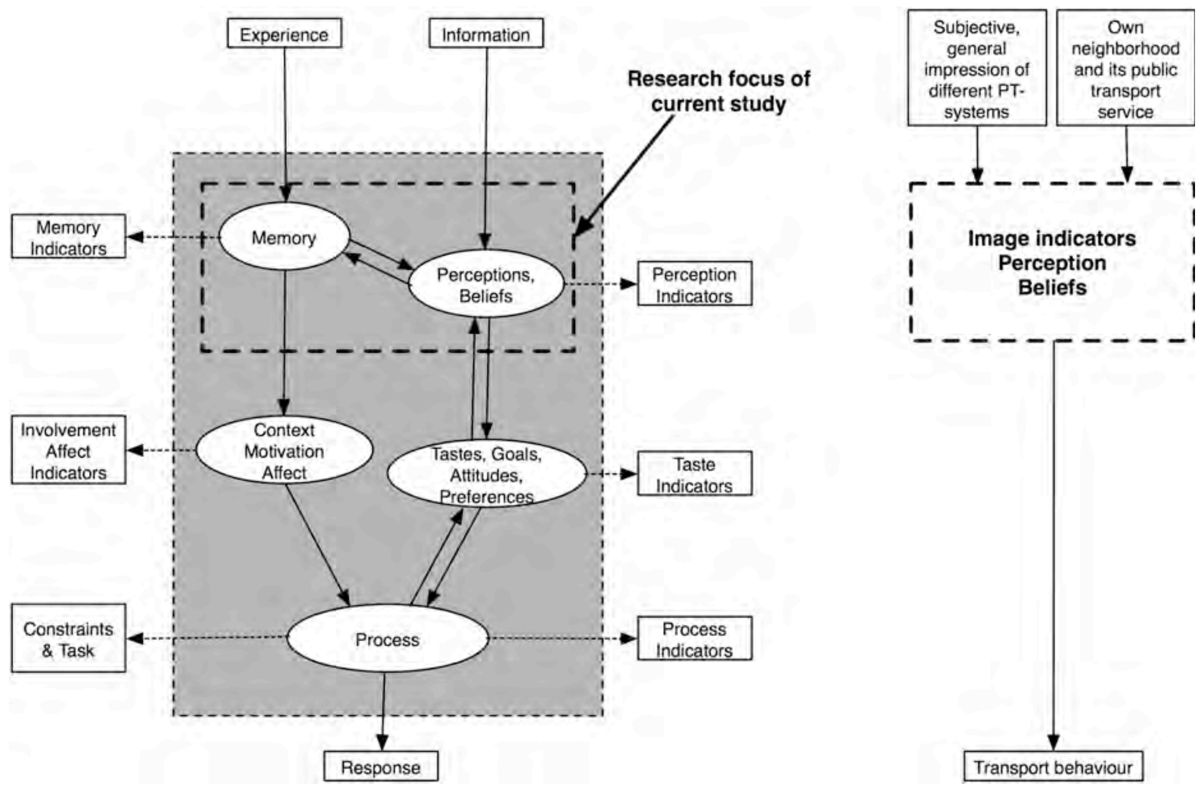
Transport planners play a special role in judging a system change of bus to tram. As experts they are aware of many objective differences between these two public transport systems. As a consequence, experts may see a higher gain when replacing bus with tram than public transport users do. The resulting higher value for this group is then explained with this higher gain that experts estimate for tram implementations.

Finally, due the variance of the reference point and the expected individual gains or losses, prospect theory allows for explications of why different stakeholders react in different ways on a replacement of bus service with equivalent tram services. Nevertheless the question of whether a rail-based system is perceived to be superior over bus systems cannot be answered by using prospect theory. However, this specification of utility theory makes a step towards individual judgment with the consideration of a reference point and under the assumption that changes rather than absolute magnitudes are taken into account by individuals.

4.2.3 Extended framework for choice behavior

Ben-Akiva et al. (1999) proposed an extended framework for modeling choice behavior where psychological factors can be incorporated (compare 4.2.3). This framework provides the theoretical background on how to treat psychological aspects that influence demand (see *Figure 11* left). In contrast to current rational choice models that look rather at input (information) and output (response), it is expanded with internal factors that affect mode choice represented by the ovals in the grey box. Memory, perceptions and beliefs, and tastes are strongly related. Hence, it is possible that various variables influence several indicators.

Figure 11 Extended theoretical framework for modeling choice behavior



Source: Based on Ben-Akiva et al. 1999, p192

In order to apply this approach, knowledge about the respective indicators has to be gained. For the underlying question about the response on different public transport systems, specified indicators for the different aspects have to be defined and measured. The framework of this approach allows identifying sources of different behavior towards bus and tram.

The focus of the dissertation is the investigation of memory, perceptions and beliefs about comparable public transport systems. As it can be seen on the right side of *Figure 11*, the input is expected to be based on general impression/knowledge about a system and neighborhood specific inputs that reflects on one hand the objective opportunities that one has and on the other hand which of these opportunities one perceive. Different indicators are investigated against the background of resulting travel behavior.

4.3 Behavioral approaches

Observed biases between economic findings and effective behavior require a change of the perspective towards effective behavior and explanations thereof beyond normative assumptions. Therefore common behavioral approaches are of high interest since they allow for insights from a different point of view.

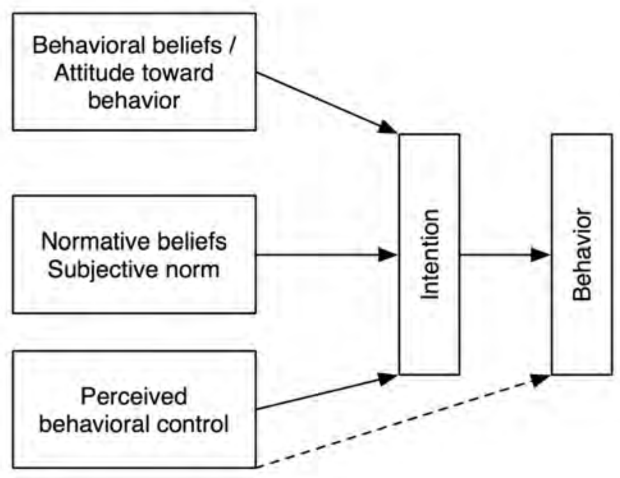
4.3.1 Theory of planned behavior

Concept

The theory of planned behavior (TPB) proposed by Ajzen in 1985 is based on the combination of beliefs that forms the attitude of an individual towards a specific behavior. This model is designed to provide enhanced explanations of informational and motivational influences on behavior. The TPB implies that individuals make behavioral decisions based on careful consideration of available information. The core of the TPB is the assumption that intensions to perform a certain behavior - understood as a person's motivation - influences behavior. Therefore intentions are guided by the three factors: behavioral beliefs, normative beliefs and control beliefs (Ajzen 1991, compare *Figure 12*).

- Behavioral beliefs define what an individual thinks about the consequences of a specific behavior and his or her attitude (positive or negative) to performing a specific behavior. This is limited to the set of accessible behavioral attributions that are linked by the subject to the specific behavior.
- Normative beliefs are influenced by the judgment of significant others and respond to socially desirable behavior. This is supported with subjective norms that express what a subject thinks that others believe about a specific behavior.
- Control beliefs are based on the person's perception whether one has the ability to perform and possibility of performing certain behavior.

Figure 12 Theory of planned behavior



Source: Ajzen 1991, p182

The model itself can be regarded as a theory of proximal determinants of behavior. For improvements to predict intentions, and consequently behavior, different extensions of the TPB are proposed in the literature (see e.g. Conner and Armitage 1998 for a review). Extensions include aspects such as belief, salience, past behavior and habit, moral norms, self-identity, environmental concerns and values, and affect.

Considering the impact of intentions as a result of the proximal determinants on real behavior, Conner and Armitage (1998) establish in their review of meta-analyses that intentions determined with the TPB account for 34% of revealed behavior. This signifies that many people do not behave according to their intentions. However, it is supposed that the variables applied in the TPB are necessary but not sufficient determinants of behavior. Amongst others, Eagly and Chaiken (1993) doubt that the TPB clarify the relation between intention and behavior. As a consequence of this critique, it became common to distinguish between decision-making (understood as forming an intention) and implementing it (behavior) (Conner and Armitage 1998).

Explanatory power for bus and tram preferences

The TPB has been applied to predict mode choice between public transport and car or bicycle and car. Additionally, the TPB can be applied to interpret findings of changes in beliefs due to specific information campaigns in favor for bus use (compare 2.4.1). The advantage of this approach is that psychological variables beyond those used in rational choice models are considered. The supposition that the intention to exert a specific behavior is a good predictor for real behavior lead, in the studies mentioned in chapter 2, to high prediction rates. The TPB showed better results compared to rational choice models, such as MNL models that usually have an explanatory power for the variances in mode choice of up to 50%.

Of special interest considering public transportation is the finding that specific attitudes such as environmental concern have been investigated in depth regarding their influence on real behavior (Bamberg 2003). The result of 30 years of scientific research is that there is no or only a weak direct relationship between environmental concern and environmentally related behavior. Deriving from the TPB general environmental concern influences the salience of an object, but has finally no longer effect on intention or behavior. Furthermore *"an intention which reflects mainly the perceived situational social pressure is less likely to be enacted outside that situation*" (Bamberg 2003, p31).

Considering the underlying exploration of a rail factor this approach is not suited for an explanation as a mode choice model between car, bus and tram since the difference between the psychological considerations of bus and tram on the main determinants (e.g. for determinants like "subjective norm," "attitude toward behavior," and "perceived behavioral control" are assumably marginally low. Furthermore the variable "intention to use bus" and hence "intention to use tram" does not allow for explanations for reasons that one of those two intentions is stronger than the other. As a consequence, the TPB would allow the detection of differences in intentions towards bus and tram use; however, two important failures for the underlying question remain. Firstly, reasons for these differences cannot be explored sufficiently and second, even if the intentions differ, this may not result in different behavior towards bus and tram use.

4.3.2 Goal-framing

Concept

For a better understanding of human behavior, it is necessary to shed light on the processes and influences beyond behavior. Human beings generally follow different ways or paths for improving their conditions; briefly, everybody tries to achieve his or her proper goals. According to Lindenberg (2008, p670) *goals are flexible in the sense that they change with respect to situational cues and affordances*. Hence, goals indicate what somebody intends to do in a specific situation, and consequently goals allow the prediction of the likelihood of a certain behavior. They consist of two major combinations; these are the motive (or purpose) and the activated knowledge structure regarding the motive/goal (Lindenberg and Steg 2007). In terms of mobility, the motive is mostly the need to get from point A to point B. Here the activated knowledge structure is of special interest, because this contains knowledge about different transport alternatives.

In their work about goal frames in environmental behavior Lindenberg and Steg (2007) distinguish between three generic goal frames: a hedonic goal-frame, a gain goal-frame, and a normative goal-frame. Whereas the hedonic and the gain goal-frames affect different time horizons and are dependent on the specific situation of a subject, the normative goal frame is associated with influences of the society or at least of significant others (comparable to normative beliefs in the TPB). Depending on the specific situation, on the decision to be made and on the knowledge available, another goal frame is activated; accordingly the other sub-goals are put in the background. People being, for instance, in a hedonic goal frame are more likely to act in a way to increase their pleasure and/or their mood (very short timeframe). In contrast, a gain-goal is activated when people act with focus on their personal resources such as time or money. Finally, a normative goal-frame is controlled by appropriateness in terms of what most others do or would do in a comparable situation.

It is supposed that preferences mainly follow rational choices, and they are partly influenced by norms. Since often-used rational explanations have their limitations, enhancements by adding norm theory can improve the accuracy of predicted behavior (see e.g. Cialdini et al. 1990 and 2006 for applications of the norm concept). Considering motives for car use, Steg (2005) found that frequent drivers and people with a positive car attitude in particular put a high value on motives for car use that are rather affective that instrumental. Derived from these findings, she recommends taking into account social and affective arguments in order to capture the reasons for car use.

Explanatory power for bus and tram preferences

Considering the underlying research question, mode choice has to be re-thought under specific circumstances: is it a long-term decision in terms of investments into mobility features such as a new car or an annual public transport pass? Or is it an everyday decision to choose car, bike or the bus if every system is easily available? This implies different backgrounds and hence different goals are activated in the decision-making process.

Mode choice is affected in two ways: Firstly, as a long-term decision for ownership of mobility tools (car, travel card) and, second, as a short-term decision for a specific trip. The latter depends highly on the ownership of mobility tools and trip purposes that in turn are influenced by habits and beliefs and consequently the knowledge structure about alternatives and specific traffic conditions such as availability of parking. The contribution of a specific goal frame to travel behavior is difficult to specify. With increasing objectivity to a specific issue, it can be assumed that normative goals become more prominent. Furthermore the question whether mode choice is a goal in itself or if it serves to reach another goal is not answered.

A higher preference for tram is assumed to derive from a normative goal frame due to more positive attributions towards environmental impacts. Since it is socially desirable to act environmentally friendly (social norm) this attribution is expected to have an important impact on decisions made in a normative goal frame. Methodologically there are some constraints because when interviewing or asking people about their mobility preferences they may activate a normative goal frame rather than a hedonic or gain goal frame, which are more often applied to everyday situations. Hence it is not clear whether a higher preference of tram compared to bus revealed under labor conditions is transferable to real behavior.

Regarding different user segments and their motives for mode choice it is expected that people's reactions are influenced by whether they have a positive attitude towards the respective mode. A strong positive attitude towards a transport mode is expected to lead to a higher share of affective reasoning for the use of this mode and might also lead to more frequent use.

4.4 Cognitive approaches

Cognition summarizes the processes and structures in mind of humans that influence behavior. This includes how individuals perceive external information, and how they process and memorize information. Cognition refers to all actions for the processing of information, applying of knowledge and changing preferences.

In cognitive psychology, two ways of thinking and deciding are proposed, described as dual process theory. These ways correspond to the concept of reasoning and intuition. Especially decisions based on intuition are based on heuristics that serve as cognitive shortcuts in order to save cognitive effort. Since the late 1970s it has become clear that individuals are limited in their capacity to process information and therefore rely on cognitive shortcuts for most of their decisions: that is, they are *cognitive misers* (Taylor 1981).

4.4.1 Dual process theory

The dual process theory refers to the two ways in which information can be processed mentally. Firstly, there is a central systematic route based on rationality and *reasoning* and secondly, the peripheral heuristic route that is based on *intuition* (e.g. Chaiken and Trope 1999, Kahneman 2003, Hogg and Vaughan 2008). The two ways differ in the cognitive effort to take a decision.

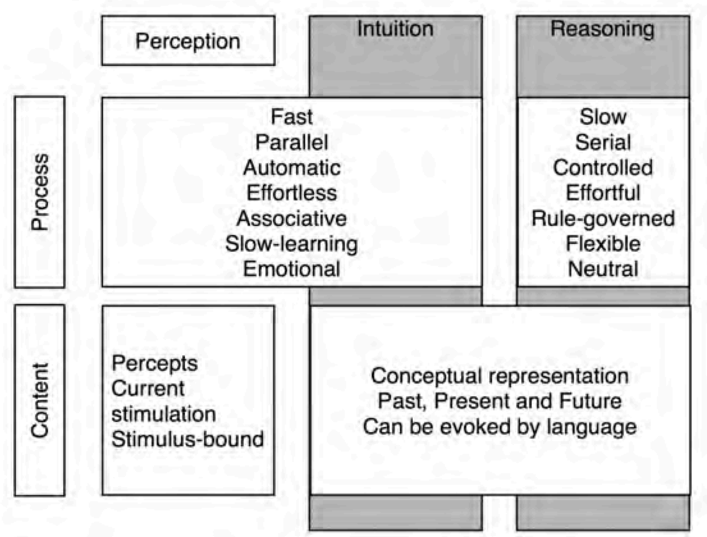
Reasoning is when we compute a product or when we carefully consider all advantages and disadvantages of an action. This systematic processing of information is based on an analytic and comprehensive treatment of judgment-relevant information. Judgments evolving from the systematic process are usually responsive to the actual content of this information. This process requires a high cognitive effort and is less likely to be seen among individuals who posses little knowledge in the respective domain.

In contrast, heuristic processing, understood as intuitive thoughts that come more or less spontaneously to mind, is activated without remarkable effort. Comparable to other knowledge structures, heuristics as judgment rules are assumed to be learned and stored in memory. *"Judgements formed on the basis of heuristic processing reflect easily processed judgement - relevant cues rather than individualistic or particularistic judgment-relevant information"* (Chaiken and Trope 1999, p74). Relatively to reasoning, heuristic processing requires a minimal cognitive effort. This process is constrained by knowledge activation and use. Thus, the judgment-relevant heuristics must be stored in and retrieved from memory (available and accessible). Furthermore the heuristic must be relevant for the judgment task (applicable).

Based on the assumption that individuals are saving cognitive effort whenever possible, heuristic processing predominates information processing (Chaiken and Trope 1999, Kahneman 2003). Chaiken and Trope extend this argument with the sufficiency principle, which means that individuals "*who are motivated to determinate accurate judgements will exert as much cognitive effort as necessary (and possible) to reach a sufficient degreee of confidence that their judgments will satisfy their accuracy goals*" (Chaiken and Trope 1999, p74). This reflects that some monitoring and quality control of our decisions is undergoing when making intuitive, heuristic decisions. Kahneman (2003) distinguishes three cognitive systems that differ in processing information and in their content: Perception, intuition, and reasoning (*Figure 13*).

Whereas rules of perception are found to be generally similar to those of intuition (heuristic processing), reasoning (systematic processing) has a different fundament regarding processing information. Since intuition is the driver for most cognitive actions, the understanding how intuition influences mode choice is seen as a key feature for the current work. Therefore the knowledge of relevant heuristics and biases is of special interest.

Figure 13 Three cognitive systems: Perception, Intuition and Reasoning



Source: Kahneman 2003, p1451

4.4.2 Heuristics and biases

In order to process information quickly, in parallel, automatically, and without "wasting" too much cognitive effort, individuals apply heuristics when making intuitive decisions. Prominent examples of heuristics are rules-of-thumb. In their research program about heuristics and biases, Tversky and Kahneman (1974) defined three groups of heuristics that are activated in the process of judgment under uncertainty; availability, representativeness, and anchoring and adjustment. Their findings indicate that people apply heuristics most of the time because it is efficient, and allows for decision-making with limited information in a short time. Furthermore they established systematic deviations from optimal solutions of the individuals. These biases indicate that people's judgment can be misleading when using availability heuristics, representativeness heuristics and anchoring heuristics. In the meantime, additional heuristics and respective biases, which influence individual's judgments and choices, such as the affect heuristic (Slovic et al. 2007) and the prototype heuristic (Kahneman 2003), have been defined.

One key characteristic of heuristics is their high inertia. Heuristics are elaborated and learned shortcuts, proven to be useful for a person - otherwise they would not be used as heuristic. It is assumed that heuristics are sufficiently automatic, thus it may require a high effort to stop employing them. Because of that fact, once a heuristic is accepted, changes to this heuristics are difficult even if new information and knowledge is available to the individual.

Many heuristics and influences may be known under different terms such as e.g. *prototypes*, which refers to (mental) images or schemata and is designated to an abstract picture in mind about a specific concept. Relevant heuristics for judgment in general and transport behavior in particular are:

Availability heuristics: Availability heuristics are employed according to how easily instances come to mind. Since frequent events and large classes usually generate more examples, this heuristic is often employed. One example may be that the risk of being involved in a car accident is assessed by recalling such instances in one's own experience. A bias to the availability heuristic is that events or experiences that occurred recently are easier to retrieve from memory and thus more available. Other influences on the bias due to the retrievability concern familiarity and salience. Another bias is the illusory correlation. This is the erroneous belief that two uncorrelated events are associated. The assumption behind this bias is that two events are associated in mind and when one event is recalled the second comes easily into mind as well, although they are not correlated. Media coverage and other forms of publicity can enforce the ease of employing availability heuristics.

Representativeness heuristics: Representativeness heuristics include questions of the type: what is the probability that object/event A belongs to class B, and hence that event A originates from process B? This means that people assess the degree of correspondence between a sample and a population, and consequently an outcome and a model. The most common biases regarding representativeness heuristics are the conjunction fallacy and the insensitivity to base-rate-information. Whereas the conjunction fallacy is based on the misperception of situations and employment of stereotypes (see also prototype heuristics below), the base-rate effect means that prior probabilities are neglected. People tend to base probability judgments only upon specific information for the required judgment without considering the a priori probability of an event. Biases of representativeness heuristics are found to be primarily associated with single-case judgments.

Anchoring and adjustment: An often-used strategy to judge or estimate a specific concept or event is to start with an initial estimate or initial assumption. In this case, the value from a previous stage serves as an anchor and future adjustments are made based on this anchor. The most common bias to this heuristic is that people tend to stick too close to the initial value and do not adjust their values properly. Anchoring is an intuitive process. This bias can be influenced by prior information given to a respondent, the sequential order of presenting information etc.

Affect heuristics: Affect is related to the quality of an object or an event. Attributes for favorable or unfavorable response such as good/bad, like/dislike, approach/avoid are employed as affect heuristics (Kahneman 2003). Slovic et al. (2007) showed that affect in terms of liking/disliking is the heuristic attribute for numerous target attributes to be judged. Affect is found to be a strong conditioner to preference and the more frequently a person is exposed to a specific affective event or object, the more positive is their response towards this event or object (see Steg 2005 for affect as motive for car use). Slovic et al. (2007) ascertain that several studies have demonstrated a strong relationship between imagery, affect and decision-making. When considering judgments of technologies, Finuncane et al. (2000) established that a technology that is liked is judged to have low costs and large benefits. This refers to a negative correlation between costs and benefits, which indicates a bias because the correlation between cost and benefits is generally positive. An affective (emotionally) driven heuristic appears to be the factor for these findings.

Prototype heuristics: Prototype heuristics refers to the representation of categories by their prototypes and is a source of consistent biases. These heuristics are a further development of the representativeness heuristics. Kahneman (2003, p1463) describes a prototype as a set *characterized by the average values of salient properties of its members. The high accessibility of prototype information serves as an important adaptive function. It allows new stimuli to be categorized efficiently, by comparing their features to those of category prototypes.* The prototype heuristic may be described as a two-part process: First, a category is represented by a prototypical exemplar and second, the prototype has a nonextensional property, which refers to the neglect of base rates, scopes and duration. This means that e.g. the monetary value attached to a public good is often insensitive to its scope and the evaluation of a temporal experience (e.g. getting stuck in traffic) is insensitive to its duration (Gilovich et al. 2002).

Application to bus and tram

Heuristics are expected to be of high value to explain different preferences of bus and tram. First, heuristics are generally applied for decision-making in everyday situations such as mode choice decisions. Second, various heuristics are purposeful for the explanation of a rail factor. Availability heuristics support the expected influence of local conditions and local public transport offers. According to availability heuristics, experiences that occurred recently are more familiar and are higher available. Thus, residents of tram cities are presumably influenced by availability heuristics. Affect heuristics reflect whether a concept is liked or disliked.

For the case of bus and tram this might explain why a tram is preferred to bus. Representativeness heuristics, and hence prototype heuristics are explanations of the relationship of expected benefits and a specific public transport system such as the relationship between reliability and punctuality and a tram system.

As a consequence, understanding prototype heuristics requires the knowledge about a prototype of a specific concept. These prototypes, also understood as mental images or schemata, are an important component of this dissertation (compare chapter 4.5.2 and chapter 6).

4.5 Cognitive elements of public transportation

Derived from the extended framework of Ben-Akiva et al. (1999) (compare 4.2.3), indicators for different cognitive elements are evaluated and discussed in the context of bus and tram. The following categories are summarized:

1. Perception, Salience and Affordances
2. Memory representation, images, schemata and prototypes
3. Attributions as basis for images
4. Impacts on attributions

These aspects are implied in different types of heuristics and affect in a combined way the preference of bus or tram and behavior towards these two public transport systems.

4.5.1 Perception, salience and affordances

Perception is here understood as awareness of elements of the environment (without any valuation). Individuals are very sensitive to salient factors in picking up information (compare availability heuristics). **Salience** refers to the property of a stimulus that attracts attention and is one way that individuals encode and value subjects in their environment (e.g., Fiske and Taylor 1991, Hogg and Vaughan 2008). Salient factors in public transport are:

- **Novelty:**
  A newly implemented transport system
  New vehicles
  New real-time information displays
  New destinations served
- **Visual design:**

Special design of vehicles
Design of stops
Bright colors

- **Visual dominance:**
  Visibility of routes due to tracks or dedicated lanes
  Visibility of stops
  Visual dominance due to high frequency
- **Presence:**
  Strong media presence
  Image cultivated through media (Gegner 2007)
  Repeating public discussions on public transport projects

Different judgments of a public transport system can be the consequence of the perception of these salient effects. Public transport systems seen as a sum of single elements with different salient attributions attract people's attention differently. For instance, a tram system may gain more attention because of a higher number of salient attributes, e.g., due to visual dominance, new (eye-catching) modern vehicles, and numerous articles in newspapers during the decision-making and construction period. The presence of salient factors may evoke the belief that tram is more important, more exclusive, or just captures individuals' attention. Higher salience also refers to increasing awareness of a public transport service and hence might lead to new ridership.

The concept of **affordances** developed by Gibson (1986) is an ecological approach to perception and is based on the assumption that the visually perceived information of an object is what we normally pay attention to. In contrast to a psychological view of an object that is composed of its qualities, Gibson states that it is not the combination of qualities of an object that we perceive, but its affordances. Applied to tram, for instance, the tracks afford individuals the ability to look for the next stop, a vehicle affords public transport customers the ability to board and conduct other activities during the ride (Lyons and Urry 2005) and the interior of a vehicle may have empty seats that afford passengers the opportunity to sit down.

4.5.2 Memory representation, schemata and images as prototypes

Categorical perceptions, also known as schemata or mental images, are concerned with generic knowledge about a subject. This knowledge can be used for (prototype) heuristics in order to reduce cognitive effort. The central tendency of an average category representative is a prototype, called a stereotype when applied to individuals. Dziekan (2008b) investigated the memory representation of public transport in Stockholm. According to her results, public transport lines are easier to retrieve from **memory** (compare availability heuristics) if they:

- Are more visible on urban streets
- Operate on main streets
- Are labeled

Applied to trams and buses, the decisive factor is the visibility of routes, and, in specific cases, the routing along main streets. This is especially the case for trams operating in pedestrian zones where buses are not permitted. Interestingly, not only was the route knowledge of the study participants remarkable, so was the estimation of service frequency by the respondents.

The ways in which people perceive and value a product or service are called attributions. A combined set of attributions forms a mental image of the product or service. Attributions can be organized into categories in order to develop a **schema**. Schemata or mental images are organized packets of information about the world, events or people, stored in the long-term memory. They include what are referred to as scripts and frames.

A script has a dynamic nature that is based on changes over time and describes processes. Scripts deal with knowledge about events and consequences of events. The classic example is a restaurant script that contains information about the usual sequences of events involved in having a meal at a restaurant. The public transport script contains information about the usual sequences of events involved in using public transport: collecting pre-trip information (e.g. departure times and stop locations), way to stop, ticket purchase, waiting, boarding, traveling, recognizing where to alight, signaling the wish to alight, alighting, way to final destination.

By contrast, frames are knowledge structures relating to some aspects of the world (e.g. buildings) containing fixed structural information (e.g. has floors and walls) and slots for variable information (e.g. materials from which the building is constructed) (Eysenck and Keane 2005). A bus frame would for instance include fixed structures like the shape of the vehicle, and the kind of entrance would be a detailed variable information in this frame.

The schemata approach is an appealing way to investigate and describe different attributions to tram/trains and buses as already shown by Megel (2001). She developed a prototype for "rural transit" and its subcategories "train ride" and "bus ride" with corresponding attributes. Analyzing cognitive structures such as schemata is important to understand human behavior. As introduced with the dual process theory, abbreviations such as mental images that allow for heuristics save cognitive resources and are activated for a majority of decisions.

An **image** as a picture in mind and the attributions of this picture are a combination of perceived attributes and beliefs respectively subjective meanings of these attributes. In Cain et al. (2009), image is defined as *"the set of ideas and impressions, both rational and emotional, which major stakeholders form about [an] organization or industry"* (Cain et al. 2009, p13). Thus the image of a public transport system is composed of attitudes and perceptions of public transport users and the general public.

4.5.3 Attributions as basis for images

Attributions to public transport are important; they form the perception of a public transport mode and the image of different public transport modes. Both perception of public transport service quality and public transport attributions have been prominent issues in transportation research, especially research oriented towards shifting automobile drivers towards public transport. Investigation of perception and attributions is usually based on qualitative research such as focus group discussions and semi-structured interviews. Several important studies considering attributions towards public transport modes are outlined in chapter 2.

Negative attributions towards a transit mode result in a poor image of this mode. This can be shown with the psychological model of barriers to train use developed by Dziekan et al. (2004). They found that barriers to train use are higher when this mode has negative attributions. However, the influence of attributions to transit modes on travel mode choice has not been proven by scientific studies so far. But it is important to know more about the quality of the attribution in order to investigate their influence on intended behavior.

A key problem with using attributions to investigate mode choice decisions is that many studies do not distinguish between public transport modes (e.g. Wirthlin Worldwide and FJCandN 2000). Nevertheless, some recent studies have made a differentiation between various bus and light rail modes.

4.5.4 Impacts on attributions

How people think about other people/subjects is culturally bounded. Culture is understood here as a set of learned and shared beliefs and behaviors that are representative for a group (e.g., Hogg and Vaughan 2008). It is not surprising that the application of this assumption to the perception of bus and light rail systems contributes to the explanation of the different findings in North American and European studies investigating a potential rail factor.

Beliefs about a specific concept (constituted by several elements) are expressed here as the conviction of the mind, arising from

- Evidence received e.g. through personal experience
- Information derived from secondary sources.

Thus beliefs are seldom from actual perception by our senses, but from knowledge/experience and hence an interpretation stored in our memory that can be retrieved easily. Beliefs can be interpreted as processed and categorized perceptions and consequently a valuation of a concept. A combination of beliefs that are concerned with generic knowledge about a subject is known as a schema.

Habits are structures derived from experience of repeated actions. There are different strength of habits what influences the need for cognitive effort. As noted in the dual process theory and the schema concept, individuals tend to take cognitive shortcuts whenever possible. Considering mode choice and travel behavior the effort can be reduced in minimizing information needed for a specific travel decision. Strong habits allow for making decisions based on a small number of pieces of information. Individuals with strong habits for a certain transport mode are more likely to choose the habitual mode whereas individuals with weak habits tend to have a higher cognitive effort to take a mode choice decision because they consider a greater amount of information and balance the arguments out.

Aarts and Dijksterhuis (2000) describe habits as a form of goal-directed behavior and they conclude that goals are capable of activating a habitual action. Habit strength was measured by respond latencies of the study participants. Regarding transport behavior, frequent use of a specific transport mode enables users to relate their goals with this mode. This leads to an increase of habitual action for similar goals, which allows the establishment of a link between past behavior and future behavior.

Verplanken et al. (1998) measured habits with questions about the first transport mode that the respondents had in mind for specific origin-destinations. In cases where behavior is habitual for an individual, this person is more likely to behave in accordance with this habit for similar decisions. This depends on the strength of a habit. As Verplanken et al. (1997) show, someone who has a strong habit of using a specific transport mode will search for less information about other transport alternatives given the opportunity because he or she is more likely to focus on information about habitual choice.

Public transport users cannot be divided into bus or tram users because they usually switch between these modes depending on their destination. Public transport in Swiss cities is bus-based and in the biggest cities tram service constitutes the backbone of the public transport service on main intra-city relations. As a consequence, habits are related to public transportation in general rather than to either one of the two modes, bus and tram. Nevertheless it is of interest that people having weak habit strengths might be influenced to change their travel behavior towards public transport.

4.6 Conclusions

To explore the differences in preferences towards bus and tram, cognitive approaches are most promising. Understanding how individuals perceive different transport systems, how they process information and to what extend this finally impacts mode choice behavior is considered to be fundamental for the explanation of a rail factor.

Attributions are therefore the basis. They constitute schemata or images that are applied as heuristics in a decision making process. However, these attributions and impact factors on attributions such as beliefs and habits can be applied in different behavioral and economical concepts. The extended framework proposed by Ben-Akiva et al. (1999), for instance, considers various cognitive impact factors on transport demand.

Attributions and the exploration of cognitive structures that might be the source of a rail factor are a necessary basis for further investigations. As a consequence they will be explored in depth. Therefore the focus lies on attributions that are used in heuristics because this path of process information is expected to have more weight in mode choice decisions.

Mode choice can be processed on both ways, the intuitive way by using heuristics for everyday situations and the way of reasoning when decision making requires considerations to balance the reasons for instance when thinking of investments in buying a car or an annual public transport card. Against this background, the dual process theory and the concept of goal framing have to be discussed. It emerges that the role of normative beliefs or normative goals that are considered to be constituted by reasoning and require a high cognitive effort might have a less prominent impact on mode choice than expected.

5 ATTRIBUTES OF BUS AND TRAM

LRT has compared to BRT "a much stronger image, passenger attraction and positive impacts on the city"
Vuchic 2005, p588

In the following chapter relevant facts and key figures of the attributes presented in chapter 2.2 are quantified and compiled for the case of Switzerland. The focus lies on attributes under Swiss conditions and data is deduced wherever possible from Swiss case studies.

This chapter is partly based on the working paper:

Scherer, M. (2010b) Tram or Bus: Analysis of revealed preference data, workingpaper, Institute of Transport Planning and Systems (IVT), ETH Zurich, Zurich.

5.1 Attributes and case study areas

5.1.1 Attributes of bus and tram

The first step in the investigation of preferences and behavior towards bus and tram consists of the analysis of attributes towards bus and tram. Therefore the following attributes of bus and tram (compare chapter 2) are quantified for specific cases of Swiss cities.

- Vehicle: Attributes that are related to the vehicle itself and aspects that affect the user during the ride. This includes design and size of vehicles and capacity and loading.
- Driveway: Aspects of the guideway, right of way and traffic conditions.
- Service characteristics: service aspects including timetables, stop distributions, travel speed and tariff.
- Environmental impacts: Energy consumption, pollution and noise emissions.

As available data often distinguish between trolleybus and dieselbus, this distinction is adopted for the comparison of attributes of bus and tram because of capacity considerations and required energy. In the case of cities trolleybuses are articulated and double-articulated vehicles and have therefore a higher capacity than standard dieselbuses. This allows for better comparison of bus and tram regarding capacities of vehicles. Furthermore, considering trolleybuses enables a direct comparison of energy consumption due to the same power supply.

5.1.2 Overview of case study areas

In Switzerland, four cities are served by several tramlines. These are Zurich, Berne, Basel and Geneva. Since Basel and Geneva are located at the border with Germany and France, there are many transport interrelations crossing the border. But since international urban public transport has just started to improve services across borders, there are still many different transport cultures that influence mobility behavior in these areas.

Finally, Berne and Zurich are chosen as case cities, because effects of international commuters can be neglected. Both cities have had tram services for over 100 years. Some tramlines have been replaced with buses and a few new lines are under construction. The two cities are of national and international importance and have a high transport demand. They are chosen in order to investigate the perception and behavior in the city itself but also to allow comparisons with each other. Table 7 shows key data of the two case cities and the third city, Lucerne, that has no tram services and serve as control group.

Table 7 Key data of Berne, Lucerne and Zurich

	Berne	Lucerne/Agglomeration	Zurich
Area (km^2)	51.6	29.1/154	91.9
Population density (persons/hectare)	25.1	20.4/10.7	41.4
Inhabitants (2010)	131’702	77’491/ 192’104	385’468
Jobs (2008)	152’645	62’997/ 108’815	362’002
Public transport mode split (commuters)	53.9%	45.8%/36.4%	45.6%

Source: Statistisches Amt des Kantons Zürich 2012, Statistikdienste Stadt Bern 2012, Amt für Statistik Luzern (LUSTAT Jahrbuch 2010)

5.1.3 Public transport service in case cities

Berne

Urban public transport in Berne is based on bus, trams and commuter trains (S-Bahn). Buses are the backbone of the urban public transport system. Six main buslines and 9 additional buslines serve the city centre. Additionally three tramlines are operating and one tramline was under construction until December 2010. The urban public transport network consists mainly of through lines that serve the main station.

The main frequency of the urban public transport is 6 minutes. Several bus lines operate more often due to capacity reasons. Bernmobil is the main public transport operator in the agglomeration of Berne. Three tramlines in Berne will be analyzed because data for the new tramline is not available yet. The bus network is divided in main lines and other lines. Main lines operate with high capacity buses (articulated buses) where some are electrified (trolleybuses). In order to compare high quality and also “similar” capacities, only bus lines of the main line will be considered.

Zurich

Urban public transport in Zurich comprises all variations of buses and trams and commuter trains as well (S-Bahn). The city area is served by 13 tramlines (one of them is connecting the airport outside the city) and by 7 main bus lines and additional bus lines. All tramlines serve the city center (at the main station) or are routed close to the center as almost through lines (lines 2,5,8,9). The main bus routes do not serve the main station, except the through line 31 and the radial line 46. The route of bus no. 32 is close to the city center and serves different densely populated areas. These three lines are served with articulated and double-articulated buses (trolleybuses). The other main bus lines are tangential lines.

In 2009 the main frequency of urban public transport was 7.5 minutes. Buses on main routes have partly different headways depending on capacity requirements.

There is one single transport operator who is responsible for the urban public transport within the cities boundaries, the VBZ (Verkehrsbetriebe Zürich). The operator is part of the city council. Decisions regarding the transport service have to be approved by the ZVV (Zürcher Verkehrsverbund), the transport council management that is responsible for the strategic marketing, transport planning and financing of the transport offer in the canton and on routes crossing the cantonal boarders.

Corridors of interest that allow comparison between tram and bus comprise on one hand the tram corridors of the lines 2, 13 and 14 (without considerations of the new extension to the airport) and the bus corridors of the following bus lines: line 31, line 46 (both serve the main station). Line 32 offers services for a neighborhood (Affoltern) with connections close to the city centre. Line 31 runs partly parallel to tramline 2. Therefore a direct comparison will be considered. Similar conditions are found for bus line 46 and tram line 13. Many sections of the tram corridors are served by more than one tramline. This has to be taken into account when comparing quality of services.

Lucerne

The public transport network is radial from the train station; four bus lines are through lines, which connect to different areas on both shores. Busline 1 serves the axis from Kriens to the Northeastern fringe of Lucerne and Busline 2 serves the axis from Emmen (in the North of Lucerne) to the city center. These are the major routes with very high demand and are served with articulated and double-articulated buses (trolleybuses).

The main transport operator in Lucerne is the Verkehrsbetriebe Luzern (VBL). The public transport service of the VBL AG serves 307 bus stops with 18 urban bus routes. Additionally to the bus service provided by the VBL there is the S-Bahn serving 8 stations in the agglomeration of Lucerne.

5.2 Vehicles

5.2.1 Design

Tram and bus vehicles are manufactured in various designs. There are visible differences between bus and tram vehicles. The design of buses tends to be rather square compared to the latest tram vehicles, which are often gently curved. This is, however, a matter of design and depends on the manufacturers and the requirements of the public transport operators. In Swiss cities, public transport vehicles have a corporate design including city specific colors for the vehicles (depending on the public transport operator or the public transport association) independent from the kind of vehicle or system. In Zurich for instance, urban public transport means are colored in blue/white (compare Table 8), those in Berne in red and in the city of Basle in green/yellow.

5.2.2 Size

The dimension of the vehicle is predefined by the width of the streets or driveways and varies in length. Considering the capacity of bus and tram, a tram vehicle provides more seats than the biggest bus operating in Switzerland (double-articulated (trolley) bus). The main reason is that the length of trams is double the length of a bus. The maximum length of operating (double-articulated) buses is about 25m, and the length of conventional articulated buses is about 17m. In contrast to this, a tram with a trailer has a length of about 35m to 40m (compare Table 8). This is possible due to rail-bounded vehicles that follow rules other than street based rules.

Table 8 Average size and number of seats of selected bus and tram vehicles in Zurich

			Width	Length	No. of seats
Buses		Double-articulated trolleybus	2.5m	24.7m	62
		Articulated-trolleybus	2.5m	17.4m	45
Trams		Mirage (double)	2.2m	34.5m	2x47
		Tram 2000 (double)	2.2m	41m	2x50
		Cobra	2.4m	35.9m	90

Source: VBZ webpage (www.vbz.ch), 16.5.2010

5.2.3 Comfort-oriented capacity

The total numbers of seats and standing places of bus and tram vehicles are listed in Table 9. Since there are remarkable differences in standing places depending on the source of information, the writer's own calculations were made for the comparison of standing places. Therefore a comfort-oriented capacity serves as a basis. To define the comfort-oriented number of standing places in the vehicles dedicated standing areas have been marked and measured in the vehicle schemes. In cases where the distance between seat rows is smaller than 60cm, this space is considered as transit area and not as dedicated area for standing. Furthermore a distance of 15cm is considered towards fixed installations (e.g. seats, windows, doors). The following comfort criteria have been applied for the capacity calculation in Table 9:

- Only easily accessible areas are taken into account (according to VDV 2001). More precisely: Dedicated standing areas are mainly located close to doors and in the area of the articulations. In cases where there is 2x2 seating, the gangway is not considered as a standing area.
- Distances of min. 15cm towards seats, walls and other fixed installations are respected.
- 3 persons per m2 standing area serve as basis for the calculation of the standing places.

Table 9 Comfort-oriented capacities of bus and tram vehicles

Vehicle	Standing area (m2)	Seats	Standing places	Total
Double articulated trolley bus	14	62	42	104
Articulated trolley bus	10	45	30	75
Cobra	24	90	72	162
Tram 2000 (x2)	12 (24)	50 (100)	36 (72)	86 (172)

It can be seen that all trams provide more seats than buses. With regard to standing areas trams provide more space for passengers; hence, trams can accommodate more passengers standing. Briefly, trams provide higher capacities when comparing bus and tram on the level of absolute numbers based on a vehicle.

5.2.4 Relative capacity

Switching the level of comparison from absolute to relative numbers, the findings change. Table 10 shows the relative capacity per meter length of the vehicle. This allows for objective comparison of the different modes of public transport. Buses have a slightly higher share of seats than trams (1.5 compared to 1.3). All vehicles analyzed provide about 2.5 seats per m length of the vehicle (+/- 0.2). Regarding standing places, there is slightly less space for standing per m length in buses compared to trams.

One tram type has a higher relative capacity than buses. A Cobra carries 4.5 passengers per m length compared to 4.2 passengers that can be carried by buses on an equal comfort-oriented basis. The main reason for this is the high share of areas for standing, wheelchairs and strollers in a Cobra tram.

Table 10 Relative capacities of bus and tram types per meter length

Vehicle	Ratio seats/ standing places	Seats per m	Standing places per m	Places per m
Double articulated trolley bus	1.5	2.5	1.7	4.2
Articulated trolley bus	1.5	2.6	1.7	4.3
Tram 2000 (x2)	1.3	2.3	1.8	4.1
Cobra	1.3	2.5	2.0	4.5

Considering relative capacities per length of the vehicle, bus and trams provide an equal number of places. In contrast, tram vehicles can accommodate 50% more passengers than a double-articulated bus and double the number of passengers of a conventional articulated bus.

Against this background it is explicable that both public transport modes may be perceived to provide more space. It strongly depends whether one has a new tram (Cobra) in mind or an older one. In the later case buses can account for more relative places/space. Further possible reasons for higher capacities are the arrangement of seats (single seats in order to get standing areas between rows), and the higher width of the Cobra tram compared to the old trams.

5.2.5 Load factor

Perceived space in a vehicle is influenced by the loading condition in the vehicle. Hence, a crowded vehicle is perceived differently to an empty one. Therefore average loadings of bus and trams are considered. Table 11 shows data on average loadings of selected bus and tramlines in Zurich between two stops. The average demand per stop and line for each course serves as input. The calculation of average loadings is then based on comfort-oriented capacities dependent on the respective operating vehicle or mix of vehicles.

$$Loading = \frac{Passengers}{Capacity}[\%] \tag{2.1}$$

Loadings on a daily demand basis lay for the selected bus and tramlines between 25% and 32%. The higher value for bus line 32 is expected to decrease with the introduction of new vehicles (double-articulated buses instead of articulated buses). Assuming stable demand and increased vehicle capacities the values of bus line 32 will decrease towards a comparable level with other lines considered. Regarding average loadings in peak hours, the range is between

43%-65%. The maximum load factor between two stops on a line lies between 40% and 60% during the day and the maximum load factor between two stops in peak hours is between 75% and 97%. Whereas there is a remarkable variation among loadings on buslines, the variance within tramlines is smaller.

Table 11 Load factors of selected buslines and tramlines in Zurich 2009

Line		Average loading (%)		Max. loading (%)	
		Per day	Peak hour (main direction)	During day	Per day
Buses	31	26	43	42	75
	32	32	43	60	78
	46	27	65	40	91
Trams	2	29	54	42	85
	13	25	54	44	97
	14	26	43	42	75

Source: VBZ, Demand data 2009

The observed variance of load factors depends on the routing of the line, and hence the areas they connect. Tramline no. 13, for instance, connects the central business district along the Bahnhofstrasse (important shopping district) with the main station. This highly demanded route results in high loadings. Similarly, bus line 46 connects the main station with a densely populated residential area. Hence it is highly loaded with commuters in the evening peak hour. As a consequence, both lines, one served by bus the other by tram, are highly demanded and loaded.

Besides the highest average loading, the knowledge about the duration of crowding along the ride is of interest. A vehicle is here defined to be crowded when the load factor exceeds 50%. The duration of crowding is then expressed as total number of stops of a line that are served with crowded vehicles.

$$Crowding \cong Loading \geq 50\% \tag{2.2}$$

Table 12 presents the number of stops served by crowded vehicles and the percentage of crowding on the whole line on a peak hour basis. Depending on the number of stops serving the city center area, more stops tend to be served by crowded vehicles. The crowded vehicles correspond mainly with the city center area.

Depending on the line length, the routing through the city center area and the spatial characteristics of the areas served, differences between crowding on the investigated lines can be seen. Whereas e.g. bus line 46 is crowded on 78% of the line length, on bus 32 this is the case on 28% of the line length. The ratios for crowding are between 35% and 67% on the tramlines. The duration of crowding during a ride is expected to influence passengers' perceptions of service conditions. Travelling every day in a crowded bus for most of the ride may result in the (subjective) assumption that buses are generally more crowded than trams. However, this depends on personal and local circumstances and cannot be generalized for one or the other public transport mode.

Table 12 Duration of crowding Zurich 2009

	Line	Number of stops served with crowded vehicle	Ratio (stops served with crowded vehicle/ total number of stops)
Buses	31	13	0.48
	32	7	**0.28**
	46	14	**0.78**
Trams	2	16	0.67
	13	16	0.55
	14	9	0.35

Source: VBZ, Demand data 2009

The previous analysis was based on data of the entire line. This raises the question of whether there are differences between parts of lines where bus and tram run parallel. In this case is one line/mode higher loaded than the other? The line segments considered in Table 13 have parallel stop distances of less than 600m.

Table 13 Average load factor on parallel segments

Line: segment (mode)	Average load factor per day	Average load factor in peak hour
2: Farbhof – Stauffacher (tram)	32%	62%
31: Farbhof – Sihlpost (bus)	34%	59%
13: Winzerstrasse – Wipkingerplatz (tram)	17%	36%
46: Segantinistrasse – Rosengartenstrasse (bus)	28%	73%
14: Heuried – Werd (tram)	26%	41%
32: Friesenberg – Kernstrasse (bus)	29%	42%

As it can be seen, differences between load factors of lines running parallel are small. The exception is bus line 46 that has twice the load factor than tram 13 on the parallel segment. One reason for this is that the area around the final station of the bus is more densely populated than that of the tram and hence the bus is already more highly loaded on the subsequent segment compared to the tram. Regarding loading, crowding and comparison of parallel segments of bus and tram there are no remarkable differences between bus and tram on the investigated lines. The finding that lines are rather crowded in the city centre area, which is primarily served with tramlines is not surprising. Considering the high demand on bus line 46 crowding is correlated with residential density and with central areas in the city. Whereas residential density affects mainly the line serving this area, attractive city center destinations affect several public transport lines.

These findings are based on local conditions for Zurich and serve as an example for local comparison of demand on bus and tramlines. Although urban public transport is organized similarly in other Swiss cities it is not possible to generalize these findings for Switzerland. Demand, capacities depending on timetables and the respective public transport fleet, and specific local conditions have to be considered when comparing demand in other cities.

5.3 Driveway

5.3.1 Regulatory framework

Considering the different guideway characteristics of bus and tram gives first clues about the source of perceived differences between these two transport means. As presented in Table 14 tram and bus are treated differently regarding traffic laws.

The qualitative comparison of the regulatory framework for bus and tram leads to the conclusion that a tram gets a preferential treatment regarding traffic laws, especially considering the right of way. Although some of the arguments, such as their own lanes, could also be realized for bus services, the state-of-the-art is that buses and trams are treated differently, in favor of trams.

Table 14 Traffic regulations of bus and tram in Switzerland

	Tram	Bus
Specification in the transportation law	Strassenverkehrsgesetz: SR 741.01 Art. 38 1 Der Strassenbahn ist das Geleise freizugeben und der Vortritt zu lassen. (Right of way for tram)	Signalisationsverordnung, Art. 34 1 Das Signal «Busfahrbahn» (2.64) zeigt eine Fahrbahn an, die für Busse im öffentlichen Linienverkehr bestimmt ist und die andere Fahrzeuge nicht benützen dürfen; auf Zusatztafeln vermerkte Ausnahmen bleiben vorbehalten. (Dedicated bus lanes where signalized)
Right of way towards pedestrians	Yes	No
Right of way towards car traffic	Yes	No
Prioritization at traffic lights	Mostly	Partly
Dedicated way	Wherever possible	Segmental, wherever needed and feasible (e.g. short bus lanes before traffic lights)
Mixed use of dedicated way allowed?	Rarely. Sometimes for security services allowed.	Partly allowed for bicycles and taxis
Operation in pedestrian areas	Often	Rarely

5.3.2 Dedicated way/mixed traffic

The analysis of the length of dedicated ways for buses and trams in case cities leads to the data shown in Table 15. Considering only the available length of dedicated tramways, the share of dedicated ways on the public transport network is higher than 18% in the city of Zurich. In contrast, Lucerne and Berne have shares of dedicated ways of 7% and 9%. There is a tendency of higher shares of dedicated tramways compared to dedicated busways. However, this depends not only of the public transport system but also on the location within the city area. In highly congested areas in the city centers there are more trams operating than buslines.

Table 15 Estimated length of dedicated ways for bus and tram

City	Total length public transport network (km)	Dedicated way tram (km)	Dedicated busways (km)	Share of dedicated ways on the public transport network
Berne	95	1.75	6.67	9 %
Lucerne	59	-	4.20	7 %
Zurich	185	33.20	12.5[1]	>18 %

Source: Weidmann et al. 2011, Table 44
[1]*Hass-Klau et al. 2003, p48*

5.3.3 Priority at traffic lights

Allowing for priority at traffic lights reduces waiting times and hence cycle times for public transport. The share of traffic lights which give priority to either bus or tram lines lies, according to Weidmann et al. (2011), between 85% and 95% for the case cities Berne, Zurich and Lucerne. Lucerne and Zurich show similar shares of priority, what may lead to the conclusion that bus and tram cities treat these two systems equally. Nevertheless it has to be considered that buses are more likely to run on streets and crossroads that are not regulated with traffic lights than trams are.

5.4 Service characteristics

5.4.1 Frequency

The average headways of bus and tram services in Swiss case cities are listed in Table 16. The range of headways in off-peak hours is between 5-7.5 minutes for both, bus and tram services. As a conclusion, no significant differences of time dependent availability can be found between bus and tram. The higher frequency of buses in peak hours is often due to capacity constraints. A higher frequency is usually necessary to cope with the peak hour demand. Furthermore, it has to be noted that no local and regional buses are included in this overview since they have a different function than city buses and trams and therefore they have a lower frequency.

Table 16 Comparison of average headways 2010

City	Tram (minutes) off-peak/peak hours/Sundays			Bus (minutes) off-peak/peak hours/Sundays		
Berne	6 /	6 /	7.5-10	5-7.5 /	3-6 /	7.5-10
Lucerne			-	6-7.5 /	5-7.5 /	10
Zurich	7.5 /	7.5 /	10	7.5 /	5-7.5 /	10

Source: Timetables 2010

5.4.2 Stop distribution

Stop distribution depends on spatial characteristics and the underlying transport network. According to the law, there are minimum standards for distances to a stop of public transport. For urban areas in Switzerland, a maximum of 400m walking distance from any location to the next bus or tram stop is required by respective cantonal laws. Due to mostly radial public transport networks, these distances are usually shorter in city centers. According to a study conducted by Umverkehr (2006) the average walking distance to a bus/tram stop for the three cities Berne, Zurich and Lucerne is 150m and less. This average distance is computed by dividing the area of the city with the number of public transport stops within this area. Since bus and tram services are treated similarly there are no differences in stop distributions between bus stops and tram stops.

5.4.3 Speed

Average speed of bus and tram lines is, apart from traffic conditions, mainly influenced by the distance between stops and the stop duration what is given by the number of doors and number of passengers boarding and alighting. Since stop distances are similar for bus and tram in Switzerland, there are no significant differences in average speed between bus and tram. Hass-Klau et al. (2003) found for the special case of Zurich, that trams tend to be slightly slower than buses (16.7km/h vs. 17.8km/h) due to shorter stop distances. Comparing usual distances between two stops in Swiss cities (ca. 350m) with those of German cities (500m), higher travel speeds are assumed for German bus and tram systems.

5.4.4 Tariff

Public transportation in Switzerland is integrated in tariff systems. This allows the usage of all public transport services within a dedicated area with the same ticket. This means that there is no difference in ticketing procedures and costs for passengers when using bus or tram.

5.5 Environmental impacts and energy consumption

In the following subsections selected attributes of bus and tram that affect the environment are presented based on the Econinvent Database (Spielmann et al. 2007). As diesel buses, trams and trolleybuses have different sources of energy, this aspect is difficult to compare. Furthermore the focus lies not only on the environmental impacts of operation of public transport service, although this is the main contributor to pollution, but also on the maintenance of vehicles and the infrastructure for bus and tram are considered.

The comparison of environmental impacts of bus and tram based on a life cycle perspective would also comprehend the manufacturing and disposal process of the vehicles. These aspects exceed the scope of the present study and are therefore neglected.

5.5.1 Operation of bus and tram

The data on public transport operation in Table 17 shows that, depending on the measurement unit and the variable, none of the three public transport systems is superior to the others. Considering e.g. the specific energy consumption per vehicle-km, a trolleybus is more efficient than a tram. This picture changes when average loadings are applied. On a passenger-km basis a tram has lower energy consumption due to higher average ridership (and capacity). However, the loadings of bus and tram vehicles differ across cities, daytimes and lines. Thus it does not allow for direct conclusions for the "better" public transport system regarding environmental impacts of bus or tram operation. A trolleybus accounts for less energy consumption per passenger on a route with high demand than a tram on a route with low demand.

Table 17 Comparison of selected life cycle inventory components of operation of average Swiss tram, trolleybuses and dieselbuses

		Tram	Trolleybus	Dieselbus
Energy consumption	Specific energy consumption per vkm:			
	Electricity, medium voltage at grid	4.55 KWh	3.04 KWh	
	Diesel, low-sulphur, regional storage			349.8 g
	Specific energy consumption per pkm:			
	Electricity	0.09 KWh	0.12 KWh	n.a.
	Diesel			
Emissions to air	Particulates>10um[1] per vkm	4.56 E-4 kg	4.24 E-4 kg	5.66 E-5 kg
	Particulates >2.5um <10um[1] per vkm	8.13 E-4 kg	7.08E-5 kg	6.16 E-5kg
	Particulates <2.5um[2] per vkm		3.0E-5 kg	4.44 E-4kg
	Heat/waste per vkm	1.71E+1 MJ	1.09E+1 MJ	1.58E+1 MJ
	CO_2-emission per vkm			1109.6 g
	SO_2-emission per vkm			3.5 E-2 g

Source: Ecoinvent Database, Report no 14: (Spielmann et al. 2007: p28, 51f)
[1]Abrasions emissions (tyre wear, break wear, road surface (for bus))
[2] Exhaust- and abrasions emissions

5.5.2 Maintenance of vehicles

The maintenance of vehicles is a point that is often neglected although it affects the environment. Data presented in Table 18 is based on the following assumptions regarding the life span of a vehicle: 12.5 years (regular bus), 17 years (trolleybus), 30 years (tram) (Source Ecoinvent report no. 14, p66ff, Spielmann et al. 2007). Regarding maintenance of vehicles, different factors are considered for bus and tram. Hence it is not possible to compare these systems directly among these factors.

Table 18 Comparison of selected life cycle inventory components of maintenance of average Swiss tram and buses

Components		Tram	Bus
Electricity	KWh/(vehicle*a)	5’426	5’426
Natural gas	MJ/(vehicle*a)	2’580’000	3’230
Light fuel oil	MJ/(vehicle*a)	2’580’000	3’230
Water consumption	m^3/(vehicle*a)	39	39
Lubricating oil	kg/(vehicle*a)		66
Cooling agent	kg/(vehicle*a)		1
Sand	kg/(vehicle*a)	3’488	

Source: Ecoinvent Database, Report no 14: (Spielmann et al. 2007: p28, 51f)

5.5.3 Noise

Noise emissions from public transport vehicles have several sources. A new diesel bus with an engine performance > 150kW is expected to have a maximal noise emission of 77dB(A). This value can be reduced with special tires to 71 dB(A). Considering trolleybuses, the noise emission is significantly smaller compared to diesel buses due to the electric traction. Since buses usually operate in mixed traffic, the noise emissions of buses are hard to separate from those of car traffic. Driving behavior is one of the main impact factors that influence the noise level of a bus.

Regarding tram vehicles, the following sources have an impact on the overall noise emission:

- Wheel-rail emissions (rolling noise)
- Noise in curves
- Engine noise
- Noise of further installations

The rolling noise and noise in curves in particular contribute mainly to the noise emission of a tram. The resulting noise emission depends on the vehicle condition (wheels and vehicle itself), the condition of tracks and the speed of the vehicle. Average noise emissions (in Switzerland) are between 90dB(A) and 100 dB(A) for vehicles with a running speed of 20km/h and between 100dB(A) and 110 dB(A) for vehicles with a running speed of 40km/h (Bayer 2005).

Buses in general and trolleybuses in particular have lower noise emissions than a tram. In contrast to noise emissions of trams that contribute to a higher noise level of traffic, noise emissions of buses are expected to be ignored in the overall noise emission of traffic.

5.6 Conclusions

Service elements depend mostly on characteristics of the location, such as residential density, space, funding etc. Nevertheless some differences that are related to the respective public transport system are established. Not surprising, the capacity is higher for tram vehicles and hence, due to the longer vehicles, there is more space in the vehicle. Considering relative capacities, there are no significant differences between buses and trams. The same findings result from comparisons of loadings on various bus and tramlines.

The discussion about space and seats is not closed. The personal impression of whether a vehicle is crowded or provides enough space is subjective. For this reason how people perceive these situations and if their personal image of a transport system can be generalized is still of interest. The question remains what service elements impact on personal views of a specific public transport system.

One aspect that was not investigated in depth is attributions of the guideway. The comparison of how bus and trams are treated effectively against the background of traffic laws shows that trams receive preferential treatment on streets, which may lead to higher appreciations of passengers. It is supposed that this aspect is one of the most important of schemata of public transport systems.

Aspects of environmental issues show an indifferent picture for tram and bus. Depending on the basis for comparison one or the other transport mode has lower energy consumption. However, considering noise emissions, buses and especially trolleybuses are found to have lower noise emissions compared to a tram.

6 Perception and Preferences regarding bus and tram

To understand preferences, then, we need to understand the psychology of emotions. (…)
Some choices are not appropriately sensitive to variations of quantity and cost –
and are better described as expressions of an affective response
than as economic preferences.
Kahneman (2003) p1463

This chapter is based on the following disseminations:

Scherer, M. (2010a) Tram or Bus: Who prefers what and why?, workingpaper, Institute for Transport Planning and Systems (IVT), ETH Zurich, Zurich.

Scherer, M., K. Dziekan and C. Ahrend (2011a) Exploring the rail factor with schemata of bus and rail: Two studies from Germany and Switzerland, paper presented at the 89th annual meeting of the Transportation Research Board (TRB), Washington D.C., January 2011.

Scherer, M. and K. Dziekan (2012) Bus or Rail: an approach to explain the psychological rail factor, Journal of Public Transportation, 15 (1), 75-93.

6.1 Schemata for bus and tram

6.1.1 Introduction

As introduced in Chapter 2, several studies have shown that public transport modes are attributed with different aspects, and accordingly different stakeholders rate transport modes differently. These attributions are not constant over locations and times and depend on existing public transport services. Furthermore, negative or weak attributions have been found to act as a barrier to a specific travel behavior.

Attributions to public transport are important; they form the individual perception of a public transport mode and thus the image of different public transport modes. Perception of public transport service quality and attributions of public transport have been prominent issues in transportation research, especially research that targets shifting automobile drivers towards public transport. Investigation of perception and attributions is usually based on qualitative research such as focus group discussions and semi-structured interviews.

The investigation of how bus and tram are perceived by users and by the general public is in the focus of this chapter. Perceptions are the starting point of attributions that form an image or a schema of a concept. Schemata and image in turn serve as a basis for heuristics. As it is assumed that schemata influence the preference formation, it is of great interest to explore schemata for bus and tram. Differences between these two schemata allow for clues to a theoretical rail factor.

The objectives of the study presented in this chapter are as follows:

- Exploring preferences of residents of different areas of Switzerland, including rural, conurbations and urban areas with and without availability of using trams.
- Identification of reasons for the preferences of bus and tram that will be compared with reasons resulted of other studies and will be used as input for a subsequent survey.
- Construction of schemata for bus and tram based on attributions towards these systems.

6.1.2 Schemata concept

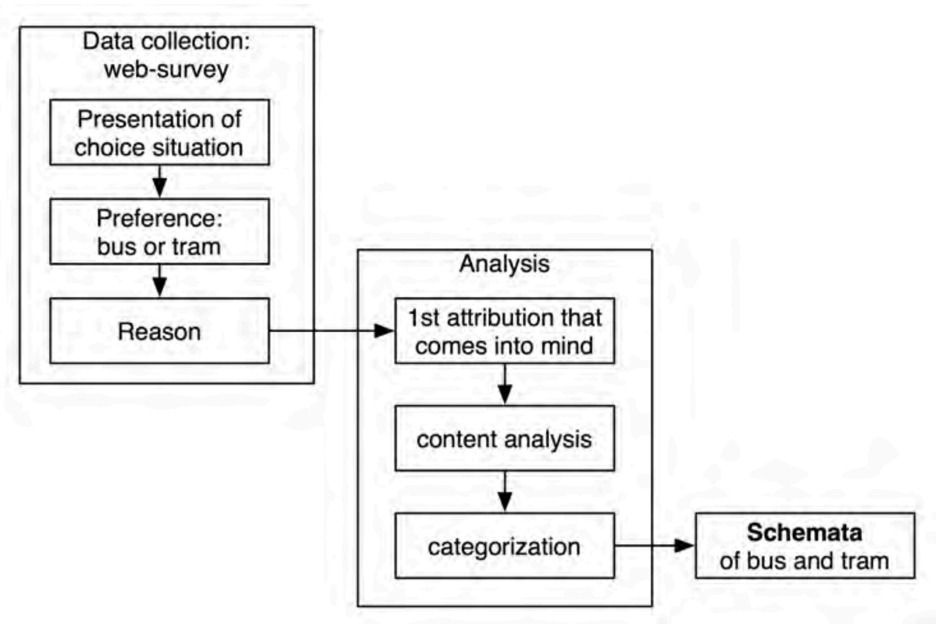
As introduced in Chapter 4.5.2, schemata are organized packets of information about the world, events or people, and they are stored in the long-term memory. Schemata describe more generally a cognitive structure of types of background knowledge that a person brings to any given context, which can be applied as heuristic (compare 4.4.2).

Understanding the schemata about public transport systems provide useful information how people perceive these transport means. The schemata concept was applied by Megel (2001) to investigate regional public transport systems in Germany (compare 2.3.4). Her schemata are built up from attributions towards regional train rides and regional bus rides.

6.1.3 Approach

To create schemata, a collection of attributions towards the specific concept (in this case the specific transport system) is required. Therefore a web-survey was applied to ask for preferences for urban public transport under equal service characteristics for tram and bus and to collect reasons for these preferences (*Figure 14*). When asking someone about the reason for their preference, the first attribution that the respondent has in mind about their choice is considered to be the most important one. As a consequence, the first attribution is used for the constitution of the schemata for bus and tram. Therefore the different attributions are categorized in an appropriate way by applying content analysis (Mayring 1993) and summarized in order to show the composition of schemata for bus and tram.

Figure 14 Approach to construct schemata of bus and tram



6.2 Data

6.2.1 Target group

The target population of this study is Swiss residents, living in the German- or French-speaking part of the country. The Italian part was neglected in order to reduce the elicitation effort in a third language. Additionally there is no tram service provided in this region. However, every municipality in Switzerland is served by public transport; mainly by local bus service and often by additional rail service, depending on the geographical location. Urban areas or conurbations are usually served by high quality bus service and commuter rail. The four biggest conurbations – Geneva, Berne, Basel, and Zurich – all have a tram network.

The small size of the country and the high availability of public transport allow the assumption that most of the residents have some experience of public transport in general and tram service in particular. According to the Swiss Federal Office of Statistics (2007, p38) every resident boards a public transport vehicle on average 218 times annually. Furthermore, as public transport infrastructures are subject to public votes among residents of a canton (political district), it is of interest how these residents perceive different urban public transport systems and whether there are differences between perceptions of residents in rural areas and urban areas. The consideration of different geographical regions allows for the identification of reasons beyond those of urban residents.

6.2.2 Data collection

A web-based survey was applied for the data collection. Similarly to the German study (Megel 2001), the survey contained questions in a hypothetical setting, which required a high cognitive effort by the participants. This imagination is mainly influenced by cognitive structures (schema, prototypes and memory representations) that are built up from the experiences, habits, attitudes, etc. of the participants. The respondents were asked to imagine two public transport modes (bus and tram) under exactly the same service conditions regarding timetables and availability, and then to state which mode they would prefer in the given situation. Next, they were asked to provide up to three reasons for their decision.

The questionnaire contained a combination of stated preference questions in an open and closed form. They were attached to a web-based omnibus survey provided by a market research institute (an omnibus is a survey where several different customers can include their questions on the same questionnaire). This is especially convenient for a small number of questions and has the advantage of sharing the costs of sociodemographical data between customers. Due to its characteristics, an omnibus covers respondents who are online at least once a week and are aged between 15 and 75 years.

Due to the omnibus survey, the sample size is guaranteed. A sample size of 500 was targeted to achieve an appropriate confidence interval of less than 5% on a significance level of 5%. The web-based survey was conducted in September 2009.

Prior to the omnibus survey, the questions were tested on a group of 13 persons living in different parts of Switzerland and varying in age, gender and educational level. It turned out that inhabitants of cities without a tram service had difficulties in imagining a situation where they had the choice between two systems. This is a common problem in hypothetical situations. As a consequence, the question was redrafted.

6.2.3 Respondents

Answers and socioeconomic information from 515 respondents were collected. With regard to the spatial distribution, 35% of the respondents live in rural areas; 29% live in urban areas that are served by tram whereas the rest (37%) live in conurbations without tram service. 66% of the respondents own a public transport card (e.g. General Abonnement (GA), Half-fare travel card, Monthly Card). Hence they are regarded as public transport users, in contrast to those respondents without any kind of public transport card.

To allow for conclusions for Switzerland, the distribution of socioeconomics of the sample size was compared to those of the Swiss population. The data was weighted according to the distribution of socioeconomic characteristics of the Swiss population (compare Table 19).

Against the expectation that web-based surveys attract more male than female respondents, the share of women was originally 65%. The weighted dataset accounts for this circumstance and also improves the share of most of the variables towards the average Swiss distribution. Mobility tools (car ownership and PT cards) tend to be overrepresented. However, since respondents show higher values on both transport modes, the expected bias caused by one or the other transport mode is small.

Table 19 Socioeconomic data

Variable	Value	Eff. count	%	Weighted[1] count	%	Ø[2] CH
Gender	Male	181	35.1	274	53.1	49.2
	Female	334	64.9	241	46.9	50.8
Age	0-19	13	2.5	32	6.2	21.2
	20-64	468	90.9	450	87.3	62.2
	65+	34	6.6	33	6.5	16.6
Education	Primary school	44	8.7	56	11.1	~13
	Vocational school	202	40.0	186	37.1	~53
	High school	259	51.3	261	51.9	~34
Public transport usage	PT card	341	66.2	353	68.6	47.6
	No PT card	174	33.8	162	31.4	52.4
Car availability	No car	66	12.9	73	14.3	18.8
	One car	243	47.6	234	45.8	50.6
	More than one car	202	39.5	204	39.9	30.5
Place of residence	Rural	178	34.6	150	29.0	~28.7
	conurbation (without tram)	189	36.7	191	37.1	~38.7
	Conurbation with tram	148	28.7	174	33.9	~32.6

[1] *Differences are because cell counts have been rounded.*
[2] *Source: Swiss Federal Office for Statistics (BFS) and (ARE) 2007*

6.2.4 Data preparation

The answers to the open question about the reason for the decision between bus and tram were categorized. Applying the method of content analysis (Mayring 1993), all answers were analyzed and categorized in pre-defined subcategories of the schemata framework. Megel (2001) used a classification with six categories in her study in regional transportation. These categories served as an input for the development of categories for the current dataset. Reviewing the data obtained for urban transportation, two adjustments were made with respect to quality of service measures that are used in public transportation planning (TCRP 2003).

First, a new category "availability factors" was created. This includes reasons that are not directly related to the mode of transport, such as service coverage, routing, frequency, and existence of a tram or bus service. Second, due to the high numbers of environmental reasons a category considering environmental issues was added. These responses are based on the general assumption that rail-based systems are more environmentally-friendly than bus systems. The resulting categorization scheme contains seven categories and subcategories and is displayed in Table 20.

While categorizing the answers to the open questions the problem of ambiguity of several expressions occurred. This concerned mainly the following expressions: *Ruhig (silent/calm), bequem (comfortable/convenient), sicher (secure/safe), komfortabel (comfortable/convenient), mehr Platz (space/loading).* In these cases the categorization was done by comparison with other reasons named by the same respondent. Then the reason was dedicated to a category that had not yet been mentioned by the respondent. As hardly any security aspects were noted, all notations for sicher/Sicherheit are coded as *safety*. This comes in line with the low level of criminality in public spaces in Switzerland compared to e.g. US cities.

Two agents categorized the attributions according the categorization key (compare Scherer et al. 2011a). An interrater reliability analysis using Cohen's kappa statistic[1] was performed to determine consistency among raters. The degree of categorization agreement (interrater agreement) resulted in $\kappa = 0.852$, which stands for almost perfect agreement. Miscategorizations occurred mostly because of the ambiguous expressions mentioned above.

Based on the assumption that the first answer is highly related to the "picture in mind" that one has when thinking about the preferred public transport mode and in order not to overrate second and third answers, only the first reasons were selected for this analysis. This means that in total, 361 reasons for a tram preference and 113 reasons for a bus preference were analyzed for the case of Switzerland.

[1] Cohen's kappa is a statistical measure to determine agreement between ratings for categorical items and is calculated as follows:

$$\kappa = \frac{\Pr(a) - \Pr(e)}{1 - \Pr(e)}$$

with Pr(a) the relative observed agreement and Pr(e) the hypothetical probability of chance agreement.
$\Kappa = 1$ stands for perfect agreement and $\kappa = 0$ for no agreement among raters.

Table 20 Categorization key

Categories	Subcategory	Examples, major expressions
1 Vehicle characteristics	Seat/space	Spacious interior, availability of seat, more space, less full, comfortable (to sit).
	Boarding	Low-floor, wider doors, easier to board.
	Atmosphere	Modern, new, air-conditioned, better atmosphere, cleanliness, more comfort, quiet.
	Sight	Overview in vehicle, better sight/windows.
2 Attributions of guideway	Reliability	Right of way, own lane, on time, reliable.
	Flexibility	No tracks/wires, flexible routing.
	Ride comfort	Comfortable to ride, less shaking.
	Orientation	Visibility of guideway.
	Safety	Safety, less accidents
3 Availability factors	Service	Distribution of stops, timetable/frequency, operation hours, connections, routing, service information, availability of service.
4 Environmental issues	Environmental aspects	Environmentally friendly, no exhaust, less noisy, energy consumption.
5 Activities during ride	Possible activities during ride	Ability to read or work during ride, bring luggage.
6 Psychological / social factors	Positive feelings	Convenient, better, something special, easier to use, ride pleasure, attractive, relaxed.
	Habit/ knowledge	Habit, practice, nostalgic reasons, familiarity.
	Special connection	Rail fan, job at railway company.
	Socializing	Meet other people.
	Connection to area	More rural, urban feelings.
	Security	Aggressive riders.
7 Other reasons	Contra reasons	I don’t like the other mode.
	Sickness	
	Other reasons	Costs, etc.

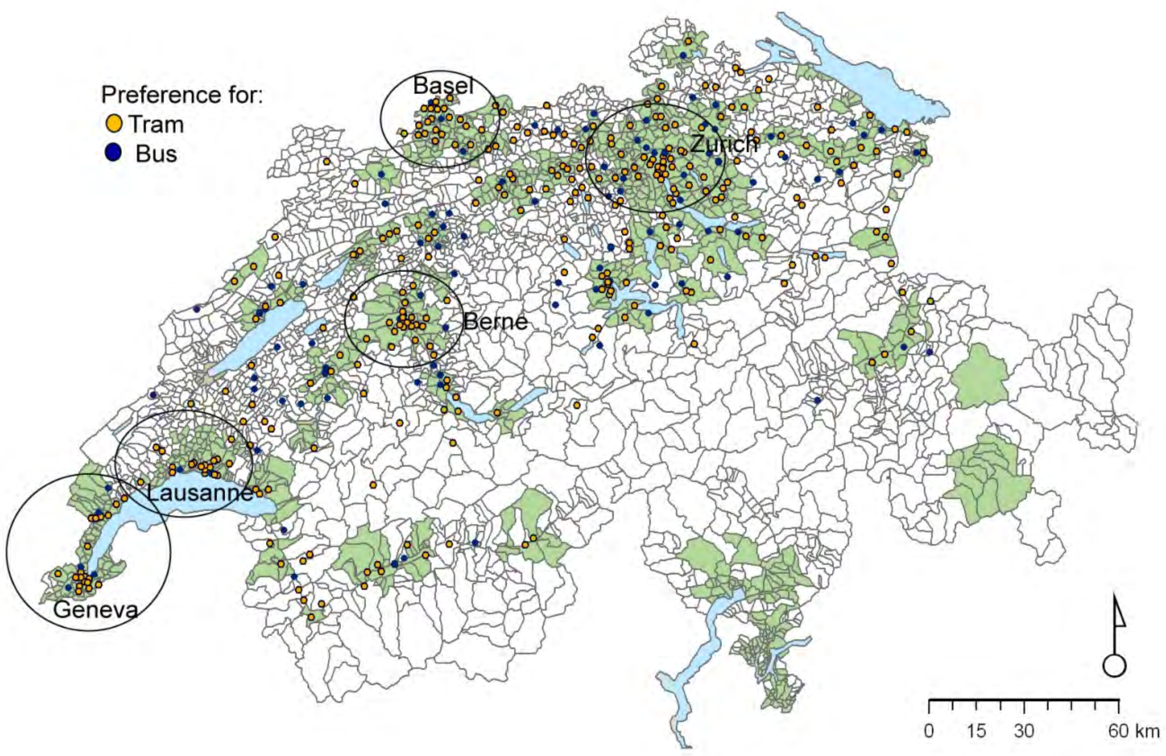
6.3 Results

6.3.1 Preferences

Responses to the hypothetical question about the choice between bus and tram operating under comparable service conditions showed a clear preference for a tram. The weighted data shows a preference of tram of 73.8%. This is slight less than in the original data set where 385 respondents (74.8%) prefer a tram.

Figure 15 shows the spatial distribution of the respondents and their preference. The green areas are conurbations. It is not possible to ascertain a preference for bus and tram depending of the location of residence since many voting for tram origin from residents of rural areas. However, the map shows a tendency towards clusters of tram preferences in areas served by trams (Basel, Berne, Zurich, Geneva, and Lausanne with its metro).

Figure 15 Spatial distribution of preferences



6.3.2 Impacts on preference

The majority of the respondents prefer a tram, independent from their place of residence. The difference between choices is 29% in rural areas, 43% in conurbations without tram service, and 66% in conurbations with tram service (compare Table 21).

Table 21 Socioeconomics and preferences

Variable	Value	Count	Tram (%)	Bus (%)	Cramer's V[2]	Approx. sig.
Age	0-19	31	41.9	58.1		
	20-64	450	75.1	24.9	0.181	0.000
	65+	33	78.8	21.2		
Education	Primary school	55	52.7	47.3		
	Vocational school	186	69.9	30.1	0.207	0.000
	High school	261	81.2	18.8		
Profession	Head	117	77.8	22.2		
	Employed	236	74.2	25.8		
	Trainee	72	55.6	44.4	0.182	0.002
	Housekeeper	29	75.9	24.1		
	No information	48	85.4	14.6		
Public transport usage	PT-card	353	78.2	21.8	0.160	0.000
	no PT-card	162	63.0	37.0		
Car availability	No car	73	90.4	9.6		
	One car	233	76.0	24.0	0.204	0.000
	More than one car	204	63.7	36.3		
Place of residence	Rural	150	64.7	35.3		
	conurbation (w/o tram)	191	71.7	28.3	0.165	0.001
	Conurbation with tram	174	82.8	17.2		

[2] To determine whether there is a relationship between variables, a chi-square test has been conducted (two-tailed). The strength of the association has been measured with Cramer's V.
Cramer's V is a statistical measure for the strength of association between two nominal categorical variables. Based on the χ^2-statistics of a dataset that containes two cateogrial variables X and Y where X has M distinct categories and Y has N distinct categories, Cramer's V is defined to be:

$$V = V(X,Y) = \sqrt{\frac{\chi^2}{n \min(M-1, N-1)}}$$

If one of the variables is dichotomous, Cramer's V is equal to the phi statistics which is defined to be:

$$\phi = \sqrt{\frac{\chi^2}{n}}$$

Compared to phi-statistics, Cramer's V is more conservative. The following ranges help to interpret the results.
0.0 <V <0.2 little association,
0.2 <V <0.5 distinctive association,
0.5 <v <1.0 strong association between variables.
Cramer's V is computed with SPSS crosstabulation.

The observed higher preference of a tram from inhabitants of tram cities comes in line with the assumption deduced from the literature research that habit and experience is a major driver for preference formation (compare chapter 4.5.4).

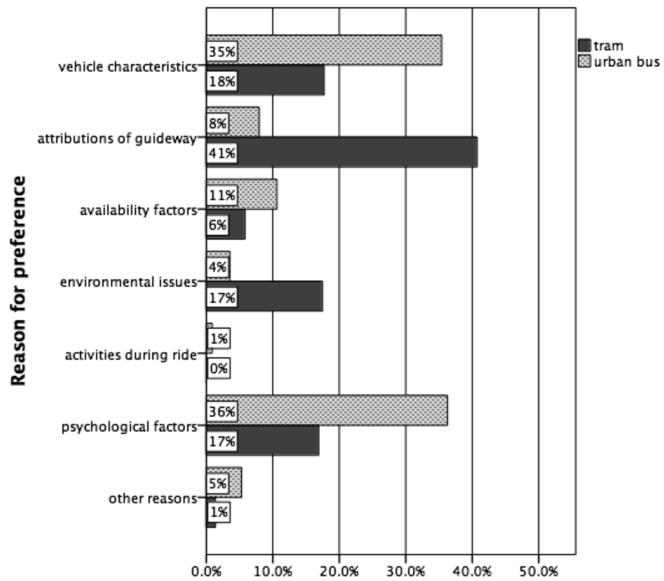
A chi-square test was conducted to test the strength of the association between different variables and the preference of bus or tram. Little association was revealed from the variables age, profession, public transport usage and place of residence on the choice of bus or tram. The variables education and car availability show slightly stronger associations to the choice of bus and tram. The higher the education the higher is the preference for a tram. Ownership of a car leads to a decrease in preference for a tram. However, there are strong correlations between these variables. Numbers of cars in households, for instance, correlate strongly with the place of residence. 62% of households in tram cities do not own a car, 33% have one and 27% more than one car. In rural areas only 6% of the respondents have no car available.

6.3.3 Attributions to bus and tram

The respondents were asked to give up to three explanations for their choice between bus and tram. Attributions for bus and tram are of main interest to establish different schemata for these two public transport systems. Respondents who prefer a tram mentioned on average 2.6 attributions and those who prefer bus mentioned 2.2 attributions.

The first attribution is regarded as being the most important to the respondent. Hence, the first reason is analyzed separately. This accounts also for differences in response rates for bus and tram preferences as mentioned above, because every respondent had to give at least one reason for their preference. As displayed in *Figure 16*, 41% of main attributions towards a tram are categorized as attributions towards the guideway. Further, vehicle characteristics, environmental issues and psychological factors account for the same share of reasons for a tram preference. Considering the preference for a bus, more than 70% of the first reasons affect either vehicle characteristics or psychological factors.

Figure 16 First attributions for preference of bus or tram



The subcategories from Table 20 are applied for a detailed analysis of attributions. From those respondents who preferred using a bus, more than two thirds of the first attributions in subcategories are (compare *Figure 17*):

- Positive feelings (22%)
- Seat/Space in vehicle (19%)
- Atmosphere in vehicle (15%)
- Habit/ knowledge (11%) and availability of service (11%)

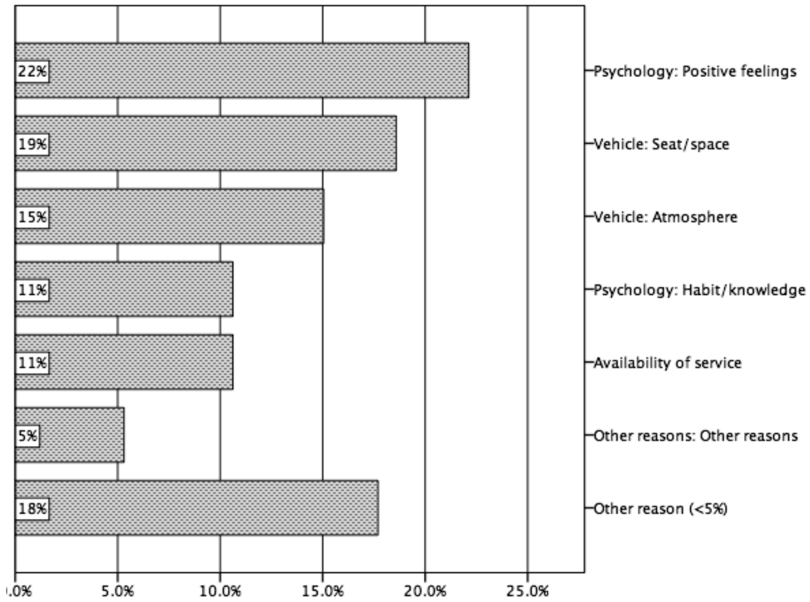
A high share of bus attributions is based on psychological factors (36%) of which attributions of positive feelings, described as better, I like more, etc. account for 22% and habits for 11%.

Of those respondents who preferred a tram, two thirds of the first attributions in subcategories towards a tram are:

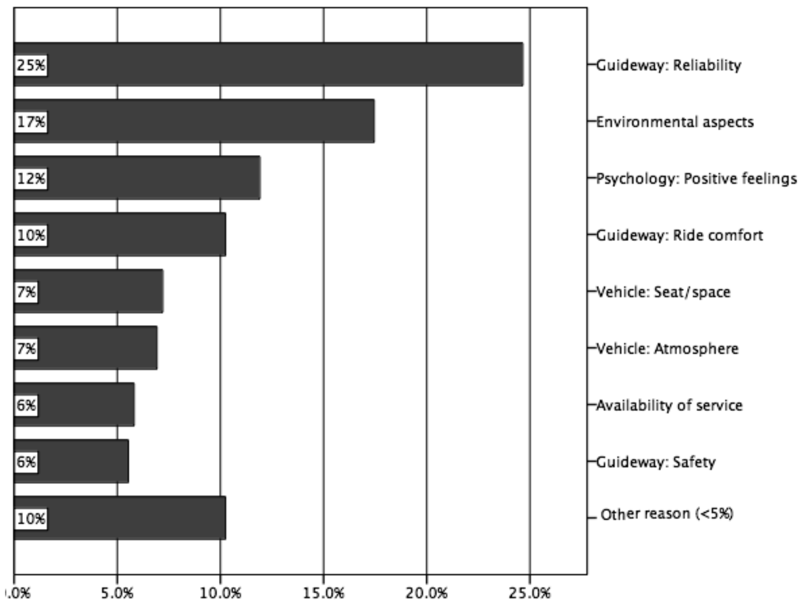
- Reliability (25%)
- Environmental aspects (17%)
- Positive feelings (15%)
- Ride comfort (10%)

Considering the first attributions for a tram, rational and objective factors related to the guideway are most prominent. Additionally, attributions of environmental issues are relevant in this list.

Figure 17 Subcategories of first attributions for choice of bus and tram



First reason for bus preference



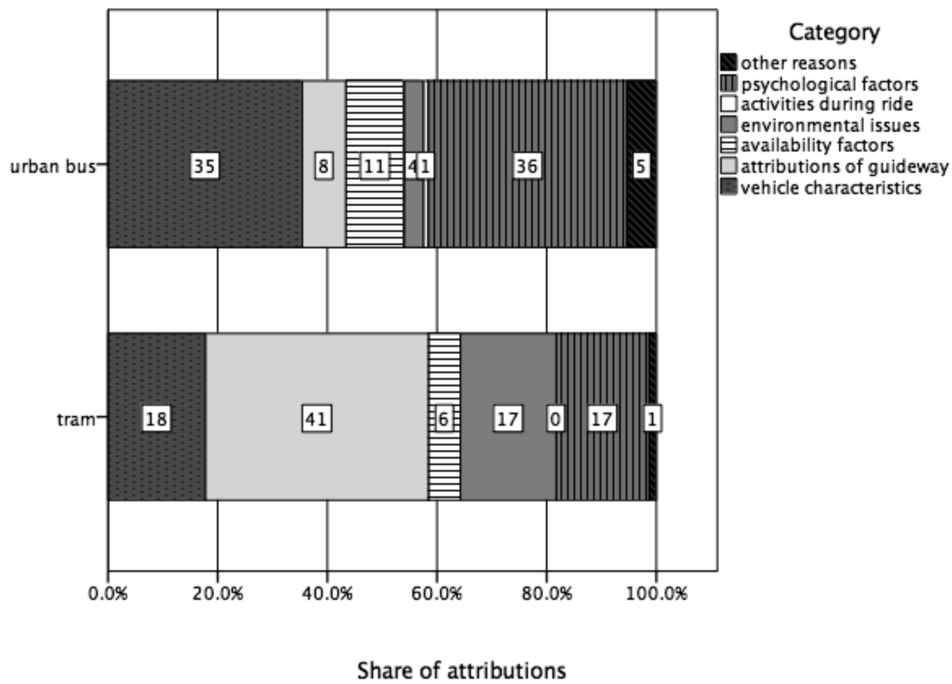
First reason for tram preference

Comparing the two transport modes, it becomes evident that they are related to different attributions. Whereas attributions for a bus have a high share of psychological, social and emotional aspects, tram preferences are often justified with rational objective factors. For the justification of a tram preference attributions mostly related to the most prominent difference between bus and tram – the guideway and the traction system which affects the environment – are mentioned.

6.3.4 Schemata of bus and tram

The resulting schemata for bus and tram, based on the first attribution mentioned by each respondent, are displayed in *Figure 18*. A schema or "picture in mind" of a bus is mainly constituted of attributions of vehicle characteristics (35%) and psychological factors (36%). Compared to the schema of a bus, the schema of a tram is dominated by attributions of the guideway, mainly expressed due to reliability.

Figure 18 Schemata for bus and tram



6.3.5 Attributions and sociodemographics

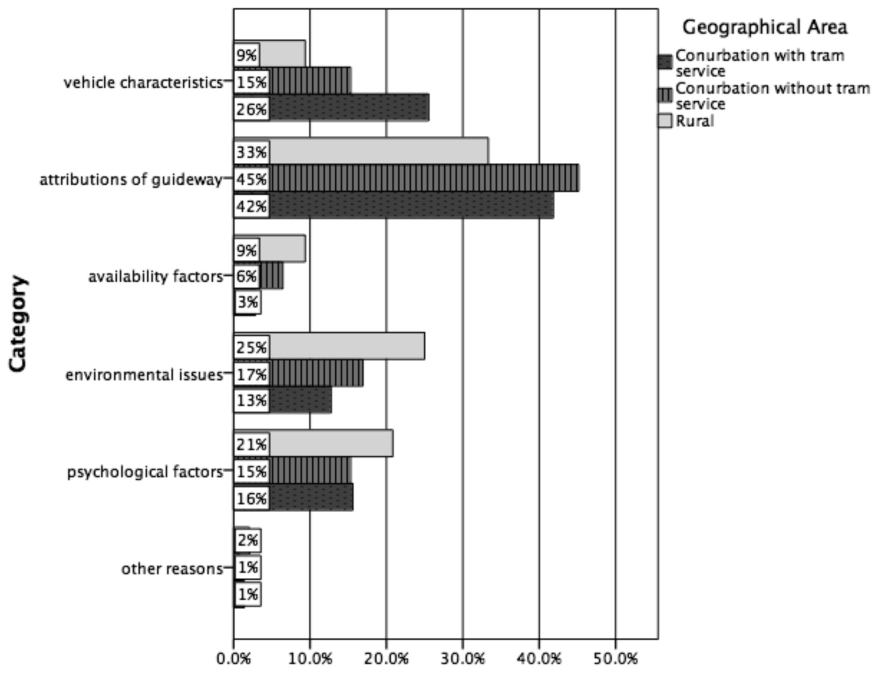
Socioeconomical variables were analyzed in order to identify patterns in attributions that may influence bus and tram preferences. In contrast to the attributions towards a tram, no significant impact of sociodemographic variables was detected for the bus schema. With regard to the set of **first attributions for a tram preference**, two variables show a significant association between attribution and preference:

- Ownership of pt-card (Cramer's V= 0.213 Sign.=0.006)
- Place of residence (Cramer's V= 0.175 Sign.=0.015)

Both PT-pass owners and non-owners rank guideway attributions as most important. However, PT-pass owners rank vehicle attributions and psychological attributions higher than environmental benefits, while non-PT-pass-owners rank environmental benefits second to guideway attributions.

In terms of place of residence, the ranking of most important attributions for inhabitants of rural areas is *guideway, environmental issues* and *emotional factors*, in contrast to people living in tram cities where vehicle attributions were mentioned far more often (compare *Figure 19*). The rank order of attributions of inhabitants of the three spatial classes (rural, conurbation without trams, conurbation with trams) follows assumed traffic concerns or traffic problems usually encountered in these locations. In dense urban areas with high public transport demand vehicles are heavily loaded and hence vehicle characteristics belong to the prominent issues. In conurbations with less public transport demand and congested traffic situations guideway attributions have the highest share of attributions. Rural areas are less affected by these issues, which might explain the high share of environmental reasons for tram preference.

Figure 19 Attributions for tram and place of residence



6.4 Discussion

6.4.1 Method and procedure

Data collection was based on an online omnibus survey. There are no missing answers, because the respondents had to reply in order to get to the next question. Nevertheless the answers given to the open question are all reproducible and hence it is assumed that the motivation of the respondents was sufficient to achieve acceptable data.

With regard to the number of attributions, and hence reasons for preference of bus and tram, a significant difference between those who prefer tram and those who prefer bus is ascertained. Giving one answer was mandatory. Nevertheless those who prefer tram mentioned on average 2.6 attributions and those who prefer bus mentioned 2.2 attributions. Since the first attributions are regarded as most important for the construction of schemata, only first answers were considered for further analysis.

Respondents had to choose between bus or tram because there was no possibility of choosing an "indifferent" option. This can lead to over- or underestimations of a rail factor (Langenheim and Schliephake 1986). Assuming a rail factor, indecisive respondents rather tend to favor a tram, which would be part of the explanation for the high preference for a tram of 74%.

There was no influence by the interviewer on the respondent due to the web-based survey instrument. The part of the study that is critical regarding objectivity is the development of the categorization key for answers to the open question and the categorization of these questions. Since the categorization key has been revised twice and is set as framework, the weakest aspect is the categorization itself. To improve the objectivity the categorization was undertaken by two different agents using the same categorization key and analyzing the interrater agreement.

Since the question relates to stated choice and stated preference, it is hard to draw conclusions for real mode choice behavior.

6.4.2 Comparison with related studies

The tram preference of 74% is higher than expected from Megel's (2001) findings of 63% and 61% from Langenheim and Schliephake (1986). Both results are based on the comparison of regional public transport. In Langenheim and Schliephake (1986) those respondents who were indecisive had the possibility of choosing a third option ("no answer") what leads to lower values for both, bus and tram preference.

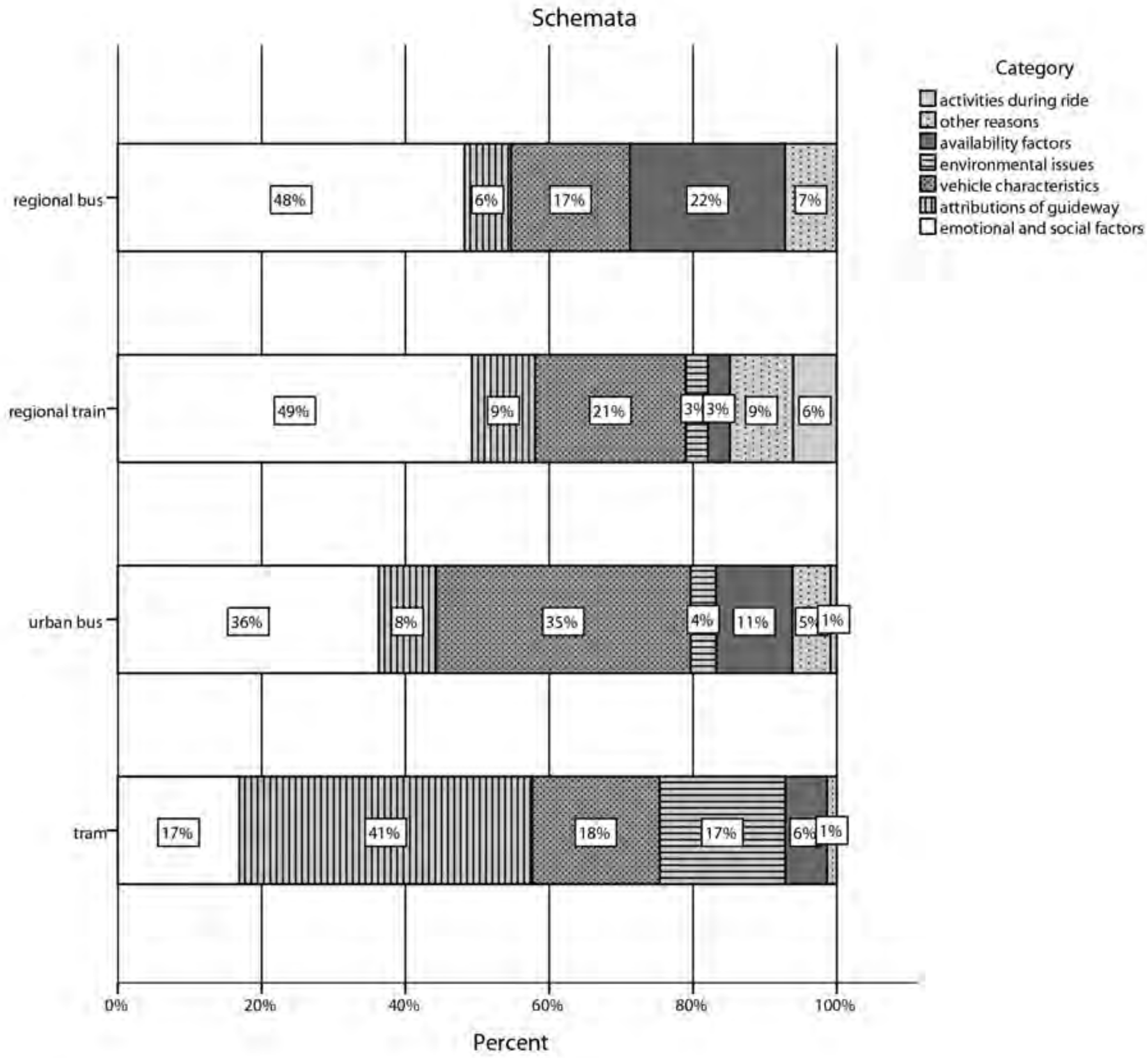
The Swiss results show that security concerns are much lower than in other studies. Compared to Schulz and Meinhold (2003) it is not the case that preferences for bus are because of "hard" reasons and those for rail-based systems due to soft factors. It is even contrariwise; reasons for bus preferences rather tend to comprehend emotional and social factors.

The schemata for regional transportation developed by Megel (2001) have been revised and compared with the schemata for bus and tram (Scherer and Dziekan 2012, Scherer et al. 2011a). Therefore both datasets have been recoded according to the categorization key. In order to construct a schema, only the first attributions per respondent from both datasets were analyzed. The main sociodemographic difference between the two datasets is ownership of a PT-card (German study = 7.5%, in Swiss study = 43%). Distributions of other variables such as gender, age, household size and number of cars per household are similar across both datasets.

General caution has to be exercised when comparing the results of both case studies, because these studies were completed in different times (2000 and 2009) and different geographical areas with variances in level of services of public transport. As public transport service has changed only marginally over the last 10 years in the German study areas, the effect of different time horizons on level of service aspects can be ignored.

Figure 20 shows the resulting schemata for regional bus, regional train, urban bus, and tram based on recoded first attributions mentioned in the surveys. It can be seen that each schema is loaded differently with the defined categories from the classification key in Table 20.

Figure 20 Schemata for regional transportation, and tram and urban bus



Source: Scherer et al. (2011a)

Considering the resulting schemata, regional bus and regional train are highly loaded with emotional (psychological) attributions. Almost 50% of the first attributions towards these transport modes fall within this category. The share of emotional and social factors is also high in the schema of urban buses (36%). Compared to that, the tram schema is far less loaded with emotional factors (17%).

Regarding regional transportation, it can be seen that reasons for preference for a bus include a higher availability of a bus service compared to train service. In contrast, a train is suitable for conducting activities during a ride. This reflects the local situation in the case study areas.

In contrast to regional transportation and bus, a tram is heavily linked to positive guideway attributions and has strong environmentally friendly attributions. These attributions correspond with congested situations and emerging environmental discussions in cities.

In both studies a high preference for rail-based systems was found. In the underlying hypothetical situations where public transport opportunities are equal, a rail factor definitely exists for the case study areas.

The schemata approach is based on the first (intuitive) response mentioned for the respective preference. An answer is expected to be more intuitive the less cognitive effort is needed to give a reason for preference. Hence, the personal interviews conducted in Germany meet this condition better than the web-based questionnaire in the Swiss study, because filling out a questionnaire requires more time and allows the respondent to reflect on the answer. Thus, it is expected that the schemata built up from reasons mentioned in the German study correspond more with the real picture in mind than the schemata constructed with reasons from the Swiss study. As a consequence, emotional and social factors tend to be underestimated in the schemata for urban bus and tram.

6.4.3 Elements of the schemata

As first attributions show a higher share of psychological factors than the comprehensive set of attributions mentioned by the respondents, it is concluded that they have a higher weight in schemata and also a higher weight for certain behavior. *Psychological and social aspects* additionally include attributions from people who were unable to define their reason for preference in words. Hence, the inability to express what someone likes about a public transport mode is expected to have a high share in this category since the respondents in this situation tend to give general answers such as “better,” “I like it,” etc. although they might really be affected by other attributions (e.g. they might have meant that one mode is more reliable).

In congested areas with high demand for public transport, the main travel concerns are reliability (*attributions of guideway*) and space in the vehicle. Reliability is attributed to trams with their dedicated rights-of-way and far less to buses. On the other hand, buses are expected to have higher seat availability than trams. This category (*vehicle characteristics*) encompasses on the one hand aspects such as vehicle size and capacity (which favor trams), but on the other hand expected crowding conditions and hence buses are seen as less crowded and thus providing more space.

The category *availability factors* tends to have a higher impact in regional areas where public transport service is less dense. In these cases, a bus is expected to be more effective to meet availability needs. This reflects differences in routing and stop-distributions between regional train and regional bus services. This category in particular can be influenced by cultural differences, since availability of regional public transport service is greater in Switzerland than in Germany.

In the category of *environmental issues*, the higher share attributed to urban public transport can be influenced by the time when the study was conducted. The climate debate was far less prominent in 2000 (when the German study was completed) than in 2009 (when the Swiss study was completed). Nevertheless, the data show the tendency of rail-based public transport to be considered to be more environmentally friendly than buses.

6.4.4 Conclusions

The findings underline the conclusion in Cain et al. (2009) that specific locations influence the image of a public transport system. Furthermore, similarly to Cain et al. (2009), the results show that familiarity with a certain mode tends to influence the preference. The ratio of preferences for trams is lower in rural regions compared to tram cities in the Swiss study. Additionally, the German study ascertained a higher preference for train by owners of specific travel cards. With regard to the findings of Beirão and Cabral (2007), the same attributions have been found relevant, except for the space in the vehicle.

Psychological and social factors play a less prominent role in the schemata of bus and tram than expected from the German study. One third of the arguments for a tram preference are based on guideway characteristics related to higher reliability. Overall, a tram gets a higher share of rational reasons for its preference being mentioned as first attribution than a bus. This high share of rational and objective reasons for a tram can be explained with the prominence hypothesis formulated by Tversky et al. (1988).

Investigating differences between choice and matching response, Tversky et al. (1988) found that the more prominent (important) attribute of an object will weigh heavier for choice than for matching. The current survey questions targeted choice between bus and tram and hence judgments about these two systems. Tversky et al. (1988) assume that different heuristics are used in these two tasks (choice and matching) and hence different judgment can result. To save cognitive effort, the choice aspect based on only a few ordinal comparisons is expected to loom larger than when judgments are made due to matching (Tversky et al. 1988)

Considering the schemata developed with first attributions, the attributions may result from a qualitative reasonable comparison between the most prominent attributes of bus and tram. Therefore the high share of attributions towards the guideway of a tram match the presented prominence hypothesis.

As the schemata are based on preferences in hypothetical situations, it is not possible to apportion the relationship between schemata of bus and tram and real mode choice behavior. However, a significant association between public transport usage and first attributions towards a tram was established. As a conclusion, frequent public transport users have different schemata of tram than respondents who rarely use public transport. Furthermore it is interesting that the schema of a bus does not differ depending on public transport usage. There seems to be a higher consensus about the picture in mind of a bus compared to the picture of a tram.

The findings about the effect of public transport usage on the schemata also supports the assertion that habits and experiences affect someone's picture in mind. In particular, the finding that the schemata for a tram of residents of different geographical areas are significantly different indicates the influence of personal experiences on schemata formation.

Since schemata support cognitive shortcuts and finally influence people's behavior, it is interesting to establish that about 20-50% of the schemata for public transport modes are psychologically driven. According to the schema theory, the influence of positive feelings towards a mode, habit and knowledge, and barriers towards other modes are expected to have a significant effect on behavior. Moreover, schemata are influenced by local conditions that affect habits and as a consequence they cannot be generalized and applied to different regions properly without considering different cultural backgrounds.

In contrast to common mode choice models that are mostly based on hard factors, this research was based on the concept that attributions towards a public transport system form the basis for system perception and image. Attributions can be combined into categories that form schemata for different modes. They give a valuable insight into irrational reasons for mode choices that are mostly excluded in common mode choice models.

Schemata are a useful background to design public transport systems. For example, thinking of barriers toward public transport use in general or buses in particular, the schema shows that implementing small individual measures to improve bus service are not likely to be effective since the bus schema is highly loaded with emotional factors, based on experiences and habits. Considering the findings of Guiver (2007) concerning negative scenarios and the importance of contra arguments combined with the psychological model by Dziekan et al. (2004), it is questionable whether single improvements targeting only one attribution can lead to higher demand. Overcoming one negative attribution is not simply a matter of creating a more positive image for a public transport mode.

For the subsequent study to analyze the image of bus and tram systems, the following attributes account for more than 75% of the schemata of bus and tram and hence, are recommended for consideration:

- Guideway: reliability
- Guideway: ride comfort
- Vehicle: more seats/more space
- Vehicle: atmosphere
- Environmental aspects
- Psychology: positive feelings
- Psychology: habit/knowledge
- Availability of service.

7 IMAGE OF BUS AND TRAM

"The image of a transport system
may ultimately be an important influence
on preference formation"
Hensher et al. (2005) p63

This chapter is based on the following contributions:

Scherer, M. (2011c) Befragung Bus und Tram: Feldbericht und erste Ergebnisse, workingpaper, Institute for Transport Planning and Systems (IVT), ETH Zurich, Zurich.

Scherer, M. (2011d) The image of bus and tram: first results, paper presented at the Swiss transport research conference (STRC), Ascona, May 2011.

7.1 Overview

7.1.1 Introduction

The idea of a rail factor is consistent with statements that the image of a transport system has an impact on demand. According to Hensher et al., the image of a transport system *"may ultimately be an important influence on preference formation, especially for new means of transport"* (Hensher et al. 2005, p63). Cain et al. (2009) used focus groups discussions to quantify the importance of image and perception of different public transport lines in Los Angeles. They found that intangible service attributes (attributes that are abstract, subjective and thus difficult to measure) have a significant influence on modal perception. Furthermore they conclude that in the perception of the general public, BRT can compete with Light Rail.

Findings in the literature concerning a rail factor are controversial. However, it has proved very difficult to evaluate and determine the rail factor precisely. Three main types of studies have been found that compare the demand of rail-based with bus-based public transport. The first uses modeling based on stated preference evaluations, the second is based on before-and-after ridership data analyses of newly-implemented systems, and the third consists of a combination of stated and revealed preference data analysis.

These studies show mixed results regarding a rail factor. In order to avoid detected methodological shortcomings of other studies, a different approach is applied here. This approach focuses on the investigation of the image of bus and tram, because the image – applied as heuristic – is assumed to influence mode choice behavior. The investigation of the image is a subsequent analysis based on the schemata of bus and tram. The schemata approach is another approach to explore the perception of public transport modes and is based on cognitive psychology (compare 4.5.2 and chapter 6). As schemata respectively images are heuristics that allows people to save cognitive effort in an everyday situation such as the use of transport modes, cognitive shortcuts are expected to serve to a certain extend as a basis for mode choice decisions.

7.1.2 Objectives

The research on schemata of bus and tram has shown that the place of residence, and accordingly experience of and habits surrounding public transport influence schemata. Thus, it is of special interest to compare cities with and without tram systems because their residents have different experience levels. Therefore images of bus and tram are here explored with focus on residents of three cities. Two cities, Berne and Zurich, have a bus and a tram network whereas public transport in the third city, Lucerne, is solely based on buses. The study seeks to identify images of public transport system (bus and trams) as perceived by public transport users and inhabitants.

The focus lies on the question of how tram and bus are represented in the residents' minds. The main goal of this study is to examine attributions and their relative influence on the judgment of bus and tram. Furthermore different dimensions behind the judgments of bus and tram are identified and compared. Considering the debate on a rail factor it is of special interest to explore the sight of non-users of public transport since this is the group that is mainly expected to change their mode choice behavior when implementing a tram (e.g. Hass-Klau et al. (2003) applied a survey on attitudes of car users towards bus and tram).

In a nutshell, the following aspects are analyzed in this study:

1. Description of a general image of bus and tram
2. Analysis of image scores of bus and tram
3. Differences in images between public transport users and non-users.
4. Differences in images between residents of the three cities.

7.1.3 Method: Image measured as semantic differential

The image of a specific concept is reflected in a subject's attitude towards this concept. Attitudes are generally composed of three elements: Beliefs about the concept, emotional feelings such as appraisals, and readiness to respond to the concept in terms of using/buying it.

For the measurement of attitudes and thus images, several techniques are common. In addition to the schemata approach that was used in previous studies to investigate differences in the perception of bus and tram systems (Scherer et al. 2011a), the semantic differential is applied in the current study. This explorative measurement is appropriate for the data collection of attitudes/beliefs towards bus and tram based on attributions towards these two modes. Furthermore it allows the detection of different valuations for bus and tram on the same attribute.

Osgood et al. (1957) developed the semantic differential for the measurement of meaning in linguistics and psychology. The semantic differential is a rating scale that allows measuring connotative meanings of various kinds of objects and concepts. The resulting meanings are used to express attitudes towards the concept to be analyzed. This measurement can be applied to any concept and is therefore suitable to explore the connotative meaning of bus and tram in order to deduce the image respectively attitudes towards these two public transport modes. Nowadays this instrument is applied in various fields such as cultural studies and marketing research but also for travel behavior and mode choice (e.g. motives for car use: Steg et al. 2001, walking: Huber 2009).

The rating scale of the semantic differential is based on bipolar adjectives of attributions towards the concept to be tested (e.g. good-bad, bright-dark). In the present case, a five point Likert scale was used in a written questionnaire. The respondents were asked to choose their position of the concept (e.g. bus) on the five-point scale between the given attributions such as old-new vehicle, spacious-cramped vehicle. The battery of adjectives and attributions was adapted to the concept of public transport modes. The attributions applied appeared from an extensive literature study and from the schemata study presented in chapter 6.

The advantage of the semantic differential is that it provides a fast graphical overview of the judgment of the investigated concepts. The analysis of the ratings within the Likert scale allows exploring the image of bus and tram. Three different analyses are made:

1. Computation of means of scores for bus and tram for single attributions to identify average ratings. Furthermore aspects of the image constituted of the attributions can be explored.
2. Computation of the difference of the mean category score between bus and tram per subject to identify the distribution of the ratings. This allows for user-type specific analysis of the rail factor and its single attributions.
3. Additionally a factor analysis was conducted to examine dimensions of latent variables that can summarize the judgment about the attributions of both public transport modes. This allows for conclusions which categories of public transport may be distinguished.

7.2 Data

7.2.1 Data collection

Data was collected with a paper-and-pencil survey that was conducted in autumn 2010 among 1,000 residents in each of the cities Berne, Zurich and Lucerne. Precedent studies concerned with the evaluation of attributions of public transport systems in Switzerland (Scherer 2010a) and first analyses of travel behavior of residents living in bus and tram corridors in Berne, Zurich and Lucerne (Scherer and Weidmann 2011) serve as a background for this study. Additionally, a pretest with 300 questionnaires with a response rate of 25% was conducted to test the usability of the questions.

In order to avoid fatigue effects and the possibility that the respondent would skip the questionnaire, some limitations to battery sizes and response burden were considered. Response burden refers to the characteristics of the questions and to the number of questions. Hence response burden is a parameter to estimate the likelihood that a questionnaire will be filled out and sent back (Axhausen and Weis 2009). Response burden was calculated to 310 points, which results in an expected response rate of about 25%.

The questionnaire was restricted to four pages of A4 to allow for an appropriate amount of time to answer the questions. The decision about the question structure is based on the expected response behavior (Dillman 1978). The different item batteries were placed according to the estimated cognitive effort to respond to these types of question.

Besides checking for sociodemographic data and questions about travel behavior in terms of mode choice for work trips and an item battery to analyze mode choice habits, the core of the questionnaire was dedicated to measure the semantic differential of bus and tram (see questionnaire in Appendix A1). The respondents were asked to rate a bus and a tram on 26 attributions towards public transport systems. The selection of attributions is based on an extensive literature study and the precedent studies.

The number of attributions was reduced to 22 attributions on transport characteristics and 4 attributions considering the area of operation (compare Table 22). The reduction was appropriate to account for the response burden and the layout of the questionnaire. Furthermore the aspects were roughly classified to allow for the respondents better orientation. The items for both concepts, bus and tram, are placed on opposite sides of a page in the questionnaire which made it difficult to manipulate or compare ratings for tram and those for bus easily. The order of attribution classes and the negative and positive poles of the bipolar attributions varied.

Table 22 Attributions of public transport on bipolar scales

Categories	Positive pole	Negative pole
Service characteristics	Favorable stop locations	Unfavorable stop locations
	High frequency	Low frequency
	Fast	Slow
	Direct routes	Indirect routes
	Clearly designed net	Confusing net
On the way	Reliable	Unreliable
	Free flow	Stop and go
	Safe of accident	Risk of accident
	Smooth ride comfort	Bad ride comfort
Environment	Environmental friendly	Environmental unfriendly
	Silent	Noisy
Vehicle	Empty	Crowded
	New	Old
	Spacious	Cramped
	Easy to board	Difficult to board
	Convenient	Inconvenient
	Modern	Old fashioned
To me this transport mode is…	Attractive	Not attractive
	Important	Not important
	Easy to use	Difficult to use
	Valuable	Not valuable
	Harmless	Dangerous
Area of operation	Belongs to city center area	Disrupt in city center area
	Goes with tower buildings	Goes with single-family houses
	Goes with new buildings	Goes with old buildings
	Goes with mansions	Goes with working-class estates

7.2.2 Respondents

In total, 3,000 questionnaires were distributed in the main survey. The resulting response rate was 23%, thus in the expected range according to Axhausen and Weis (2009). 663 questionnaires out of 2,881 delivered questionnaires were returned (for details see the field report: Scherer 2011c). Between 212 and 227 questionnaires were obtained for each of the three cities Berne, Zurich and Lucerne.

Regarding the completeness of the returned questionnaires, 77% of the questionnaires were fully answered. Considering the different item batteries, 93-98% of the respondents completed them full. The most missing data was in the sociodemographic questions and concerned age, gender and the address of workplace. One third of the respondents returned voluntary a travel diary of the last week that was offered to estimate the number of trips. This allowed cross-checking of the number of trips with those respondents who only noted their estimates.

The comparison of the sociodemographics with average numbers for the three cities revealed that the following groups are underrepresented in the survey sample:

- People aged under 20 years or older than 65
- People from single households
- People with a basic graduation (this correlates with people younger than 20 years).
- People who are mainly occupied as homemakers and retired persons.

As a consequence, data was weighted according to the averages of education and gender of the respective city. In Table 23 an overview of the sociodemographics and mobility attributes is presented. The ratio of public transport users is within the range of urban averages. Derived from the ownership of different public transport cards, 52% of the respondents are frequent public transport users (pass-holders), 23% are optional users (multi trip card), and 25% are classified as non-users. Table 23 shows that mobility tools are distributed differently between the three cities. Whereas car availability is the highest among residents of Lucerne, the ownership of a public transport pass (frequent user) is remarkably higher in Berne and Zurich compared to Lucerne. This reflects also the lower number of average public transport trips per week in Lucerne.

Table 23 Overview of survey sample

Block		Total	Zurich	Berne	Lucerne
Gender	Male	51.7%	50.8%	54.7%	49.2%
Age (years)	Average	44.8	44.5	44.6	45.3
Duration of residence (years)	In city	23.8	24.9	23.9	22.7
	In neighborhood	14.2	14.2	14.6	13.8
Driving license	yes	87.0%	85.5%	86.0%	89.3%
Car-sharing	yes	8.6%	10.8%	8.0%	7.4%
Car availability	Always	55.3%	47.5%	53.5%	64.3%
	Often	17.0%	21.5%	15.6%	14.4%
	Rarely	12.5%	13.3%	17.5%	6.6%
	Never	15.2%	17.7%	13.5%	14.7%
Public transport card*	Annual all access pass (GA)	12.6%	8.1%	13.2%	15.9%
	Half fare card (Halbtax)	55.4%	61.1%	56.9%	48.5%
	Gleis 7	0.8%	1.8%	0%	0.8%
	Monthly pass/annual pass (Monats-/Jahreskarte)	34.7%	46.3%	38.3%	20.1%
	Multi trip card	22.6%	21.0%	23.4%	23.3%
	Pass for specific passage	4.3%	3.0%	6.2%	3.5%
	Others	0.8%	0%	1.5%	0.9%
Average number of trips per week by…	Public transport	6.9	7.6	8.3	5.0
	Car/motorbike	6.0	4.2	6.0	7.7
	Bicycle	3.5	3.7	3.9	2.9
	Walking	4.0	3.6	3.8	4.5
	Total	20.5	19.2	22.0	19.9

* more than one answer possible

7.2.3 Data preparation

Data preparation included geocoding of addresses of place of residence and workplaces and the calculation of distances to the closest public transport stop. These calculations were used to control for the next public transport stop mentioned by the respondents.

The respondents estimated the time they needed to get from their home to their next public transport stop as average of 4 minutes. The estimated walking time from the closest public transport stop to their workplace was 5 minutes.

The judgments on the bipolar five point rating scale were recoded according to positive and negative end of scales. Low scores correspond with more positive ratings and high scores with negative ratings of the respective attribution (e.g reliable: 1; not reliable: 5). This means that the lower the score the more positive was the judgment of the respective aspect.

7.3 Images of bus and tram

7.3.1 Image scores

The image of a public transport mode that a subject has in mind is represented as mean score of attributions per subject. The mean scores of a bus and a tram are computed across each subject p to investigate the distribution of the images for every respondent. In a second step subjects and their scores are classified according to their public transport usage.

$$ImageScoreBus_p = \frac{\sum_{1}^{n} ScoreAttributionBus_p}{n} \tag{3.1}$$

$$ImageScoreTram_p = \frac{\sum_{1}^{n} ScoreAttributionTram_p}{n} \tag{3.2}$$

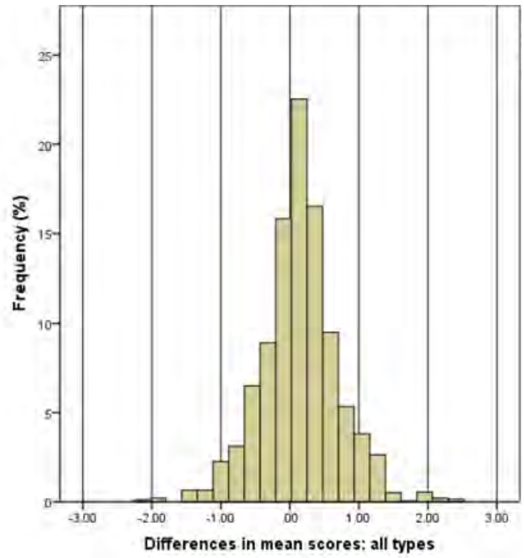
p = person p

n = number of attributions

The mean score for a bus is 2.26 (Std. dev. = 0.470) and the mean score for a tram is 2.15 (Std. dev. = 0.532) (on a scale from 1 (best) to 5 (worst)). The difference between the means of the scores between bus and tram is 0.107 (Std. dev. = 0.539). A positive difference value represents a better judgment of tram compared to a bus and is interpreted as more positive image of a tram. A t-test of the difference of the means shows that the mean score of a tram is significantly higher (dif.=0.107, Sig.=0.000) in the dataset than the mean score of a bus.

The distribution of the differences of mean scores per subject is displayed in *Figure 21*. There is a slightly better image of a tram (mean > 0) across respondents. Considering the chosen attributions as representative for the image of each public transport mode, this results in 12% of the respondents having a more positive image of a tram compared to their image of a bus.

Figure 21 Differences of mean image scores

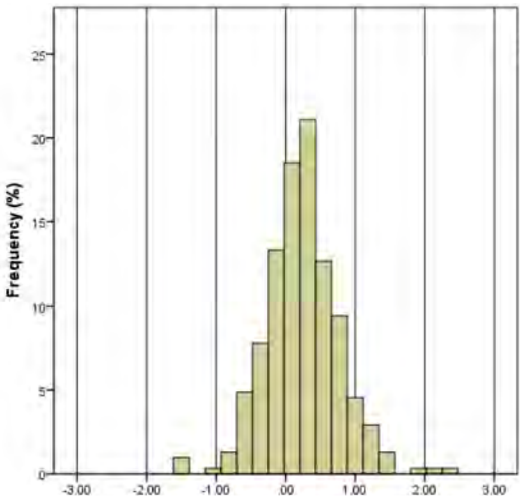


Mean = .1416
Std. Dev. = .56031
negative (-): 38%
positive (+): 62%
12% of respondents have a higher image score of a tram than of a bus.

With regard to different user types of public transport, the difference in the mean scores of bus and tram decreases (compare *Figure 22*). Whereas frequent users show the highest mean score difference, with 0.24 in favor for tram attributions, the difference is 0.05 for occasional users and 0.00 for non-users of public transport. This results in a variation of a more positive image for tram compared to bus of 3%-18% depending on the user type. The higher the public transport use, the better is the judgment for attributions that form the image of a tram. A t-test revealed that the difference of mean scores are significant on a 5% level for frequent users (Sign.=0.000) whereas the difference in mean scores of occasional users (Sign.=0.224) and non-users (Sign.= 0.983) turned out not to be significant. As a consequence the image of bus and tram differ less than previously expected for the two user groups of occasional users and non-users of public transport.

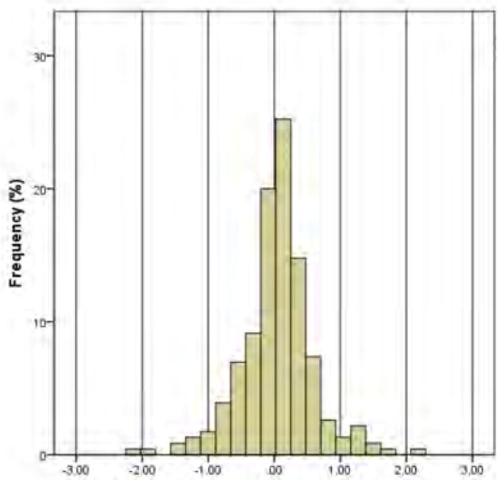
In contrast to public transport users where the difference of mean scores follows a normal distribution, the distribution of differences of non-users shows a tendency for two peaks (*Figure 22*). This might be a reference for two classes of non-users comparable to the distinction between captive (car) drivers and choice drivers as potential public transport users (Krizek et al. 2007).

Figure 22 Distribution of differences of mean scores by user type

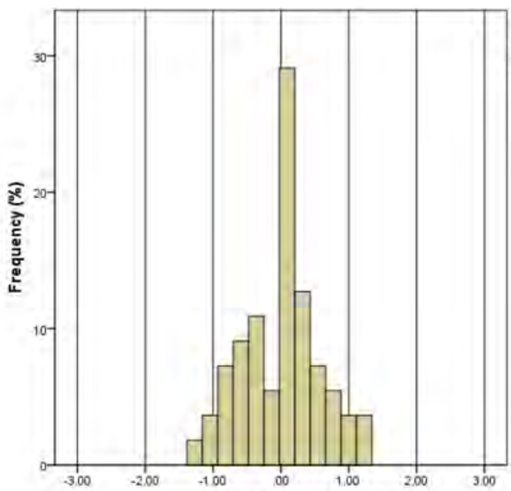


Difference of mean scores:
frequent user

Mean = .2442
Std. dev. = .5295
- : 32%
+: 68%
Image of tram significantly better than image of bus



Difference of mean scores:
occasional user
Mean = .0451
Std. dev.= .5602
-: 45%
+: 55%
NO significant difference in image scores of tram and bus



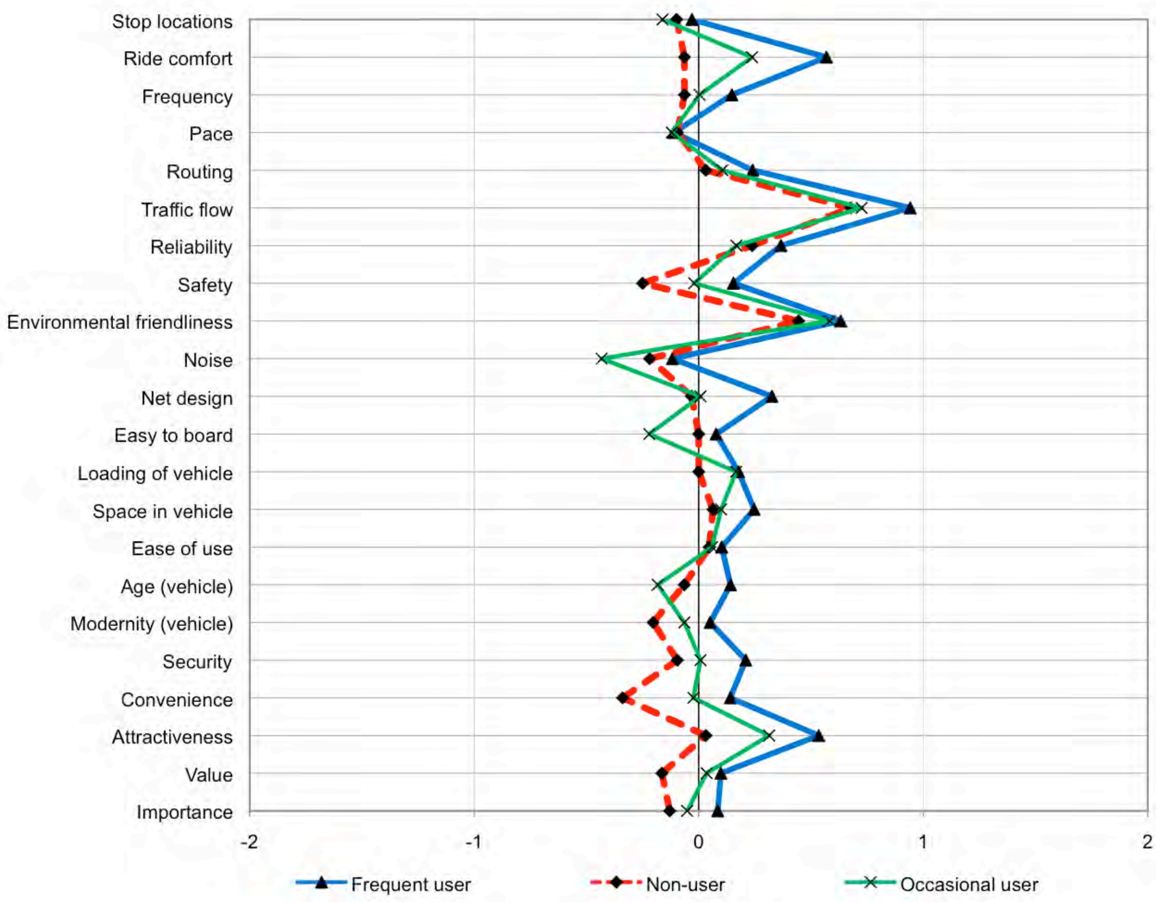
Difference of mean scores:
non-user
Mean = .0017
Std. dev. = .5758
-: 47%
+: 53%
NO significant difference in image scores of tram and bus

The next step is to identify sources of differences in the attributions of bus and tram on a user type basis (see Scherer 2011 for details). Differences in scores for the specific attribute are computed and tested for significance on a 5% level on a subject basis in the different user groups. According to the hypothesis that there is a difference between the judgments of attributions of a tram and a bus, the test score was Difference $Score_{Bus} - Score_{Tram} = 0$. The resulting difference in the score of bus and tram per user type is displayed in *Figure 23*. The rating difference for every attribution is smaller than 1 (on a five point scale).

At first sight it can be seen that frequent users give higher scores for trams than for buses on most of the attributions. In contrast, non-users of public transport tend to score both modes equally or are more positive about buses. In particular, the difference in scores between bus and tram of occasional users is noticeable. Against the expectation of finding that their scores would be between those of the frequent users and non-users, there are some remarkable outliers on the attribution of *stop locations, pace, reliability, noise, ease of boarding,* and *age of vehicle* (see Tables 1-3 in Appendix A2 for details).

- Frequent user: Since the mean scores of bus and tram differ significantly, it is of interest which attributions have a high impact on this result. By far the highest impact is due to the *free flow* (mean difference 0.94) of a tram, followed by the *environmental friendliness* (mean difference 0.63). Those attributions that received better scores for buses, noise, pace and stop locations are not significantly different to those for a tram.
- Occasional user: The difference in mean score of bus and tram is 0.045 and hence is not significant on a 5% level. Regarding single attributions, there are four variables that are rated significantly higher for a bus than for a tram on a 5% level: *Age of vehicle (diff:-0.18), noise (diff:-0.43), easy to board (diff:-0.22), and stop locations (diff:-0.16)*. From an occasional user perspective there are throughout aspects that are scored more positive for a bus than for a tram. Nevertheless the positive aspects of free flow and environmental friendliness are significantly higher for tram than for bus (diff: 0.73 and 0.58).
- Non-user: For this group the mean score for bus and tram was found not to differ significantly. Interestingly, the differences in ratings of single attributions for bus and tram are significant (5%-level) for four variables: *traffic flow* (diff 0.68), *environmental friendliness* (diff: 0.44), *convenience* (diff: -0.34) and *reliability* (diff: 0.24). Overall, a bus got higher ratings than a tram on 13 out of 22 attributions, two attributions are rated equally for bus and tram and 7 attributions are rated higher for a tram.

Figure 23 Differences in scores per attribution depending on user type



Negative difference score (left part): Mean bus judgment higher than tram judgment on this attribution
Positive difference score (right part): Mean tram judgment higher than bus judgment on this attribution

7.3.2 Dimensions of the image

To identify dimensions based on the ratings of bus and tram a factor analysis was conducted. This method allows detecting latent variables based on a comprehensive set of numerous attributes what leads to a reduction of the attributes. This method is applicable for the searching of structures behind the ratings of attributions in order to reduce the complexity and amount of attributions.

Participants' ratings of the attributions of bus and tram were subjected to a factor analysis (principle components analysis) using a varimax rotation. Considering only the eigenvalues higher than 1, a five dimensional solution appeared to be most appropriate for both transport modes. The first five factors account for 54% of the variance of the judgments of attributions for a bus and 57% of the variance for the judgments of attributions for a tram. Subsequently only variables with loadings >0.35 are listed in the respective tables.

Bus

The five resulting factors for bus are composed and named as following (compare Table 24):

- Factor 1 (eigenvalue 2.897, 13% of variance) reflects affective emotional aspects and concerns towards bus use.
- Factor 2 (eigenvalue 2.634, 12% of variance) shows high loadings on rational vehicle aspects.
- Factor 3 (eigenvalue 2.584, 12% of variance) has high loadings on rational service characteristics.
- Factor 4 (eigenvalue 2.327, 11% of variance) represents mainly impacts from the bus on others (incl. general public) and users with high loadings on noise, and environmental friendliness, ride comfort and safety/security.
- Factor 5 (eigenvalue 1.329, 6% of variance) accounts for impacts on the user on the way.

Five attributions show loadings higher than 0.35 on more than one factor. This is *convenience* what is classified in the dimension of affective emotional aspects and in the factor that describes impacts on the user on his or her way. The perception of the *space* in the vehicle affects, on one hand, vehicle aspects, but also impacts on others (F4). Furthermore *reliability* and *traffic flow* load on the factors F3 (service characteristics) and F4 (impacts on others/users). And finally the *loading* of the vehicle targets the dimension of impacts on others/users and impacts on the user itself on his or her ride. For the judgments of a bus, mainly rational factors (F2-F5) share several attributions.

Table 24 Factor loadings of attributions of bus

Attribution	F1 (13%): Affective emotions/ concerns	F2 (12%): Vehicle aspects	F3 (12%): Service char.	F4 (11%): Impacts on others/users	F5 (6%): Impacts on the way
Importance	.812				
Value	.764				
Ease of use	.580				
Attractiveness	.530				
Security	.508				
Convenience (vehicle)	.461				.403
Age (vehicle)		.842			
Modernity (vehicle)		.774			
Space (vehicle)		.640		.391	
Easy to board		.601			
Routing			.725		
Frequency			.712		
Stop locations			.667		
Reliability			.541	.394	
Traffic flow			.459	.499	
Noise				.656	
Ride comfort				.610	
Environmental friendliness				.489	
Loading (vehicle)				.459	.492
Net design (orientation)					.677
Pace					-.443
Safety					

Tram

The five resulting factors for tram are similar to those of the bus and are composed as following (compare Table 25):

- Factor 1 (eigenvalue 3.201, 15% of variance) reflects rational vehicle aspects.
- Factor 2 (eigenvalue 3.169, 14% of variance) shows high loadings on affective emotional aspects and concerns towards tram use.
- Factor 3 (eigenvalue 2.296, 10% of variance) has high loadings on rational service characteristics.
- Factor 4 (eigenvalue 2.221, 10% of variance) represents mainly (expected positive) impacts from the tram on others and users and is partly loaded with affective emotional aspects (value, attractiveness).
- Factor 5 (eigenvalue 1.762, 8% of variance) accounts for impacts on the user on the way.

Six attributions load on more than one factor higher than 0.35. *Space* in the vehicle is dedicated to vehicle aspects and impacts the user on his or her way. The subjective attribution *reliability* is loaded on the factor of affective emotions but also on impacts on others/users (F4). Two further attributions that are rather emotional are loaded on both factors emotional aspects and impacts on others: *value* and *attractiveness*. *Safety* is dedicated to the factors affective emotions/concerns and impacts on the user on his way. Lastly, the aspect of *net design/orientation* is loaded on service characteristics and affective emotions/concerns. Rational factors are partly loaded with attributions that are dedicated as well to affective emotional aspects (F2).

Comparison

Assuming that there is no difference in the image of the two transport modes, it would be expected that the result of the factor analysis for bus and tram is equal. In fact, there is a high consistency and comparability of the resulting dimensions for bus and tram judgments. The factor solution has an explanatory power of about 55% of the variance of the judgments for bus and tram. The calculated factors are similar in attributions and they account for similar percentages of the variance within a range of +/- 2%. For a tram, vehicle aspects and affective emotional aspects get a slightly higher explanatory power of the variance than the same factors for a bus. The factor solutions show a structure for public transport attributions that is applicable for each mode, bus and tram.

Table 25 Factor loadings of attributions of tram

Attribution	F1 (15%): Vehicle aspects	F2 (14%): Affective emotions/ concerns	F3 (10%): Service char.	F4 (10%): Impacts on others/users	F5 (8%): Impacts on the way
Age (vehicle)	.815				
Modernity (vehicle)	.811				
Easy to board	.764				
Space (vehicle)	.664				.399
Convenience (vehicle)	.570				
Importance		.736			
Value		.669		.387	
Ease of use		.651			
Attractiveness		.603		.443	
Security		.541			
Safety		.496			.385
Reliability		.397		.564	
Net design (orientation)		.371	.569		
Frequency			.701		
Routing			.765		
Stop locations			.554		
Traffic flow				.705	
Pace				.647	
Environmental friendliness				.399	
Loading (vehicle)					.746
Noise					.617
Ride comfort					.531

Comparing the attributions of the different factors it can be seen that for a bus, subjective attributions are strictly dedicated to *affective emotional aspects* and concerns. For judgments of a tram these aspects additionally load on rational factors such as *service characteristics* and *impacts on others and users*. This leads to the assumption that judgments for a tram are less rational than those for a bus because they are mixed with subjective emotional aspects.

What is interesting is the dedication of the attributions reliability and traffic flow to the factor F4 and to the factor considering service characteristics for a bus in contrast to the tram where reliability is loaded additionally on affective emotions. The aspect of safety has no loading >0.35 for a bus and thus cannot be dedicated to one of the dimensions. In contrast, this attribution loads for a tram on affective emotions and impacts on the users.

In a nutshell, five dimensions of image attributes of public transport are revealed from the factor analysis. They can be distinguished in affective emotional aspects and concerns towards public transport use, rational aspects on different public transport characteristics, and impacts expected from public transport. These are:

- Affective emotions/concerns
- Vehicle aspects
- Service characteristics
- Impacts on others/users
- Impacts on the way

The five factors that have been calculated can be applied to the two public transport systems, bus and tram, with minimal differentiations as mentioned above. The fact that the attributions that constitute the five dimensions are almost identical for bus and tram and that the factors reveal similar explanations of variance for each factor leads to the assumption that these dimensions are applicable to public transport in general. Furthermore it is interesting to establish that the differences between dimensions of the general image of bus and tram are minimal.

7.3.3 General image of bus and tram

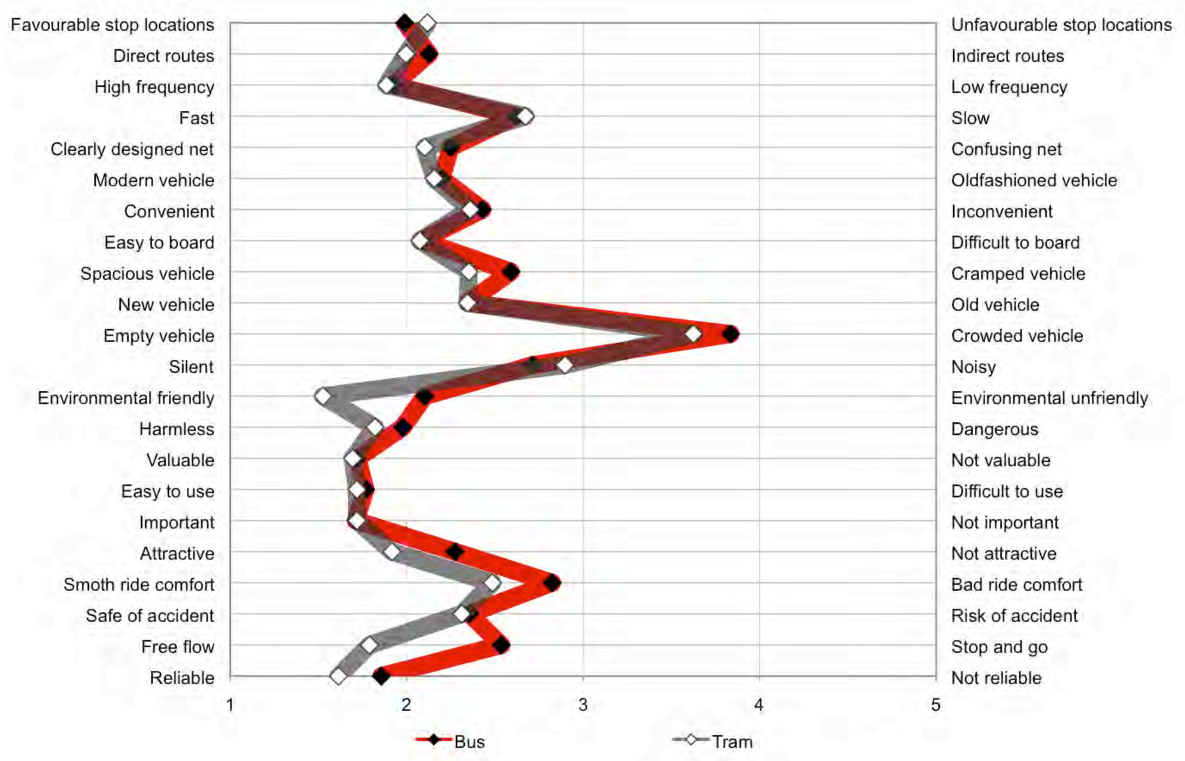
The general image of bus and tram constituted of ratings of 22 attributions is displayed in *Figure 24*. The calculated differences were tested for significance between each bus and tram attribution with a t-test. Judgments of 12 attributions turned out to differ significantly on a 5% level. The aspects with the highest difference in judgments concern *traffic flow, environmental friendliness and ride comfort* in favor for tram (compare Appendix A2).

The best scores for buses are found on the variables: *Importance, value* and *ease-of-use* and they turned out not to differ significantly from the scores of a tram. These attributions are affective emotional and express the appraisal of the mode.

In contrast, the best scores for trams target rather rational attributions: *environmental friendliness, reliability* and *value*. A tram achieves on average better (lower) scores on most of the attributions than a bus, except on the following attributions where a bus was rated better than a tram (see Table 4 and Table 5 in Appendix A2 for details on mean scores and significance test for differences):

- Stop locations
- Noise
- Pace

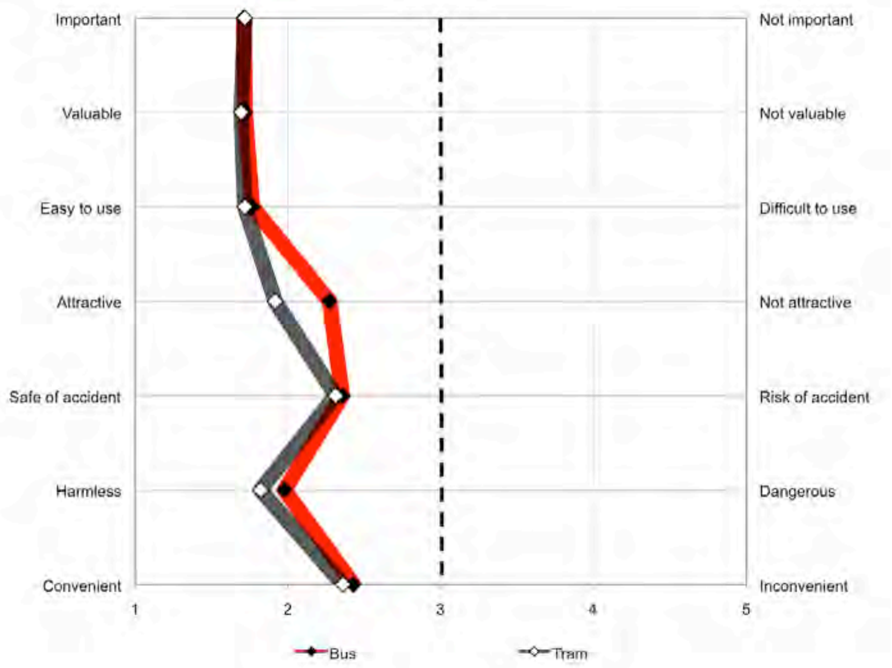
Figure 24 General image of bus and tram: overview



The following figures discuss the semantic differential of bus and tram on the five dimensions deduced from the factor analysis. Similarly to the classification by Steg et al. (2001), the figures are divided into affective-emotional aspects (*Figure 25*) and others that are described as rather rational-reasonable and descriptive (*Figure 26- Figure 29*).

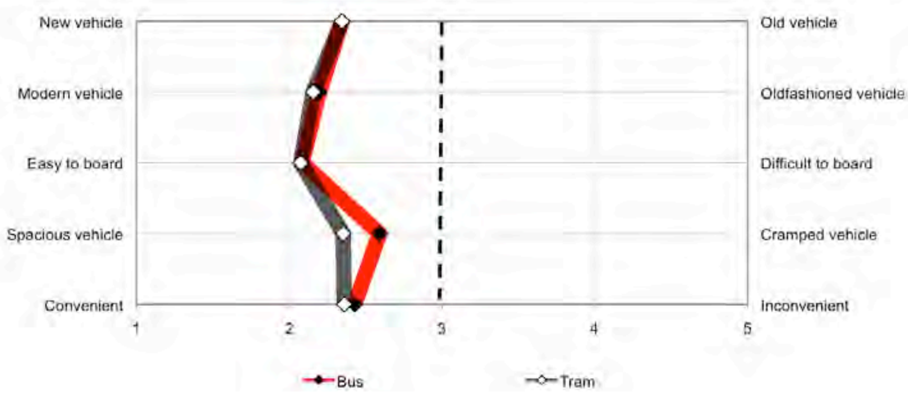
The main difference in ratings of affective emotional attributions for bus and tram concern the attribution *attractive-not attractive*. On this attribution, a tram is rated better than a bus. Differences in ratings of the other attributions in this category are small. As a conclusion, *affective-emotional aspects* of the image of bus and tram are similar and hence, the image is comparable for this dimension.

Figure 25 General image of bus and tram: affective-emotional



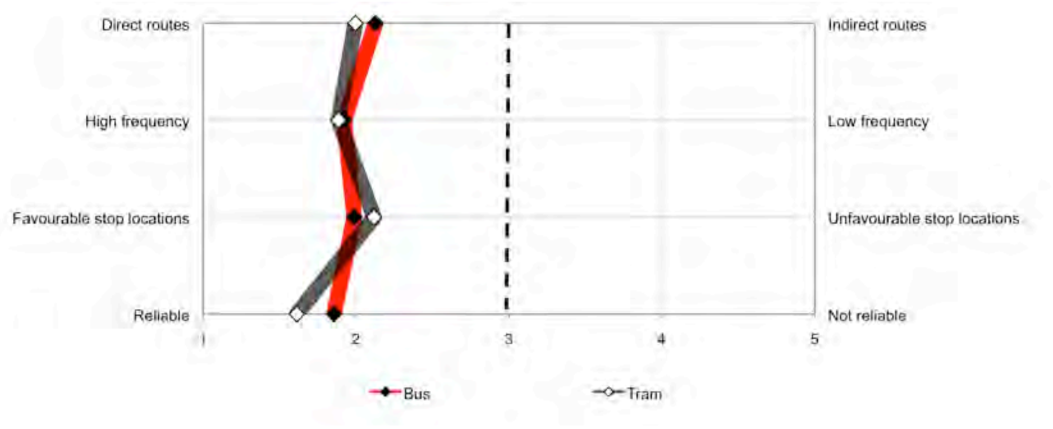
Regarding the second factor that comprises rational *vehicle aspects* (*Figure 26*), the attributions are rated the same for bus and tram with the exception of space in the vehicle. A tram is considered to be more spacious than a bus. Nevertheless the difference in ratings is small, though the class of the image considering the vehicle is similar for bus and tram.

Figure 26 General image of bus and tram: vehicle aspects



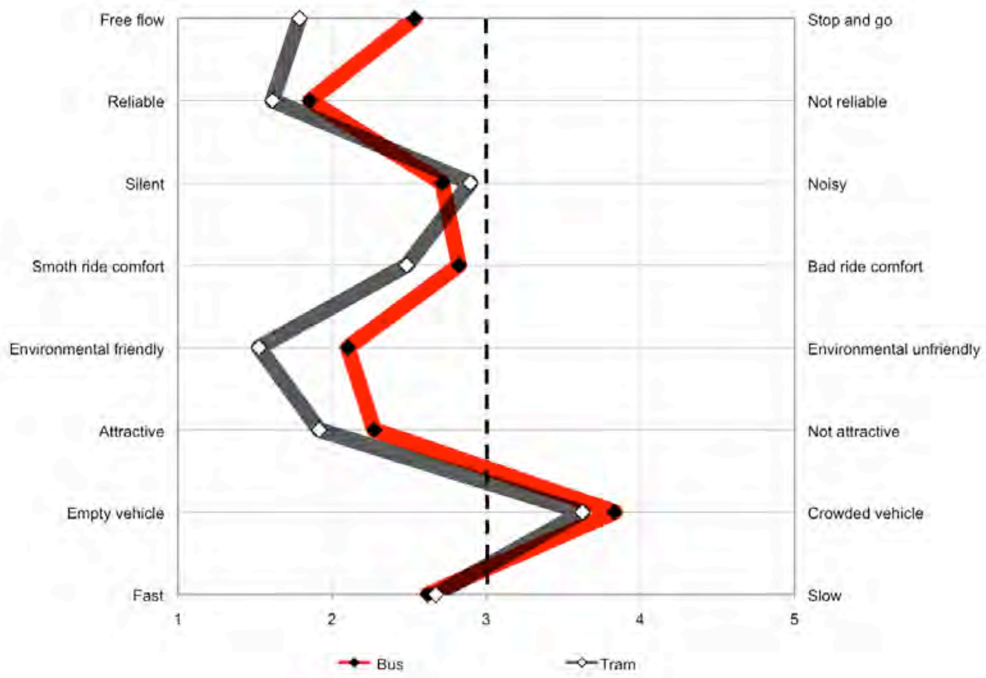
Service characteristics of bus and tram service hardly differ (*Figure 27*). Only *reliability* is rated better for a tram. As a consequence, this part of the image is considered as identical for bus and tram.

Figure 27 General image of bus and tram: service characteristics



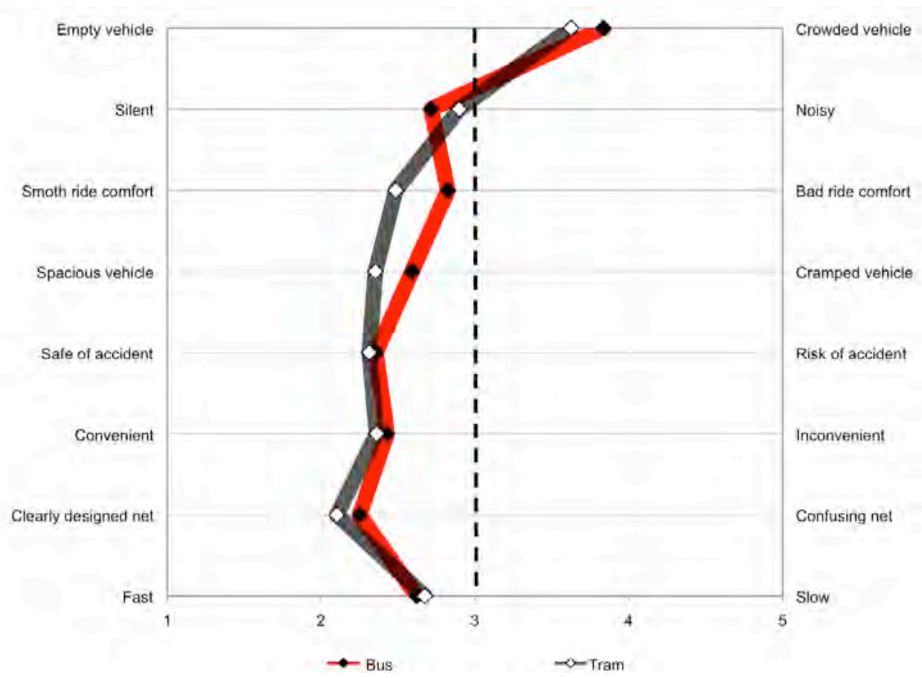
The highest difference in ratings for bus and tram can be on attributions that form the category *impacts on others/users* (*Figure 28*). In particular *traffic flow* and *environmental friendliness* are rated as significantly different for bus and tram. Also attributions with high loadings on two factors, such as *attractive* and *reliable* are listed in this category. Since these attributions show different ratings for bus and tram, the overall difference between bus and tram is the highest in this category.

Figure 28 General image of bus and tram: impacts on others/users



Attributions of the impacts on the way are rated similarly for bus and tram. The biggest difference affects ride comfort and space in the vehicle. However, the attribution of space in the vehicle is dedicated for tram in this category. For bus, this attribution is loaded only in the dimension of vehicle aspects.

Figure 29 General image of bus and tram: impacts on the way



It can be seen that there is a similar image of bus and tram considering *affective-emotional aspects*, *vehicle aspects*, *service characteristics* and *impacts on the way*. Only in the category described as *impacts on users and others* does the image between bus and tram differ. There seems to be a higher consistency in attitudes on affective-emotional aspects towards bus and tram than on the specific rational-reasoned aspects such as environmental friendliness, traffic flow, reliability, and ride comfort.

7.3.4 Differentiation of images by city

As Scherer et al. (2011a) found that perception and beliefs towards transport modes vary depending on experiences and locations, the subjects are classified for further analysis. Therefore images of bus and tram are analyzed separately for each city considered in the survey. In particular, differences in images between cities that are either served by bus or by tram are of interest for further conclusions regarding a rail factor.

The image of a bus is consistent for residents of the three cities (*Figure 30*). There are only marginal differences in ratings of the attributions by the residents of Berne, Zurich and Lucerne. In contrast to this consistent image of a bus, the image of a tram varies depending on the city (*Figure 31*). The range of tram ratings of the attributions is significantly wider than those of the bus.

Figure 30 General image of bus by cities

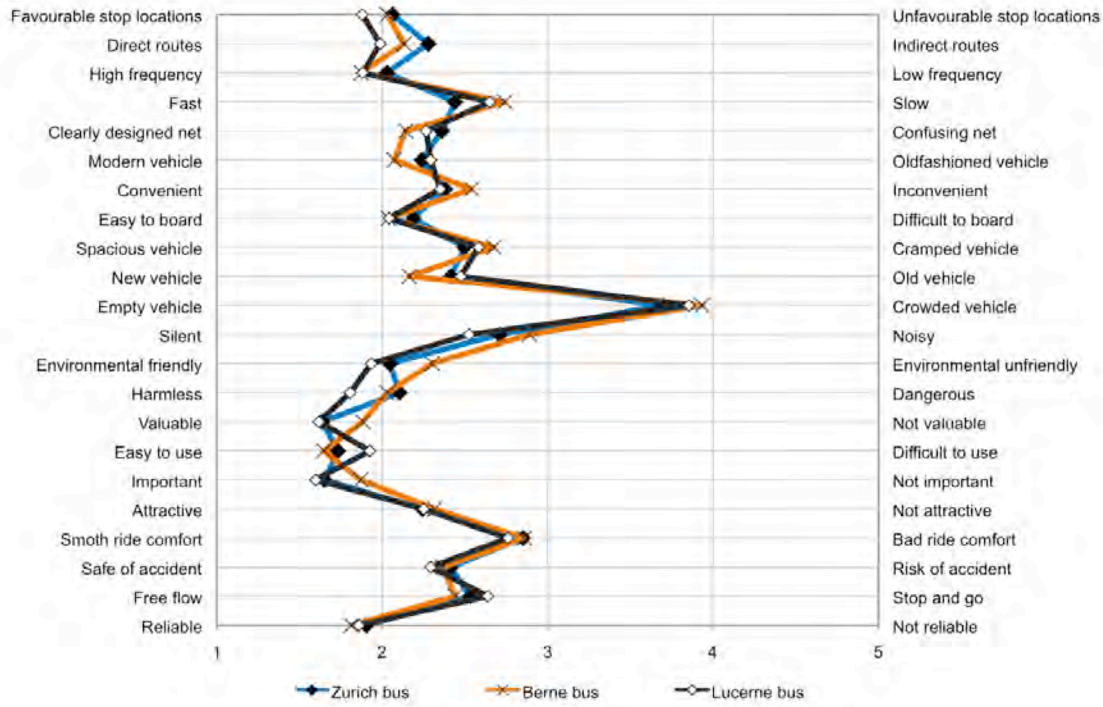
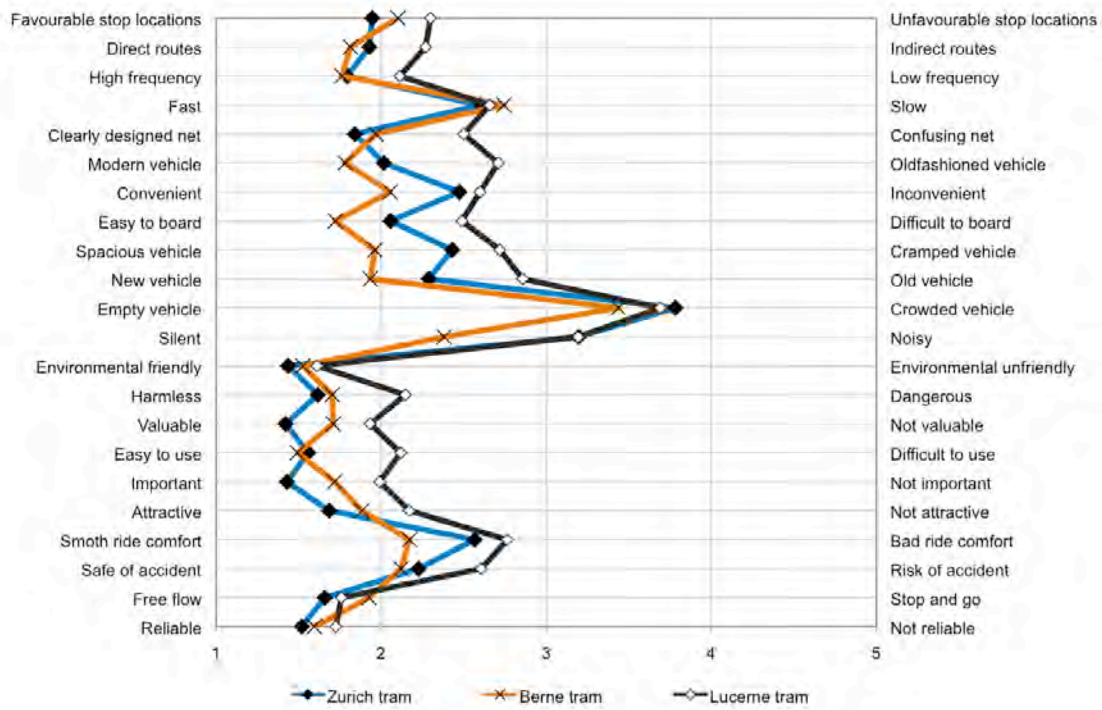
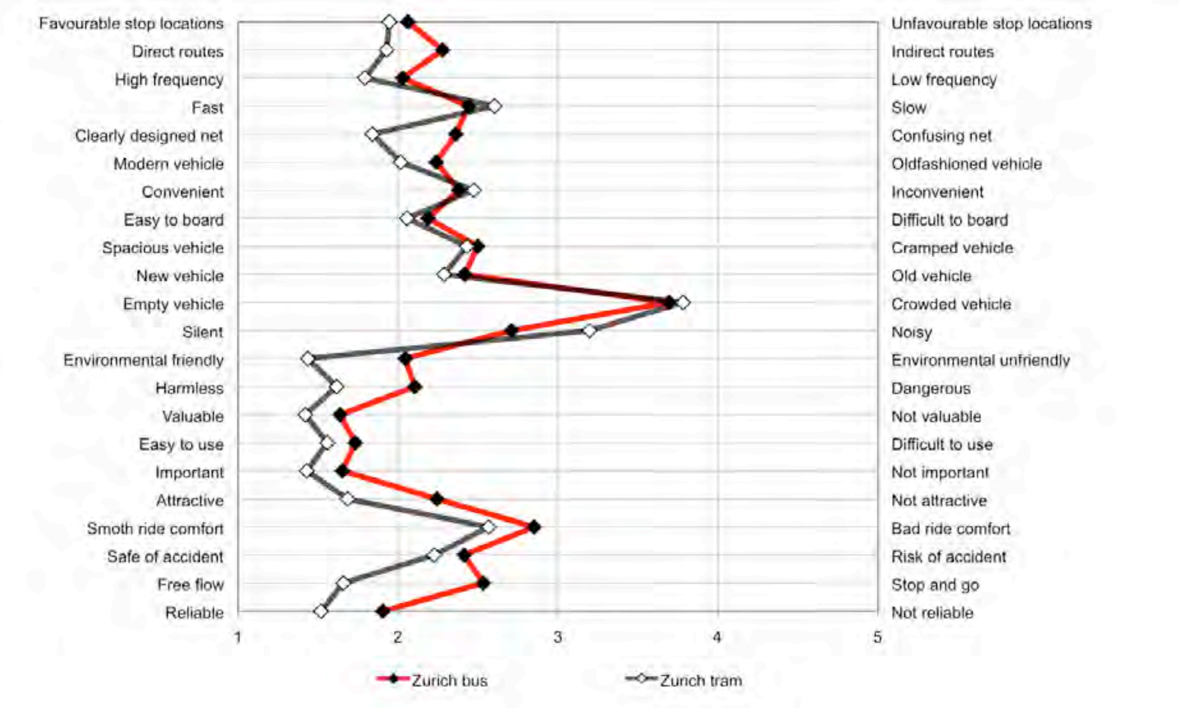


Figure 31 General image of tram by cities



Comparing the image of bus and tram city-wise leads to the semantic differential displayed in *Figure 32–Figure 34*. Whereas the ratings for a tram are generally better than those for a bus in Zurich and Berne, this picture differs for Lucerne. For Zurich, the highest differences in ratings occur for traffic flow (0.875), environmental friendliness (0.610), attractiveness (0.558), and net design (0.521).

Figure 32 Zurich: comparison of image of bus and tram



For Berne, differences in ratings on other attributions between bus and tram are most prominent: environmental friendliness (0.777), space in vehicle (0.713), ride comfort (0.687), and traffic flow (0.519).

Figure 33 Berne: comparison of image of bus and tram

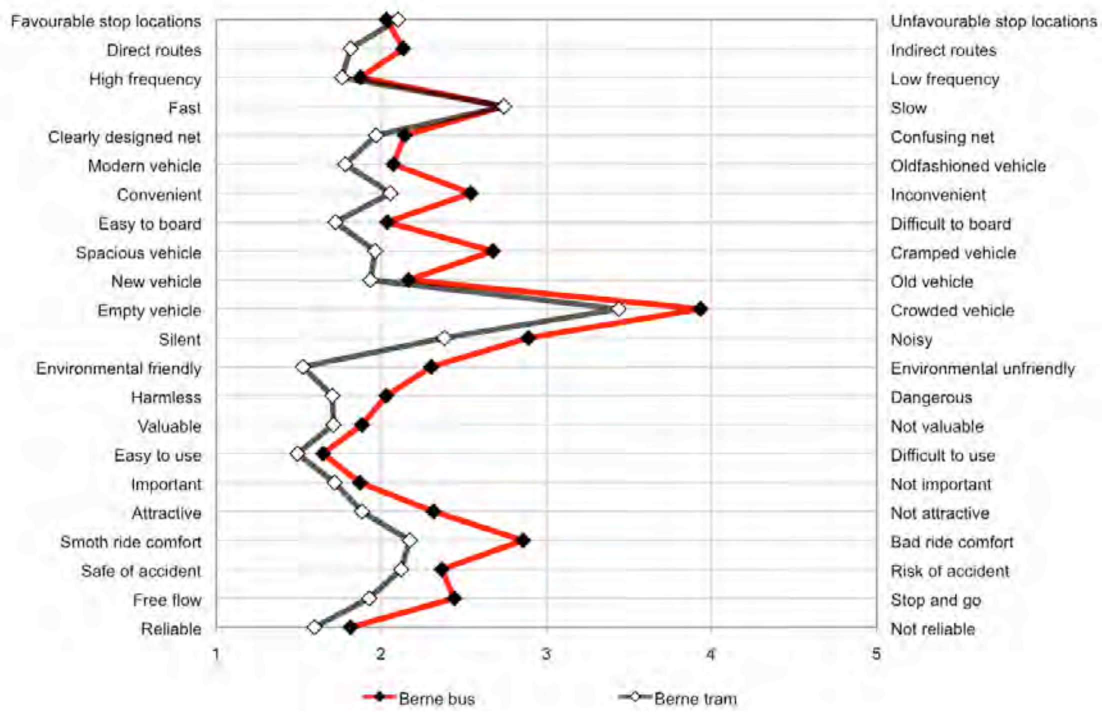
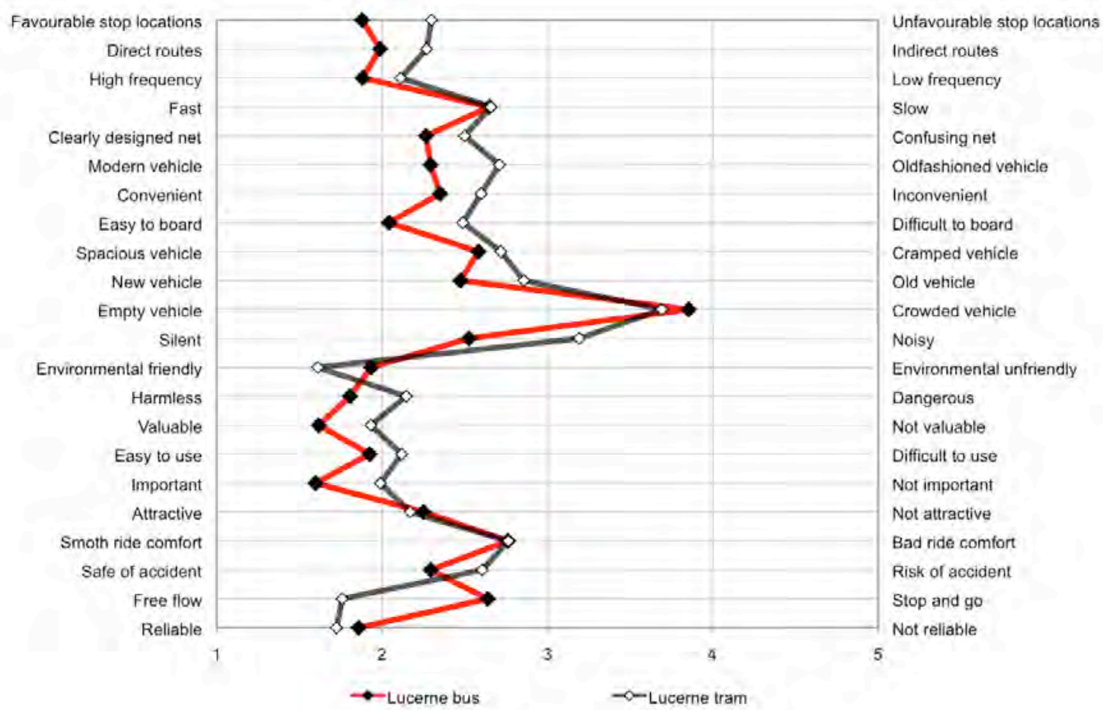


Figure 34 Lucerne: comparison of image of bus and tram



7.4 Discussion

7.4.1 Methodological limitations

Similar to the studies reviewed, the findings highly depend on the attributes used in the study. Although a broad literature study to collect attributions regarding the image of bus and tram and a preliminary web-based survey among over 500 Swiss residents to specify the attributions for Swiss cities were conducted, there might be aspects of the image that are neglected due to limitations of the item batteries.

Nevertheless the chosen attributions account for all aspects that were found in the previous studies to be relevant components of the schemata or image of bus and tram in Switzerland. Another source for biases is whether the respondents do have a common understanding of the attributions. However, since subjective judgments of the specific attributions are requested, this bias is accepted because it considers the variation of subjective beliefs and perceptions.

7.4.2 Conclusions

Mean score

The image of bus and tram constituted of 22 attributions was analyzed in depth in order to detect differences by using judgments from 663 respondents of a survey. The mean score of the bus and tram image over all respondents turned out to differ on a 5% significance level, although the difference is small.

Differences in ratings

The attributions that got significantly higher scores for tram than for bus are mainly traffic flow and environmental friendliness. There seems to be a general belief that electrified public transport systems are more environmentally friendly than motorized ones. This aspect is related to the traction and not to the tram itself so it is generally possible to provide environmentally friendly public transport service by bus. Nevertheless the image in terms of the picture in mind turns out that the majority of people rather combine a tram with environmental friendliness than a bus.

Considering the aspect of traffic flow, the better rating for a tram is explained by its right of way and its dedicated guideway. This is a rational advantage in cases where no bus lanes and no pedestrian crossings exist, since a tram does not operate according the rules of road traffic. This is an aspect that targets the law and is dependent on the legislation and not strictly system specific for a tram.

Against the background that e.g. the environmental friendliness is due to the electrification, which can also be the case for trolleybuses, and that the free flow is dependent on dedicated ways, some reasoned-instrumental attributions are partly not inherent in the system for a tram, but they reflect general public's sense of these systems.

The analysis of dimensions of judgments reveals that judgments of a tram might be less rational than those of a bus. Nevertheless since dimensions and their explanatory power for judgments are very similar between bus and tram it is assumed that the dimensions found are applicable for urban public transport modes in general.

In a nutshell, it is not possible to generalize a better image of a tram compared to the image of a bus. The two modes are judged similarly whereas a bus is rated more rationally than a tram, which shows higher affective emotional attributions that are mixed with rational aspects. This is especially the case for attributions that target the general public and public transport users. For a tram this dimension is partly affected by aspects that are subjective and emotional.

Familiarity and local conditions

As it is known from other studies that the image is influenced by experiences, the mean score differences were analyzed depending on public transport usage of the respondents. The better image of a tram compared to that of a bus is then only found in the group of frequent public transport users. The less the respondents use public transport modes the less is the difference in images. From this point of view no possible rail factor in terms of a better image of a tram can be ascertained from the data.

As Lucerne was the only non-tram city analyzed, a final assessment of whether residents of other bus-based cities share the same opinion is not possible for of two reasons. First, local conditions influence the rating for a bus (and a tram) and if the residents are content with the bus service the ratings for a tram may be lower. Second, depending on the experience of the residents a tram might get a higher rating if usual destinations for these residents lay in tram cities and/or if residents live close to tram cities (e.g. in conurbation of Zurich).

Impacts on behavior

Similarly to the findings of Cain et al. (2009), Steg et al. (2001), and Scherer and Dziekan (2012) it was revealed that affective emotional aspects are relevant for the image and hence are expected to influence mobility behavior. However, although affective emotional aspects are found to be relevant, it turned out that they do not significantly differ between bus and tram.

In contrast to the affective emotional aspects it is doubtful whether the aspect of environmental friendliness affects mobility behavior in terms of bus or tram usage. As it is known from the literature that respondents tend to give answers that are politically correct, and hence respondents rather pretend to act environmentally friendly, it is not clear whether this is a motive for tram use instead of bus use. Nevertheless more research is needed to explore the relation between images, respectively affective emotional aspects and mobility behavior in order to deduce conclusions about a rail factor.

Application of a rail factor

Since the repeating argument of a rail factor is often used by decision makers to support a modal switch towards public transport use by implementing a tram, the image of bus and tram of the group of occasional users and non users is highly relevant. With the current study we could show that these user groups do not have significantly better images of a tram than of a bus and so it is questionable whether they would change their mobility behavior in cases where all other service characteristics remain the same.

To the author's knowledge this is the first study that investigated the image of urban public transport systems of different user groups. With the growing traffic problems in urban areas it becomes more and more important to understand the attitudes of different stakeholder groups that are affected by traffic. This allows for the provision of transport solutions that correspond with specific stakeholder groups. Therefore, for further research, enhancements with different segmentations of public transport users and non-users are recommended.

8 TRAVEL BEHAVIOR IN BUS AND TRAM CORRIDORS

This chapter is based on the following documents:

Scherer, M. and U. Weidmann (2011) Differences in travel behavior and demand potential of bus and tram based neighbourhoods. Evidence from a cluster analysis, Transportation Research Record, 2217, 1-10.

Scherer, M. (2010b) Tram or Bus: Analysis of revealed preference data, workingpaper, Institute for Transport planning and systems (IVT), ETH Zurich, Zurich.

8.1 Overview

8.1.1 Introduction

While some studies presented in chapter 2 established a rail factor, methodological problems call into question these findings. More specifically, modeling studies based on stated preference data depend highly on the attributes applied in the experiments. Ben-Akiva and Morikawa (2002) suppose that sources of a rail preference may be usually neglected attributes.

Before-and-after studies face the problem of bias, since the implementation of a new public transport system is usually accompanied by changes in other service elements such as stop locations, access and egress times, and frequency. Thus, there is often a lack in comparable level of service, which makes it difficult to determine the system-dependent contribution to any increase or decrease in demand (i.e. is it the fact that public transport is rail-based or that it operates at a higher frequency what increases demand?).

Furthermore, sociodemographic changes and higher spatial development activities have been observed around new rail stations. These changes and developments in demand potential lead to higher effective demand. This is accompanied by different travel behavior than before the implementation.

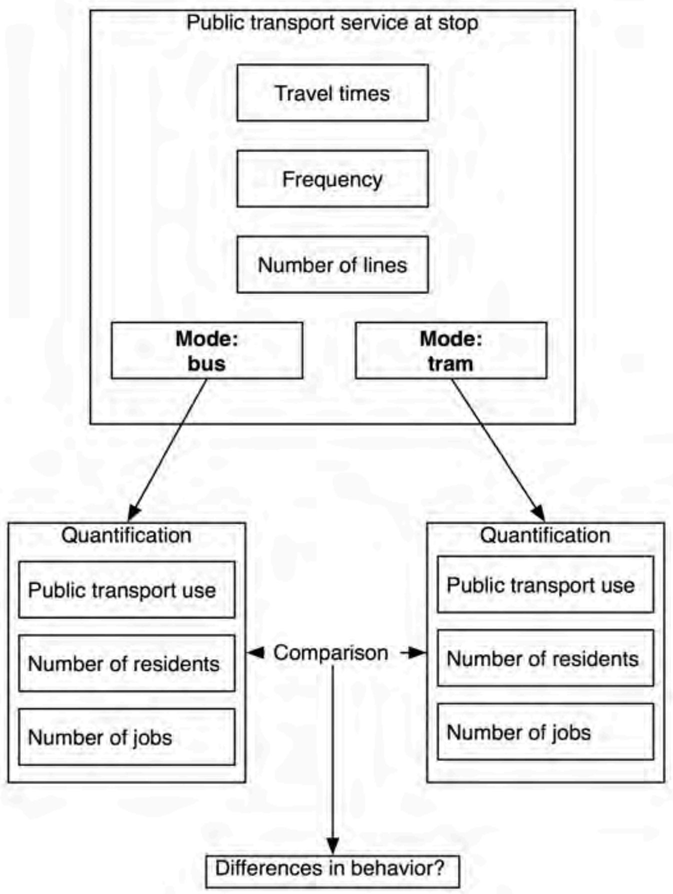
Considering the success of newly implemented systems in France (compare chapter 2.3) and the findings that a new (tram) system is more salient due to its newness and repeated (public) discussions of infrastructure investments, it is expected that every newly implemented system will attract attention within the first period after implementation. In contrast to short-term effects, long-term effects have rarely been investigated. It is of great interest to compare established public transport systems in order to draw conclusions on possible effects after the implementation period. For this reason, the focus of this chapter lies on the long-term demand effects of tram systems compared to bus systems. Therefore reactions towards established public transport services are analyzed in terms of mode choice behavior and demand potential expressed as numbers of residents and number of jobs.

For that purpose a new approach is followed. Assuming that a rail factor affects mode choice behavior, mode choice should be different in rail-served public transport corridors compared to bus-served corridors, all other aspects being the same. Based on this assumption, mode choice is analyzed with respect to the availability of bus and tram.

8.1.2 Approach: Comparable level of service of bus and tram

As experiences and habits influence the image of public transport, it might be expected that these factors also affect mode choice behavior. Thus, it is supposed that residents react to the public transport service provided in their neighborhood. Given an assumed rail factor, a higher public transport use is expected of residents living close to rail-based public transport services compared to that of residents living close to bus services, all other service characteristics being the same.

Figure 35 Approach to compare mode choice behavior



Therefore a method that allows a comparison of bus and tram on the level of public transport stops is required. The hypothesis behind the comparison of similar stops of bus and tram is the assumption of choice theory that potential passengers (mainly residents and employees in the specific area) are expected to react mainly to provided service elements in their surroundings.

8.1.3 Method: Cluster analysis

Cluster analysis enables researchers to detect patterns in a multivariate dataset by identifying clusters with similar characteristics. The method has been applied to many different fields including management research, spatial planning and transport analysis. Fielding et al. (1985) used cluster analysis to develop a typology for bus-based public transport based on performance criteria. Another example is the cluster-based study of Karlaftis and McCarthy (2002) on public transport system cost structures.

Cluster analysis is the chosen method to define groups of similar stops. This explorative method is convenient to cluster objects based on more than two variables. The assumption behind this clustering is that clusters based on comparable public transport service should also show similar structures of demand, given the same demand potential (e.g. residential density, job density). Hence appropriate clustering constitutes the basis for subsequent analysis and modeling.

The main aim of the cluster analysis is to classify stops with direct services to the city center. Clustering allows the detection of similar observations, in this case the identification of stops that provide comparable public transport services. The different clusters are analyzed in order to investigate differences and similarities between variables of bus-based and tram-based stops. Data from 209 stops are used as input for the cluster analysis

The cluster analysis is applied to well-established public transport networks, which reduced the impact of system “newness” on reactions. This is important because most public transport-related economic benefits and changes in land use structure and socioeconomic patterns occur in a short time following project implementation; these effects are expected to have declined over the years of operation. In summary, the cluster analysis procedure allows for an investigation of a rail factor independent from benefits coming with new rail-based public transport investments.

Based on clusters with comparable level of service conditions between bus and tram, further data analysis is conducted. This implies data about mode choice behavior and demand potential for transport. Data is applied from the case cities Berne and Zurich that have bus and tram services and from the bus served city of Lucerne. The considered cities Zurich and Berne are the largest cities in Switzerland that are not located on the border with another country. Both cities have extensive urban public transport systems with service provided by both tram and bus. Additionally the city of Lucerne is analyzed in order to compare the results of Zurich and Berne with a solely bus-based city (compare 5.1.2).

8.2 Clustering of similar public transport service

8.2.1 Preparation

Cluster analysis requires several methodological decisions and considerations that will be described in the context of the current research in the following subsections:

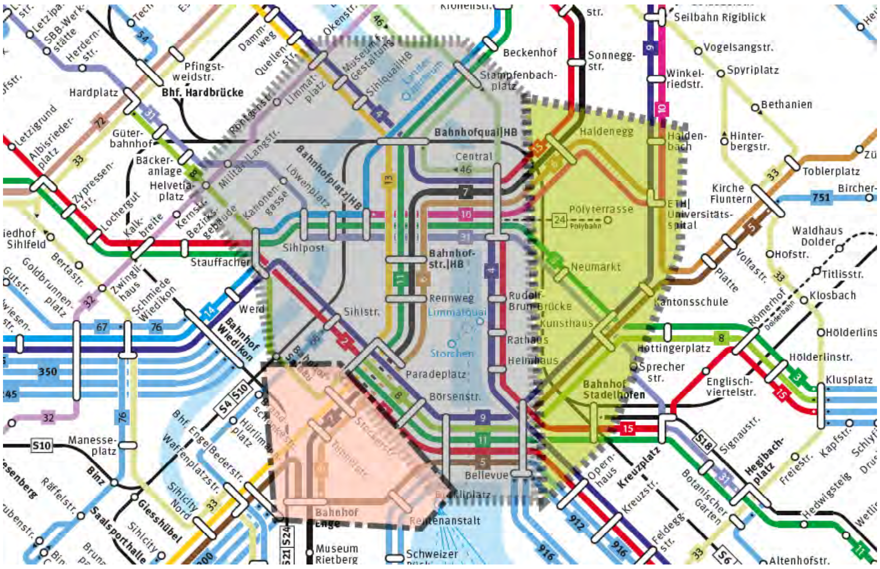
1. Selection and treatment of clustering variables;
2. Choice of appropriate clustering algorithm;
3. Decision about number of clusters;
4. Discussion and validation of clusters.

Clustering variables

The clustering variables are defined as the main service characteristics of the public transport stop. These characteristics are: travel times to destinations, frequency, and number of lines serving the stop. Because the number of service variables is small and there is no evident correlation between them, no factor analysis was conducted to reduce the number of clustering variables (Backhaus et al. 2000).

Travel time is considered as the most important variable in mode choice. Since travel time data from origin to destination is not suitable for classifying public transport stops, the relative travel time from a stop to the city center was used. In this case the city center is defined as an area bordered by gateways. These gateways are railway stations, public transport stops surrounded with a high amount of workplaces or other central points like theaters and hospitals (for details see Scherer 2010b). To test the sensitivity of the city center area, different borders have been tested for the three case cities (e.g. Zurich, *Figure 36*)

Figure 36 Different borders of the city center area (Zurich)



Travel times from each stop were expressed as the shortest average travel time to the boundary of the city center determined from public transport timetables. Only stops that offer direct connections to the city center area with travel times greater than 3 minutes are taken into consideration.

Frequency of service is an important factor but was removed from the set of clustering variables because the urban public transport systems considered are mostly based on equal headways. During the analysis period the standard headway in Berne, Zurich and Lucerne was 6 minutes and 7.5 minutes on specific lines.

The *number of lines* consists of the number of public transport lines that serve the specific stop. A distinction is made between buses and trams. Also, very importantly, only bus routes that provide a high level of service (i.e. use high capacity vehicles and serve inter-zonal trips) were considered in the analysis, since buses with lower service levels would reduce the similarity of the bus and tram service.

As shown in the overview of clustering variables in Table 26, Zurich has a 2-minute higher mean travel time to the city center boundaries than Berne (including the municipalities Ostermundigen and Köniz) because of its larger size. Lucerne (including the municipalities Kriens and Emmenbrücke) is slightly smaller.

Table 26 Characteristics of clustering variables

Stop characteristics (outside city center area)	Zurich	Berne	Lucerne
Average travel time from stop to city center boundary (min)	10.6	8.6	7.9
Range of travel times (min)	4-23	4-20	4-16
Average number of direct bus lines per stop	0.83	0.98	1.37
Range of direct bus lines per stop	0-3	0-3	1-5
Average number of direct tram lines per stop	1.09	0.28	0
Range of direct tram lines per stop	0-4	0-2	0
Stops			
Total number of stops in service area	451	310	271
Stops with direct connections to city center	213	130	80
Considered stops outside city center area (travel time > 3 mins)	148	93	51

With regard to the average number of bus lines and tram lines serving a stop, it can be seen that Zurich has a higher share of stops served by trams than Berne. Berne has a higher focus on bus public transport. And Lucerne has no tram services and hence the highest share of stops served by bus. Finally, standardized values in terms of transformed Z-scores were applied for the calculation because travel times have a significantly higher range than the number of bus and tram lines (4-23 minutes compared to 0-4 lines) respectively, because the input variables are measured on different scales.

To determine outliers, a hierarchical cluster analysis applying the single-linkage or nearest neighbor method was conducted. This method has the nature to agglomerate extreme values in the last steps of the clustering which serves to identify outliers.

Clustering algorithm

How data points are assigned to a cluster depends on the chosen cluster algorithm. Therefore different mathematical procedures exist, such as combining data with a minimal variance to a cluster or by adding a data point with minimal difference to a cluster center. The measure used to determine the distances in clustering was Squared Euclidian distance for every clustering algorithm.

The SPSS statistical software was used to compute the clusters. The resulting clusters of various hierarchical cluster algorithms are compared in order to support the choice for one algorithm (see Scherer 2010b for detailed discussion and visualization of cluster algorithms). The validation of the chosen cluster algorithm is supported with the calculated Rand index; the Rand index represents the similarity between pairs of clustering resulting from two different methods (Rand 1971).

Finally, Ward's algorithm, which is based on the increase of the variance between clusters, showed the best results and therefore was chosen for subsequent work. The choice of this algorithm is supported by its application in most other cluster analyses that have been reviewed. Nevertheless, possible outliers were checked each time using the single-linkage algorithm.

Number of clusters

The number of clusters (k) was determined using two methods. First the number of clusters was roughly estimated using equation (4.1) where n represents the number of data points (Mardia et al. 1979):

$$k = \sqrt{\frac{n}{2}} \tag{4.1}$$

The second method consisted of making a visual observation of the dendrogram and the change of agglomeration coefficient of cluster numbers around the estimated k (Janssen and Laatz 2010, p494). For the case of Zurich (n = 148) k = 9 clusters were determined, for the case of Berne (n = 93) k = 6 clusters resulted and for Lucerne (n = 51) the optimal number of clusters would be 5. The final number is reduced because two clusterings were quite similar and resulted in one cluster when choosing k = 4.

8.2.2 Resulting clusters

The characteristics of the public transport service of the clustered bus and tram stops are summarized in Table 27. Nine clusters result, whereas for the city of Lucerne only bus-based clusters exist.

Cluster 0: City center area.

Cluster 1: Very short travel time, bus, tram – public transport stops very close to the city center area and that are served by several bus and tram lines. The maximum travel time to the city center boundaries is 6 minutes. Public transport lines from different directions gather together at these stops in order to share the route to the center area.

Cluster 2: Short travel time, tram – tram-only stops that are close to the city center. The maximum travel time to the city center border is 12 minutes and the average travel time is about

6.5 minutes. Regarding the classification of the Berne data, these clusters can be compared to the Zurich data on the basis of travel times but they differ in the number of tram lines serving the stop. Since the Zurich cluster is based on two tram lines and Berne on one line, the Berne group can also be assigned to cluster 6.

Cluster 3: Short travel time, bus – bus-only stops with a range of travel times similar to those of cluster 2 (the mean travel times differ by less than 1.25 minutes). Due to the short travel times, these stops are located relatively close to the center area.

Cluster 4: Short travel time, multiple buses – stops served by two or more bus lines with average travel times similar to those of clusters (2) and (3). The difference here lies in the plurality of public transport opportunities based on buses.

Cluster 5: Short travel time, bus, tram – stops served by both bus and tram lines with travel times in the same range cluster 2-4. The main characteristics are that the stops in this cluster are served by both bus and tram lines.

Cluster 6: Short travel time, tram – this group of stops is similar to cluster 2, but is based on a single tram line and has slightly longer travel times.

Cluster 7: Medium travel time, bus, trams – this group of bus and tram stops is characterized by a medium travel time to the city center area. As all tram lines in Berne are relatively short, there is no cluster for Berne in this category.

Cluster 8: Long travel time, bus – stops in this cluster are the furthest away from the center area and served only by bus. The travel time to the city center area is over 11 minutes.

Cluster 9: Long travel time, trams – this cluster is characterized by the longest travel times to the center area, similar to cluster 8. The difference is that service is based on trams. This group also does not exist for Berne.

In order to investigate whether a rail factor exists, the following clusters are of main interest:

- Clusters 2 and 6 (tram) in comparison to clusters 3 and 4 (bus) with short travel times
- Cluster 9 (tram) in comparison to cluster 8 (bus) with long travel times.

Table 27 9 clusters distinguished by number of tram lines and bus lines and travel times

Cluster description		Zurich No. of stops	Zurich Mean	Berne No. of stops	Berne Mean	Lucerne No. of stops	Lucerne Mean
(1)	Travel time		5.33		4.50		4.50
Very short tt	Buses	3	1.67	2	2	6	2.5
Bus and tram	Trams		3.67		2		0
(2)	Travel time		6.76		*6.33*		
Short tt	Buses	17	0	*18*	*0*		
Tram	Trams		2		*1*		
(3)	Travel time		8.00		6.75		5.64
Short tt	Buses	13	1	36	1	25	1
Bus	Trams		0		0		0
(4)	Travel time		8.09		8.23		
Short tt	Buses	11	2.36	13	2.08		
Several buses	Trams		0.18		0		
(5)	Travel time		8.11		6.75		
Short tt	Buses	19	1.63	4	1		
Bus and tram	Trams		2.05		1		
(6)	Travel time		9.16		*6.33*		
Short tt	Buses	32	0	*18*	*0*		
Tram	Trams		1		*1*		
(7)	Travel time		12.88				9.20
Medium tt	Buses	25	1.28			10	1
Bus and tram	Trams		1				0
(8)	Travel time		16.33		14.85		13.00
Long tt	Buses	12	1.33	20	1	10	1
Bus	Trams		0		0		0
(9)	Travel time		17.25				
Long tt	Buses	16	0				
Tram	Trams		1.19				
Total	Travel time		10.57		8.57		7.9
	Buses	148	0.83	93	0.98	51	
	Trams		1.09		0.28		0

The location of the resulting clustered stops and hectare areas of the three cities is displayed in *Figure 37-Figure 39*.

8.2.3 Data and data assignment

Input data

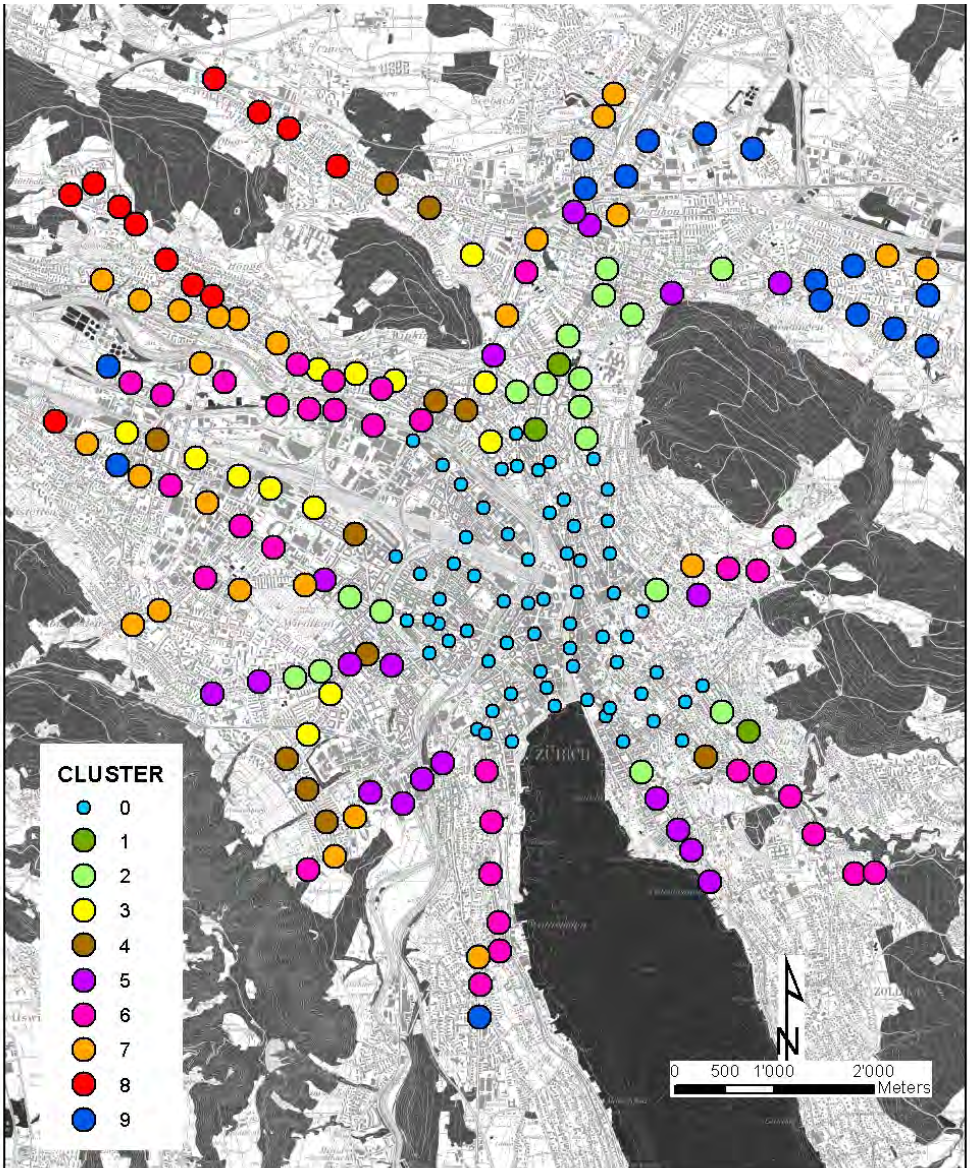
The sources of the structural and behavioral data are the Federal Population Census 2000 and the Business Census 2005 of Switzerland (BfS). The Federal Population Census reveals the demographic, spatial, social and economic conditions in Switzerland. The statistical basis is individuals, households and employed persons. The Business Census is a complete census and contains microdata about businesses in Switzerland. Both datasets are aggregated and available on a hectare basis.

The main types of data used in this analysis were data that indicate transportation demand potential, such as number of residents and jobs, as well as commuting behavior data. The census data was used to calculate public transport mode split for commuters. This variable was considered best for the research since this group generally has a greater choice of transport mode to work compared to students or the elderly.

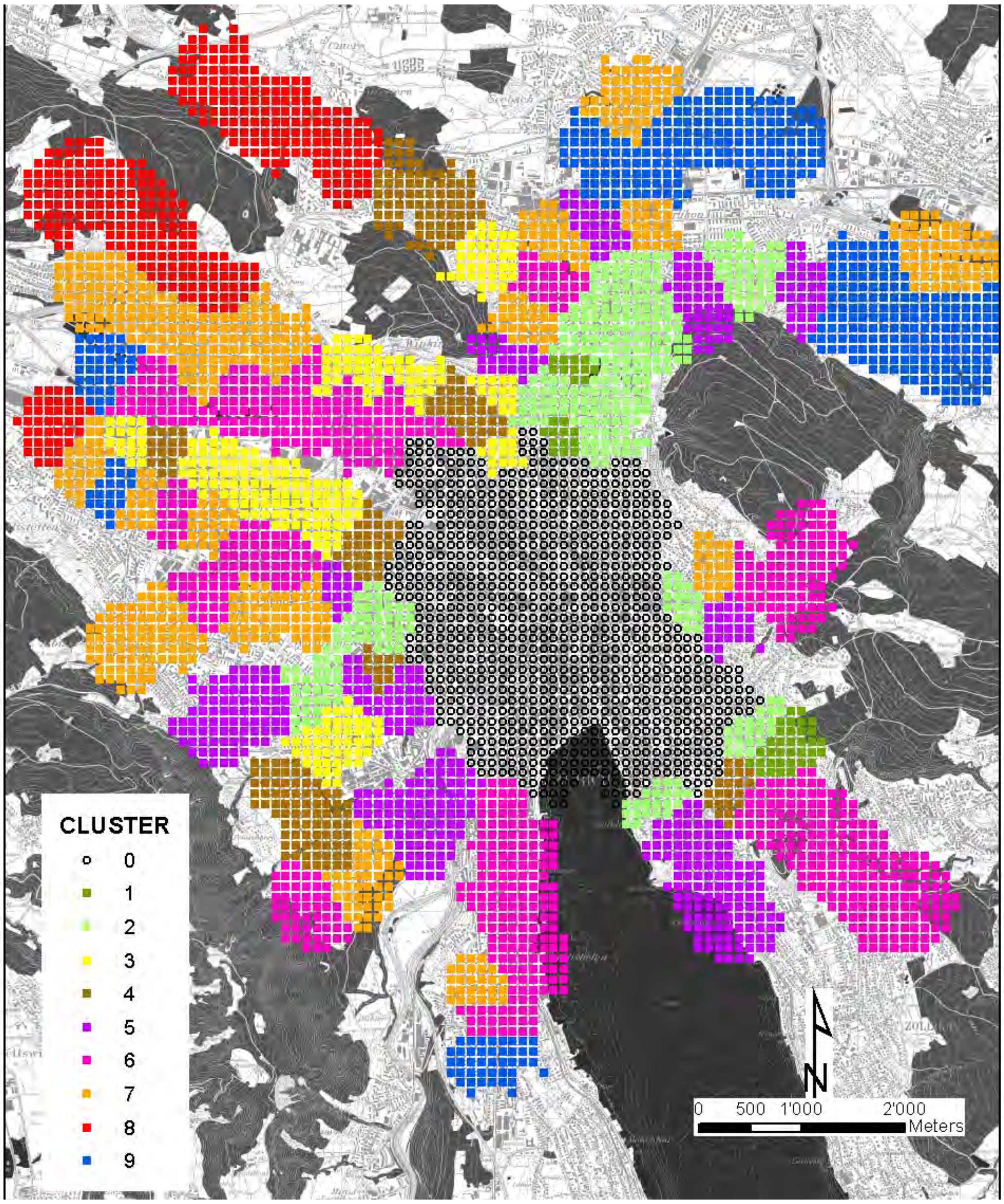
Data joining to stops

The next step was assigning the hectare-based data to specific public transport stops. Recognizing that public transport passengers react to the public transport services in their neighborhood, the research started by considering the closest stop to the middle of the census hectare raster by applying the "nearest-function" in the geographical information software ArcGIS. However, since the closest stop could be one with a lower level of service than those stops considered in the clustering analysis (i.e. higher service level stops), it was necessary to consider corrections (see Scherer and Weidmann 2011).

Figure 37 Resulting stop cluster and dedicated hectares in Zurich

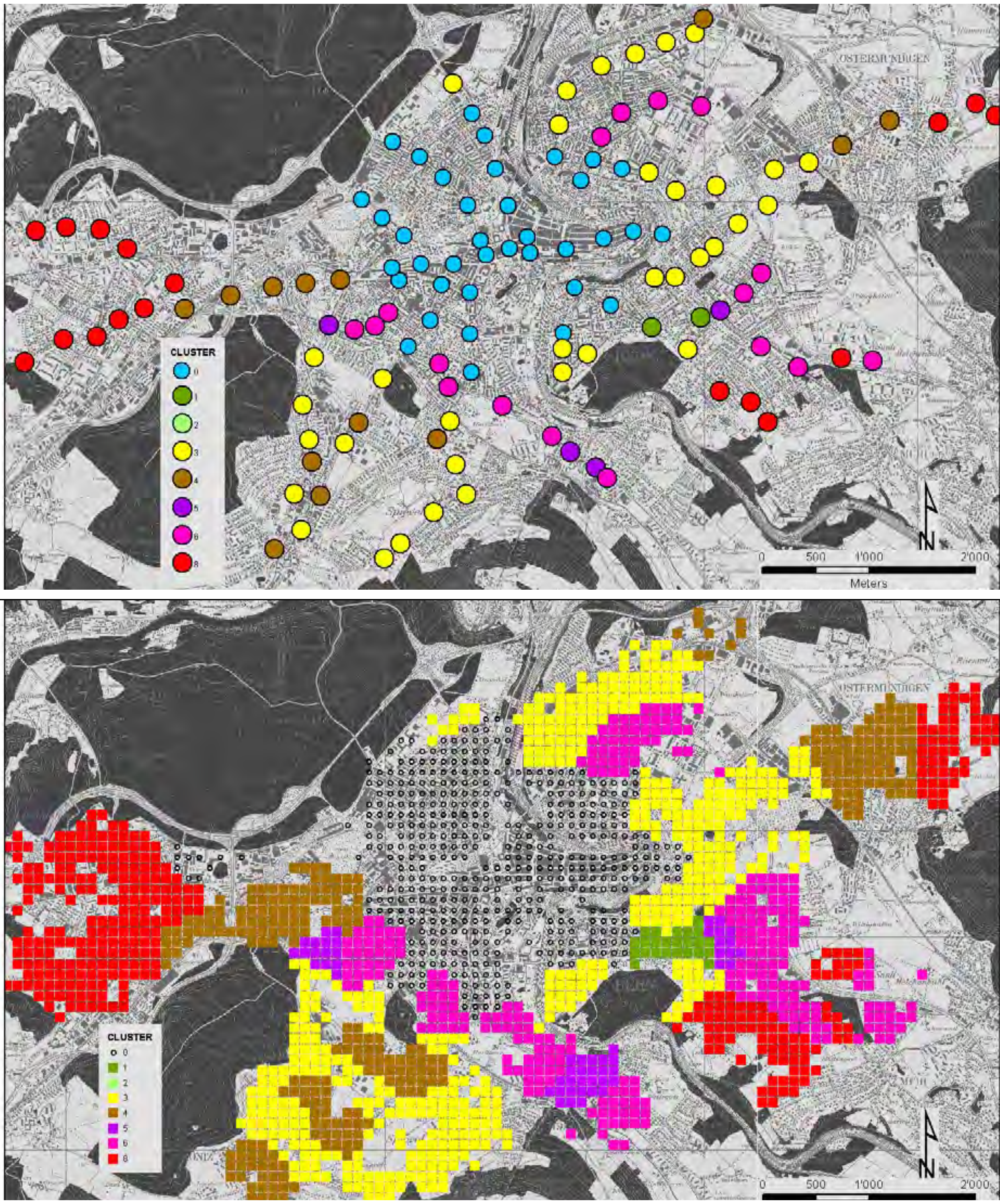


Map source: Swisstopo



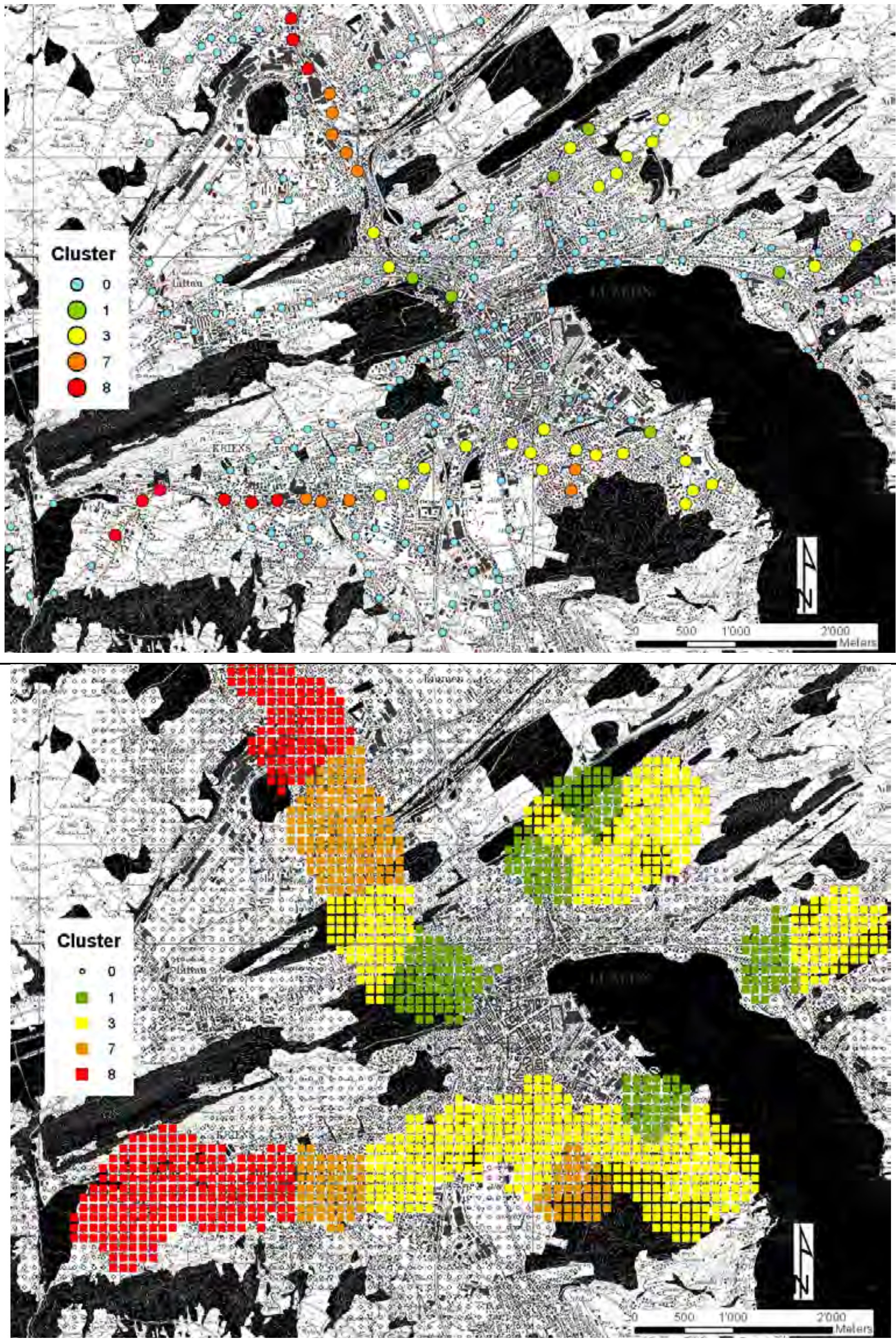
Map source: Swisstopo

Figure 38 Resulting stop cluster and dedicated hectares in Berne



Map source: Swisstopo

Figure 39 Resulting stop cluster and dedicated hectares in Lucerne



Map source: Swisstopo

8.3 Demand potential and public transport use in clusters

8.3.1 Stop catchment area statistics

Two types of data were considered in the analysis: socio-demographic data (number of residents, number of jobs, and company size expressed as employment per company) and transport data (mode split on public transport for commuters).

The average range of residents per stop (within a maximal radius of 500m) in the clusters considered is between 800-2,000. The average employment figures per stop are 300-600 and average company size per stop is between 50 and 130 employees per company. Furthermore, the average public transport use of commuters living in the catchment area of a stop is between 41-48% in Zurich and 52-57% in Berne.

Based on the hypothesis that similar clusters with comparable public transport services follow similar spatial characteristics, selected cluster have been compared. Therefore the analysis was based on the means of aggregated data. Hectare cells were aggregated stopwise according to dedicated clusters. The result is data based on each stop. Against the background of the null hypothesis "the distribution of the variable is the same across comparable clusters" the variables residents, jobs and mode choice for work trip are analyzed in detail.

8.3.2 Residents

Residential data per stop in clusters was found to follow a normal distribution and the Levene's test of homogeneity of variances turned out to be highly significant; hence the variances are too different across the data. As a consequence non-parametric tests were conducted to detect differences in residential distribution across clusters that differ by transport mode and across cities.

Comparison of tram-bus clusters: The null hypothesis is that the distribution of residents is the same across clusters to be compared. A Mann-Whitney U-test was applied to the data. The distribution of residents is in most cases not significantly different across bus and tram clusters on a 0.05 level, thus the null hypothesis is not rejected (compare Table 7 in Appendix A3). These results assume that bus and tram are not drivers for significant differences on the residential development. Otherwise there more differences in residential distribution between bus clusters and tram clusters would be expected.

8.3.3 Jobs

Data regarding number of jobs per stop almost follow a normal distribution. Furthermore, the homogeneity of variances is not given regarding the results of the Levene's statistics. Hence non-parametric test are conducted. The results are displayed in Table 8 in Appendix A3).

Comparison of tram-bus clusters: The null hypothesis is that the distribution of jobs is the same across clusters to be compared. A Mann-Whitney U-Test was applied to the data. The pairwise comparison showed that the distribution of jobs is not significantly different across clusters on a 0.05 level. The conclusion is that there is no difference in job numbers between similar bus and tram clusters. There are not significantly more jobs close to tram stops compared to job numbers in the catchment area of buses.

8.3.4 Mode choice for work trip

Commuter data is analyzed in terms of transport mode for work trips. The share of public transport usage of a stop in a cluster is expressed in the current study as ratio of commuter by public transport per commuter. Since only mode choice for work trips could be considered with the data available, the effect of leisure trips is not known.

A Mann-Whitney U-Test was applied to the data. The pairwise comparison showed that the distribution of mode choice is not significantly different across clusters on a 0.05 level. One exception is the tram cluster in Zurich (6) which shows significant higher public transport user rates than the comparable bus cluster (3) and, considering the bus cluster with several bus lines (4), the difference in public transport usage is significant on a 10% level.

8.4 Discussion

8.4.1 Method

An important part of using cluster analysis is considering whether or not the clusters are representative, i.e. whether the data points in the cluster are similar and can be considered together in the analysis. In this research the cluster validity was tested during the algorithm choice process.

Cluster reliability was ensured in two ways. First, different hierarchical clustering methods were used to calculate the clusters and then the resulting clusters were compared. Second, the clusters were compared with clusters computed using the k-means method. The final clusters computed with the Ward algorithm were found to be representative for Zurich. Additionally it was found that the same clustering system can be applied to the data from Berne and Lucerne in order to achieve comprehensible clusters.

After ensuring that the cluster descriptions show the representative characteristics of the three input variables it is possible to use the η coefficient to evaluate the strength of the relationship between cluster membership and each input variable (Fielding et al. 1985).

The eta coefficients for the cluster input variables used in this research are as follows:

$\eta_{\text{Travel time}}$ = 0.803 for Zurich and 0.849 for Berne (total 0.866)

$\eta_{\text{Number of bus lines}}$ = 0.902 for Zurich and 0.987 for Berne (total 0.878)

$\eta_{\text{Number of tram lines}}$ = 0.970 for Zurich and 1.000 for Berne (total 0.828)

As shown the eta coefficients are between 0.8 and 1.0, indicating a high correlation between variable and cluster dedication.

The three input variables for the clustering are analyzed with regard to their effect on the resulting clusters. Whereas the number of lines is not affected by changes, the variable travel time to the city center area is highly dependent on the definition of this area. The effect of different definitions of the city center area, respectively of the bus and tram stops that form the entrance to this area, was considered by three different assumptions of the city center area borders.

Considering the criterion-related validity, this is often assessed through significance tests with external variables that are not part of the clustering variables (Ketchen and Shook 1996). Although other cluster-related variables were not available, criterion-related validity can partly be tested by comparing cluster specific socio-demographical variables.

8.4.2 Summary of findings

A pairwise multiple comparison between each cluster was conducted to estimate the significance between mean values of the clusters using SPSS. The ANOVA and multiple comparisons between each pair of clusters per city showed no significant differences in the distribution of data. For those clusters that only differ by public transport mode as introduced in the cluster section, the following findings are outlined:

- The differences of means for public transport usage are not significant on a 0.05 level. Hence a rail factor for public transport usage for commuters cannot be confirmed for the cities of Berne and Zurich.

- Regarding residential density, the highest density in Zurich is found close to stops served by either several trams or several buses or both. In Berne, the highest residential densities occur in tram clusters and close to bus stops served by several bus lines. Nevertheless, the difference between stops with single bus lines (800 residents) and single tram lines (1,500 residents) turned out to be significant. This is the only case where a significant difference was revealed in the pairwise comparison.
- Considering average number of jobs, the clusters being compared are not significantly different. Nevertheless, stops in cluster 5 (short travel times and served by bus and tram) show a remarkably high number of jobs.

8.4.3 Conclusions

Clusters

The clusters defined in the research turned out to be reasonable for the research objective. The resulting 9 cluster types account for differences in level of services based on travel times, the number of high quality public transport lines serving a stop and the type of public transport service (bus, tram or both). Cluster analysis was found to be an adequate method to compare the level of service at stops. The research results contribute to an additional perspective for discussions about a rail factor independent of findings from newly implemented bus rapid transit or light rail lines.

No difference in mode choice

The research found no evidence for a rail factor, expressed as different effects in tram clusters compared to bus clusters in the cases of Zurich and Berne. There was no significant difference in the percentages of public transport users found between bus and tram clusters. Although the mode of public transport commuters per commuter is slightly higher (2-5%) for tram stops with short travel times to the city center compared to equal bus services, the ANOVA showed no significant differences. Furthermore no higher usage of tram was revealed for longer travel times.

Although some sources in the literature expect higher ridership because of a rail factor, this research on revealed aggregated data showed, in the case of Zurich and Berne, that higher ridership is more likely because of higher demand potential in the catchment areas of tram compared to bus. Demand potential is expressed here in terms of residential density and number of jobs.

Demand potential

The residential density does not follow the expected pattern of higher densities in tram clusters. It is concluded that urban public transport implementation does not strictly follow residential development patterns and vice versa. This can be further demonstrated by considering the high-density residential areas that were constructed in the 1970s at the urban fringe. In both cities, these areas were connected with bus lines to the city center area, an approach that has more to do with the zeitgeist than with public transport planning theory.

With regard to the average number of jobs, the research showed that job locations are more likely to be close to stops that are served by tram or by several bus lines. The cluster with a combination of both trams and buses showed the highest average employment figures. We conclude that clusters characterized by several public transport connections contribute to a higher demand potential (especially cluster 5 in Zurich). Considering customer-based transport demand it is expected that workplaces also attract customers.

Estimations of customer transport demand are usually based on type and area of the business. Reference values are suggested by FGSV as an average of daily 10-20 customer trips per job in mixed-used areas (FGSV 2007, p22). Since the location of high employment is more likely to be close to stops characterized by cluster 5, absolute public transport demand is expected to be significantly higher at these stops. This finding cannot be supported using the data from Berne, because there are too few stops with the same characteristics.

However, there are no significant differences in demand potential of similar bus and tram clusters with respect to job numbers. Although there are tendencies that tram clusters have slightly higher means of job numbers in tram clusters than in bus clusters, this cannot be supported on a statistically significant basis.

Public transport usage varies

Although there can be higher public transport usage in areas served with trams, this is not a regular pattern because in some bus clusters the means of the ratio of public transport usage are higher than for the corresponding tram cluster. With regard to commuter data, there is no significantly higher public transport usage by employees living in tram clusters. Hence it is assumed that the public transport mode (bus or tram) does not influence mode choice in a way that is reflected in demand numbers. Other criteria beyond system specific service such as timetables, travel times and parking restrictions are expected to have a greater effect on mode choice behavior.

Nevertheless, since only commuter data is analyzed, it is not possible to say if higher public transport usage would occur for leisure trips, e.g. if people living in tram clusters have a higher public transport use in their leisure time than those in bus clusters. This question is still open.

9 Synthesis and outlook

9.1 Synthesis

9.1.1 Review of objectives and hypotheses

The assumption that different public transport systems in general do cause different effects on public transport demand and especially that light rail or tram attracts more passengers than buses was the main driver for this dissertation. This phenomenon of different ridership attraction under equal service conditions is known as rail factor. As hardly any evidence about a rail factor is known for urban conditions, this field of application is of special interest.

Briefly, to investigate an assumed rail factor, the research question focuses on the relationship between system attributes of bus and tram and the related stakeholder's perception of and reaction to these system attributes. Therefore the following knowledge was elaborated:

1. System attributes of bus and tram. Identification of relevant system attributes and quantification of differences in attributes of bus and tram.
2. Perception of system attributes by various stakeholders. Definition of stakeholders of interest and investigation of their perception of public transport systems and single system attributes. Stakeholders include current public transport users and potential public transport users in terms of residents. Different economical and psychological concepts have been analyzed and discussed to determine appropriate methods to measure stakeholder's perception of bus and tram.
3. Mode choice behavior of different stakeholders. Mode choice as a factor of public transport demand is analyzed with reference to the availability of bus and tram.

Considering the underlying definition of a rail factor, the leading hypothesis assumes that *in a hypothetical case that in an urban area, both systems bus and tram are available for the same route and provide equal service characteristics, there is a stronger preference to choose tram than bus (1).* As hardly any equal bus and tram services exist on the same routes, this situation is investigated for a hypothetical case.

Different preferences are interpreted as being influenced by variations of perception of these two systems. In other words the sociocognitive model in mind expressed as image differ significantly for tram and buses. Therefore the image of bus and tram is analyzed to test the following hypotheses:

2. *Bus and tram are perceived differently which leads to different images of these two urban public transport systems.*

2.1 System characteristics are valued differently for bus and for tram

2.2 The image of a tram is more positive than the image of a bus.

Assuming that the unequal image of bus and tram affects travel behavior, this should be observable in different mode choice behavior of residents living in bus and tram corridors. Thus, a rail factor would lead to a higher public transport use of individuals who live close to a tram stop compared to those who live in the catchment area of a bus stop, given all other service characteristics such as travel times and frequency being the same for bus and tram. The following hypotheses are postulated:

3. *Public transport use is higher in neighborhoods served by tram than in neighborhoods served by bus.*

3.1 The image of a tram is more positive for residents living close to tram services than for residents living close to bus services.

3.2 The image of bus is more positive for residents living in bus corridors than for residents living in tram corridors.

In the subsequent sections, the presented hypotheses are discussed in the context of the elaborated studies for this dissertation.

9.1.2 Hypothetical rail factor in schemata

For the hypothetical case that bus and tram services are equally available, the research found a rail factor in a hypothetical context by applying the schema theory. This means that the hypothesis (1) of a stronger preference for trams than for a bus service is accepted, based on the example of Switzerland. The schemata for tram load highly on two aspect groups:

- Objective expected benefits related to dedicated lanes, which affects traffic flow and reliability.
- Factors related to environmental friendliness.

Perceived benefits of a tram concern attributions that are related to the guideway such as free flow and a higher reliability. However, differences in treatments of bus and tram are mainly caused by traffic laws and by providing separate infrastructure, which is partly inherent to the system. Due to a tram's right of way and far less mixed traffic conditions than a bus, it is perceived to be more reliable and stuck less in traffic than a bus. Residents of urban areas, where congestion is a daily issue, often state this argument.

According to data for energy consumption and emissions of bus and tram for selected Swiss cities a tram is not per se better than a bus regarding environmental friendliness. Depending on the point of view, a bus system can thoroughly compete with a tram system. However, as a tram has a higher capacity than a bus, energy consumption is lower per passenger in cases of equal loadings of both vehicles. Regarding air pollution, the standard of the vehicle and various pollutants have to be taken into account, which does not allow us to define a superior transport system. Considering noise emission, trolleybuses are quieter compared to trams and to dieselbuses. Briefly, it cannot be stated from an objective standpoint that one or other public transport mode is more environmentally friendly than the other. Nevertheless the generalized schemata shows that a tram system is often regarded to be superior to buses.

9.1.3 Concept: Schemata vs image

The leading hypothesis of a rail factor in a hypothetical situation is accepted. The findings of the schemata on bus and tram leave open the question of how theoretical preferences can be measured. Therefore two concepts have been applied. As a consequence, results about attributions and ratings thereof vary depending on the concept.

As mentioned previously, the two systems are found to differ in their schemata. Initial attributions towards bus and tram are remarkably different, which supports the assumption that these two systems are perceived differently. The foundations of the schemata of urban public transport systems constitute preferences and reasons for preferences. In contrast, the image deduced from ratings of the same attributions for bus and tram reveals a different picture to the schemata. Established differences in schemata diminish when investigating the images of bus and tram with the measurement of the semantic differential.

9.1.4 Different images

Analyzing the image in detail, images formed by different user groups differ. Whereas frequent public transport users rate most attributions significantly better for tram than for bus, occasional and especially non-public transport users do not have higher ratings for a tram.

Furthermore, residents of cities with a tram network show better ratings for tram than for bus compared to residents of bus-based cities. Briefly, residents of the tram cities Berne and Zurich have a better image of a tram than of a bus. In contrast, inhabitants of Lucerne have a better image of a bus than of a tram.

System characteristics were partly rated differently for bus and for tram. Whereas aspects regarding the *vehicle*, *service characteristics*, and *psychological and emotional attributions* reveal to be rated similarly for bus and for tram, *aspects that impact public transport users and the general public* are rated differently for the two public transport systems. In particular ratings for *environmental friendliness* and *traffic flow* differ for tram and bus, comparable to the schemata of bus and tram.

Hypothesis 2 assumed different images of bus and tram. However, images of bus and tram are found to be similar for 2 of 3 investigated stakeholder groups. As a consequence, this hypothesis is rejected. In contrast, hypothesis 2.1 that assumes a different valuation of system attributes is accepted for the attributes concerning environmental friendliness and traffic flow. Finally, hypothesis 2.2 has to be rejected, because there is no persistent better image of a tram compared to the image of a bus.

9.1.5 No impact on mode choice

Although schemata based on preferences for bus or tram revealed differences in the perception of these two systems and the image of bus and tram turned out to be rated differently depending on the user type, no significantly different mode choice behavior is ascertained in bus and tram corridors. Revealed behavior in clusters does not show a significantly higher public transport usage in tram clusters compared to bus clusters with comparable level of service. Based on these findings, hypothesis 3 has to be rejected.

Hypothesis 3.1 assumes a better image of a tram for residents living close to tram service than for residents living close to bus services. On the fundamentals of the three case cities this hypothesis is accepted. Inhabitants of tram cities do have a better image of a tram than inhabitants of the bus-based city. However, hypothesis 3.2 is also accepted.

The image of a bus is better than the image of a tram for residents of bus corridors. If there was a rail factor, the image of a tram was expected to be better than the image of a bus in every case. Thus, the image of a bus is much better than expected, depending on the experience and habits of the residents.

As images and schemata are used as heuristics, a more positive image or schemata with more positive attributions would be expected to impact mode choice behavior. Since images and schemata mainly differ on the aspects of right of way and environmental friendliness it is assumed that the higher ratings in these two categories do not have a sufficient weight in order to change someone's mode choice behavior. According to the literature considering environmental behavior, it is assumed that especially higher ratings on this attribute are not correlated with higher use of public transport. However, the impact of improvements regarding the right of way may influence public transport demand for bus because such improvements also affect hard factors such as travel times, which are known to be a main factor for mode choice.

9.1.6 Revealed data vs explanations for preference

It is interesting to establish that bus and tram can compete regarding environmental friendliness although this aspect is the most prominent factor for preference of a tram and for differences between bus and tram. Similarly, the treatment of right of way is highly related to a tram and therefore often used as justification for a tram preference. However, providing dedicated bus lanes and prioritization in mixed traffic should lead to comparable data regarding traffic flow and reliability for bus and for tram.

A higher theoretical preference for a tram can be explained by the prominence effect. People seek the most prominent differences to justify their choice. Furthermore, respondents often mention socially desirable arguments, such as environmental friendliness, to explain their preference. However, studies considering environmentally friendly behavior found a bias between arguing environmentally friendly and effective behavior.

In a nutshell, schemata based on preferences reflect the respondent's justification of their choice, which is strongly influenced by social norms. Images expressed as quantified attributions have shown that the difference between ratings of bus and tram is smaller than expected from the schemata. Attributions that differ most are related to environmental impacts and traffic flow/reliability. Nevertheless, quantified data of energy consumption and emissions are similar for bus and tram, depending on the type of vehicle, traction and average loading of the vehicles. Finally, established preferences cannot be justified with revealed mode choice behavior.

9.2 Conclusions

9.2.1 No rail factor for trams

No difference in mode choice behavior: The rail factor in terms of higher ridership attraction is not confirmed for the example of urban areas in Switzerland considering bus and tram. Mode choice behavior does not differ significantly for comparable levels of service for these two systems. One explanation is that public transport in general has a high level of service in Switzerland independent of whether the system is bus or rail based. Another aspect affecting public transport is restrictions for car traffic, especially limited parking spaces. These two aspects are reflected on one hand in high public transport usage and on the other hand in high customer satisfaction ratings for public transport, independent of having a tram service, bus service or both.

Impact of experience on image: As is known from other studies, image is influenced by experiences. It was revealed that the less the respondents use public transport service the smaller is the difference between ratings of bus and tram images. As a consequence no rail factor in terms of a better image of a tram can be ascertained from the data. Vice versa, frequent public transport users show a higher preference for tram and better ratings of attributions for a tram compared to a bus. Hence, habits and experience may lead to differences in images. In this case, higher public transport use is accompanied with a more positive image of a tram. This cannot be explained with a rail factor, since a rail factor is not expected to be only effective for these stakeholders.

Relevance of environmental friendliness on behavior is small: Considering image formation, affective emotional aspects are relevant, however, the study reveals that they do not significantly differ between bus and tram. In contrast to the affective emotional aspects it is doubtful whether the aspect of environmental friendliness affects mobility behavior in terms of bus or tram usage. It is known from the literature that respondents tend to justify their answers to be politically correct. As a consequence, respondents rather pretend to act environmentally friendly, thus it is questionable whether this is a motive for tram use instead of bus use. Nevertheless more research is needed to explore the relation between images, and consequently affective emotional aspects and mobility behavior in order to deduce conclusions about a rail factor.

Politics and environmental friendliness: Considering the importance of environmental friendliness on political decisions, the picture changes. As political decisions are strongly influenced by normative aspects, the argument of environmental friendliness has a high weight. Although it is found that both public transport systems can compete regarding environmental friendliness, the image of a tram is found to be better on this aspect compared to the image of a bus. This better image can be used and enforced as argument in favor of tram for political decisions.

Knowledge about non-users is important: Since the repeating argument of a rail factor is often used by decision makers to support a modal switch towards public transport use by implementing a tram, the image of bus and tram of the group of occasional users and non users is highly relevant. These groups do not have significantly better images of a tram than of a bus so it is questionable whether they would change their mobility behavior in cases where all other service characteristics remain the same.

Free flow and environmental friendliness lead to higher public acceptance: The findings in this thesis lead to the conclusion that the argument of a rail factor is generally not valid for bus and tram in urban areas of Switzerland when considering public transport demand. However, there are aspects where a theoretical rail factor can be applied. The better image of a tram on environmental aspects and the attribution of free flow and reliability to a tram are expected to be the main factors for a higher public acceptance of a tram system.

9.2.2 Transfer of positive attributions of a tram onto bus systems

Considering the prominence theory and salient aspects of a tram, this contributes to the explanation of a theoretical rail factor. A tram is more prominent on positively attributed aspects and hence public awareness and public acceptance is higher for tram infrastructures compared to bus infrastructures. However, the merits of greater environmental friendliness of a tram are not supported by the facts.

Under the precondition that buses and trams are treated equally regarding traffic law, a bus system can theoretically attract the same ridership number as a tram system. This requires measures on the right of way, dedicated lanes and priority at intersections. Thus, ridership numbers are limited by the capacity of vehicles and by the frequency of service.

The dedicated way of a tram tends to be more salient than dedicated buslanes because buslanes are hardly continuous in Swiss cities. Fragmentary buslanes as they currently exist in many cities in Switzerland are not comparable to the dedicated way of a tram, which is expressed in the image of a tram. In order to change the image of a bus on this attribute, it takes a long time until dedicated buslanes manifests in the image of a bus. This is mainly because images and schemata derive from experiences and habits and are therefore difficult to change.

9.2.3 Effects of positive images

Although the image or schemata are found not to influence mode choice behavior significantly, differences in images of bus and tram may influence other decisions. For instance, those who have a better image (frequent user) may search for residential locations in tram corridors whereas other groups do not distinguish between bus and tram service in their residential location.

Not only residential location choice but also location choice of companies may be influenced by the image of a tram and by the higher awareness of tram infrastructure. Further, investment decisions in spatial development may be affected by the expected higher preference of tram compared to bus. Since schemata and image of tram are better compared to those of bus for residents of tram cities, this positive valuation may also lead to a higher acceptance of tram infrastructure investments. This supposition comes in line with results of public votes in respective cantons. Recent votes for tram investments have been positive, thus the share of acceptance was remarkably higher in urban areas with existing tram systems than in regional areas. Nevertheless, a majority of inhabitants of regional areas also support tram investments.

Considering the better image of bus compared to tram of residents in the bus-based city Lucerne, the higher acceptance for tram as previously mentioned is expected to diminish for this city. Regarding the high number of cities with public transport systems based on buses, it is assumed that on a national level the acceptance for tram is lower compared to the results of tram-based cities. However, the range of aspects influenced by a possible rail factor beyond public transport demand has not been investigated and is subject to further research.

9.3 Further research

Further research on the rail factor and effects of different public transport systems is recommended in four fields. Methodological considerations, stakeholder groups involved in public transport, resolution of input data, and different geographical study areas.

Qualitative methods proved to be adequate to explore an assumed rail factor. Different psychological concepts, such as the schema theory, support the investigation of different perceptions of public transport systems. However, for the research at hand quantitative data was collected and analyzed. Qualitative methods, especially qualitative interviews, are expected to allow for further insight into different impacts of public transport systems. The relation between images and effective behavior is of particular interest for in-depth research. Qualitative methods are expected to be helpful for gaining knowledge on behavior of different stakeholder groups based on their perception of public transport systems.

It has been shown that habits and experiences influence the image of bus and tram. As a consequence, groups of stakeholders should be enlarged with respect to transport planners. Experience and also knowledge about public transport are important impact factors on the image formation. Since transport planners have detailed knowledge about technical data and environmental impacts of transport systems, it is expected that their image of bus and tram is different to images of other stakeholder groups. Transport planners have a remarkable influence on the decision making process for transport infrastructure developments and therefore it is of special interest to investigate their image of public transport systems in relation to their recommendations on infrastructure developments.

Another aspect related to additional stakeholders includes the effect of different public transport systems on spatial development. As different images for various stakeholders are established, this could influence decision making for location choice and also for land-use regulation. However, research is needed to investigate behavior of investors, spatial developers and stakeholders involved in location choice regarding different public transport systems. Furthermore the role of land-use regulation and zoning in conjunction with public transport systems and public transport infrastructures should be the subject of further research.

Considering the input data of this dissertation, mode choice behavior was analyzed on an aggregated level. A higher resolution might be useful, especially with the combination of qualitative interviews. Furthermore, travel data could be enlarged by other purposes than work trips. As leisure trips account for most of the trip numbers, this category would be of great interest for further research on mode choice behavior regarding bus and tram.

Finally, the example of Switzerland, with focus on three cities, gives no answer about regional transportation. Regional transportation is of interest since there is a debate on the replacement of train services with bus services. Against this background, effective ridership numbers have been found to decrease. Reasons and explanations for the development of demand would be of great interest.

Furthermore, the application of the image study on other locations in other countries allows for reflections about different levels of services of public transport, which is expected to result in different images of public transport systems. The comparison with other countries and other geographical regions may allow for further conclusions for a rail factor because this comparison helps to identify differences between various public transport services and differences in usage of these services. Nevertheless, local conditions, business environment and regulatory frameworks such as restrictions towards car traffic and parking have to be considered.

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APPENDIX

A1 Questionnaire of survey to identify the image of bus and tram

A2 Image score of bus and tram

A3 Comparison of cluster data

A 1 Questionnaire of survey to identify the image of bus and tram

Befragung zum Stadtverkehr

Institut für Verkehrsplanung und Transportsysteme
Institute for Transport Planning and Systems

Fragebogen für:

Sind Sie…?	männlich weiblich		
Wann sind Sie geboren?	Jahr		
Wie lange wohnen Sie schon	…in dieser Stadt? Jahr(e)	…in diesem Quartier? Jahr(e)	
Wohnen Sie…?	in einem Einpersonenhaushalt in einem Paarhaushalt in einem Haushalt mit Kindern (unter 16 Jahren) in einer Wohngemeinschaft		
Welchen Ausbildungsabschluss haben Sie als Letztes erworben?	Primar- oder Grundschulabschluss Sekundar-, Real-, Hauptschulabschluss Matura /Abitur sonstige:	Lehrabschluss Fachhochschulabschluss Hochschulabschluss	
Was ist Ihre momentane berufliche Stellung?	in Ausbildung berufstätig auf Arbeitssuche	Hausfrau / Hausmann pensioniert erwerbsunfähig	
Besitzen Sie einen Führerausweis für Personenwagen?	ja	nein	
Wie häufig steht Ihnen einen Personenwagen (allenfalls nach Absprache) zur Verfügung?	immer häufig selten nie	Car-sharing (z.B. Mobility)	
Welche ÖV-Haltestelle in der Nähe von Ihrem Zuhause benutzen Sie am häufigsten?*			
Name der Haltestelle		Leider weiss ich den Namen der Haltestelle nicht	
Fussweg Zuhause - Haltestelle	ca. Minute(n)		
Geschätzte Fahrzeit Haltestelle - Stadtzentrum	ca. Minute(n)		
Besitzen Sie eines oder mehrerer der folgenden Abonnemente des öffentlichen Verkehrs?	Generalabonnement (GA) Halbtax-Abonnement Gleis 7 Monats- /Jahreskarte Verkehrsverbund Mehrfahrtenkarte Streckenabonnement sonstige:		
Falls Sie berufstätig oder in Ausbildung sind:			
Adresse des Arbeits- oder Ausbildungsortes	Str.	Nr.	
	PLZ	Ort	
(Bei mehreren Arbeits- oder Ausbildungsorten wählen Sie diejenige Adresse, an der Sie sich hauptsächlich aufhalten)			
Welche ÖV-Haltestelle bei Ihrem Arbeits- oder Ausbildungsort benutzen Sie am häufigsten?*			
Name der Haltestelle		Leider weiss ich den Namen der Haltestelle nicht	
Fussweg Arbeitsplatz – Haltestelle am Arbeitsplatz	ca. Minute(n)		

* Falls Sie kein ÖV-Nutzer sind, geben Sie bitte die Haltestelle an, die Sie am ehesten benutzen würden.

Befragung zum Stadtverkehr

Institut für Verkehrsplanung und Transportsysteme
Institute for Transport Planning and Systems

Womit haben Sie sich in der letzten Woche fortbewegt? Bitte schätzen Sie die Anzahl Wege, die Sie mit dem jeweiligen Verkehrsmittel zurückgelegt haben.
Bitte benützen Sie das Beiblatt zur Abschätzung der Anzahl Wege die Sie zurücklegen.
Ein Weg ist eine Kombination von Etappen, Teilwegen, um ein bestimmtes Ziel zu erreichen (z.B. Arbeitsort, Einkaufsort, Wohnung von Bekannten). Diese Etappen werden mit verschiedenen Verkehrsmitteln zurückgelegt werden, z.B. zu Fuss zur Haltestelle, Bus, Tram, zu Fuss zum Ziel.

Wie viele Wege haben Sie in der letzten Woche...					
mit öffentlichen Verkehrsmitteln (Bus, Tram, Zug) zurückgelegt?	ca.		Wege	☐	Keine
mit einem Auto (auch als Mitfahrer) zurückgelegt?	ca.		Wege	☐	Keine
mit einem Velo (Fahrrad) zurückgelegt?	ca.		Wege	☐	Keine
Wie viele Fusswege dauerten über 10 Minuten?	ca.		Wege	☐	Keine

Womit legen Sie normalerweise Wege zurück, die den nachfolgenden Beispielen entsprechen?
Kreuzen Sie das Verkehrsmittel an, welches Ihnen als ERSTES in den Sinn kommt.

	Zu Fuss	Velo	Motor-rad	Auto	ÖV
Beispiel: Besuch von IKEA	☐	☐	☐	☒	☐
Arbeitsweg	☐	☐	☐	☐	☐
Ausflug zum Rheinfall in Schaffhausen	☐	☐	☐	☐	☐
Altglas entsorgen	☐	☐	☐	☐	☐
Essengehen in der Stadt	☐	☐	☐	☐	☐
Verwandte in Basel besuchen	☐	☐	☐	☐	☐
Schnell etwas für den täglichen Bedarf einkaufen (z.B. Brot)	☐	☐	☐	☐	☐
Brief in den Briefkasten einwerfen	☐	☐	☐	☐	☐
Ausflug in den Zoo Zürich	☐	☐	☐	☐	☐
Besuch des Autosalon in Genf	☐	☐	☐	☐	☐
Kinobesuch	☐	☐	☐	☐	☐
Jemanden im Universitätsspital Zürich Besuchen	☐	☐	☐	☐	☐
Kurztrip nach Locarno	☐	☐	☐	☐	☐
Im Quartier einen Kaffee trinken	☐	☐	☐	☐	☐

Wie sehr stimmen Sie den folgenden Aussagen zu Ihrem Quartier zu?

	Stimme voll zu	Stimme eher zu	Teils / teils	Stimme eher nicht zu	Stimme gar nicht zu
Die Anbindung meines Quartiers zu mir wichtigen Orten ist gut	☐	☐	☐	☐	☐
Das Stadtzentrum ist einfach erreichbar	☐	☐	☐	☐	☐
Auszugehen ist unkompliziert von meinem Quartier aus	☐	☐	☐	☐	☐
Mein Quartier liegt sehr zentral	☐	☐	☐	☐	☐
Es gibt im Quartier genügend Möglichkeiten des ÖV zu benützen	☐	☐	☐	☐	☐
Der Takt des ÖV ist ausreichend für die Bedürfnisse der Anwohner	☐	☐	☐	☐	☐
Der ÖV bietet gute Verbindungen zum Rest der Stadt	☐	☐	☐	☐	☐
Die Haltestellen liegen für mich am richtigen Ort	☐	☐	☐	☐	☐
Die Fahrzeuge des ÖV sind oft zu voll	☐	☐	☐	☐	☐
Die Luftqualität im Quartier ist gut	☐	☐	☐	☐	☐
Es ist ein ruhiges Quartier	☐	☐	☐	☐	☐
Das Quartier ist dreckig	☐	☐	☐	☐	☐
Der Verkehr in meinem Quartier stört die Anwohner	☐	☐	☐	☐	☐

Befragung zum Stadtverkehr Institut für Verkehrsplanung und Transportsysteme / Institute for Transport Planning and Systems

Untenstehend sind verschiedene Gegensatzpaare aufgelistet. Bitte stellen Sie sich ein beliebiges TRAM vor und stufen die Gegensatzpaare dafür ein.
Zum Beispiel: Wenn Sie finden, dass ein Tram ein eher grosses Fahrzeug ist, stufen Sie dieses wie folgt ein:
Grosses Fahrzeug ☐ ☒ ☐ ☐ ☐ Kleines Fahrzeug

Wenn Sie aber finden, dass ein Tram ein sehr grosses Fahrzeug ist, dann machen Sie das Kreuz ganz aussen:
Grosses Fahrzeug ☒ ☐ ☐ ☐ ☐ Kleines Fahrzeug

TRAM						
Zuverlässig	☐	☐	☐	☐	☐	Unzuverlässig
Freie Fahrt	☐	☐	☐	☐	☐	Behinderte Fahrt
Gefährlich	☐	☐	☐	☐	☐	Sicher
Sanfte Fahrweise	☐	☐	☐	☐	☐	Ruckartige Fahrweise
Attraktiv	☐	☐	☐	☐	☐	Unattraktiv
Unwichtig	☐	☐	☐	☐	☐	Wichtig
Kompliziert zu benützen	☐	☐	☐	☐	☐	Einfach zu benützen
Wertvoll	☐	☐	☐	☐	☐	Wertlos
Umweltfreundlich	☐	☐	☐	☐	☐	Umweltschädlich
Laut	☐	☐	☐	☐	☐	Leise
Voll	☐	☐	☐	☐	☐	Leer
Neu	☐	☐	☐	☐	☐	Alt
Geräumig	☐	☐	☐	☐	☐	Eng
Einsteigen leicht	☐	☐	☐	☐	☐	Einsteigen schwierig
Unbequem	☐	☐	☐	☐	☐	Bequem
Modern	☐	☐	☐	☐	☐	Altmodisch
Busnetz ist unübersichtlich	☐	☐	☐	☐	☐	Busnetz ist übersichtlich
Fährt schnell	☐	☐	☐	☐	☐	Fährt langsam
Fährt selten	☐	☐	☐	☐	☐	Fährt oft
Fährt Umwege	☐	☐	☐	☐	☐	Fährt direkt
Ungünstige Haltestellenlagen	☐	☐	☐	☐	☐	Optimale Haltestellenlagen
Gehört in die Innenstadt	☐	☐	☐	☐	☐	Stört in der Innenstadt
Passt zu Hochhaussiedlungen	☐	☐	☐	☐	☐	Passt zu Einfamilienhaussiedlungen
Passt zu neuen Gebäuden	☐	☐	☐	☐	☐	Passt zu alten Gebäuden
Passt zu Villenquartieren	☐	☐	☐	☐	☐	Passt zu Arbeiterquartieren

Wie viele Wege haben Sie in den letzten 2 Wochen mit einem TRAM zurückgelegt?

☐ Keinen ☐ Ca. 1- 4 Wege ☐ ca. 5-10 Wege ☐ Ca. ☐ täglich mehrere Wege

Wie wichtig sind Ihnen diese Angebotseigenschaften des öffentlichen Verkehrs?

	Weniger wichtig	Wichtig	Sehr wichtig
Hohe Fahrgeschwindigkeit	☐	☐	☐
Dichter Fahrplantakt	☐	☐	☐
Direkte Verbindungen	☐	☐	☐
Pünktlichkeit / Zuverlässigkeit	☐	☐	☐
Haltestelle in der Nähe	☐	☐	☐

Befragung zum Stadtverkehr

Institut für Verkehrsplanung und Transportsysteme
Institute for Transport Planning and Systems

Wie wichtig sind Ihnen diese weiteren Eigenschaften des öffentlichen Verkehrs?

	Weniger wichtig	Wichtig	Sehr wichtig
Sanfte Fahrweise	☐	☐	☐
Sehr hohe Unfallsicherheit	☐	☐	☐
Umweltfreundlichkeit	☐	☐	☐
Neues Fahrzeug (Inkl. Klimaanlage etc.)	☐	☐	☐
Eigene Fahrspur (z.B. Busspur, Tramspur)	☐	☐	☐
Kein Gedränge im Fahrzeug	☐	☐	☐
Einfaches Einsteigen in das Fahrzeug	☐	☐	☐
Freie Sitzplätze	☐	☐	☐

Bitte stellen Sie sich einen beliebigen STADTBUS vor und stufen die Gegensatzpaare ein:

STADTBUS						
Zuverlässig	☐	☐	☐	☐	☐	Unzuverlässig
Freie Fahrt	☐	☐	☐	☐	☐	Behinderte Fahrt
Gefährlich	☐	☐	☐	☐	☐	Sicher
Sanfte Fahrweise	☐	☐	☐	☐	☐	Ruckartige Fahrweise
Attraktiv	☐	☐	☐	☐	☐	Unattraktiv
Unwichtig	☐	☐	☐	☐	☐	Wichtig
Kompliziert zu benützen	☐	☐	☐	☐	☐	Einfach zu benützen
Wertvoll	☐	☐	☐	☐	☐	Wertlos
Umweltfreundlich	☐	☐	☐	☐	☐	Umweltschädlich
Laut	☐	☐	☐	☐	☐	Leise
Voll	☐	☐	☐	☐	☐	Leer
Neu	☐	☐	☐	☐	☐	Alt
Geräumig	☐	☐	☐	☐	☐	Eng
Einsteigen leicht	☐	☐	☐	☐	☐	Einsteigen schwierig
Unbequem	☐	☐	☐	☐	☐	Bequem
Modern	☐	☐	☐	☐	☐	Altmodisch
Busnetz ist unübersichtlich	☐	☐	☐	☐	☐	Busnetz ist übersichtlich
Fährt schnell	☐	☐	☐	☐	☐	Fährt langsam
Fährt selten	☐	☐	☐	☐	☐	Fährt oft
Fährt Umwege	☐	☐	☐	☐	☐	Fährt direkt
Ungünstige Haltestellenlagen	☐	☐	☐	☐	☐	Optimale Haltestellenlagen
Gehört in die Innenstadt	☐	☐	☐	☐	☐	Stört in der Innenstadt
Passt zu Hochhaussiedlungen	☐	☐	☐	☐	☐	Passt zu Einfamilienhaussiedlungen
Passt zu neuen Gebäuden	☐	☐	☐	☐	☐	Passt zu alten Gebäuden
Passt zu Villenquartieren	☐	☐	☐	☐	☐	Passt zu Arbeiterquartieren

Wie viele Wege haben Sie in den letzten 2 Wochen mit einem STADTBUS zurückgelegt?

☐ Keinen ☐ Ca. 1- 4 Wege ☐ ca. 5-10 Wege ☐ täglich einen Weg ☐ täglich mehrere Wege

Herzlichen Dank für Ihre Unterstützung! M. Scherer

Are you…?	☐ Male ☐ Female	
Year of birth?	Year ____	
How long to you live	…in this city? ____ year(s)	…in this neighborhood? ____ year(s)
Do you live in a…?	☐ Single household ☐ Household as a couple ☐ Household with children (aged under 16) ☐ Flat share	
What is your latest qualification?	☐ Primary school ☐ Secondary school ☐ Graduation diploma ☐ Others: ____	☐ Apprenticeship ☐ Polytechnic degree ☐ University degree
What is your current occupation?	☐ Education ☐ Working ☐ Job-seeking	☐ Homemaker ☐ Retired ☐ Unable to work
Do you have a driving license?	☐ Yes	☐ No
How often do you have a car available?	☐ Always ☐ Often ☐ Rarely ☐ Never	☐ Car-sharing (z.B. Mobility)
Which public transport stop close to your home do you usually use?* Name of stop ____ Walking distance home – public transport stop Estimated travel time to the city center	 ☐ Unfortunately do not know the name of stop Approx. ____ Minute(s) Approx. ____ Minute(s)	
Do you own one or more of the following public transport cards?	☐ Annual all access pass (GA) ☐ Half-fare card (Halbtaxabonnement) ☐ Gleis 7 ☐ Monthly pass / annual pass (Monats/ Jahreskarte) ☐ Multi trip card ☐ Pass for specific passage (Streckenabonnement) ☐ Others: ____	
In case you are working or in education: Address of place of work or Place of education (If you have more than one workplace, write down the address where you spent the most time)	 Street ____ Nr. ____ ZIP ____ City ____	
Which public transport stop close to your workplace to you usually use?* Name of stop ____ Distance workplace – public transport stop	 ☐ Unfortunately I do not know the name of stop Approx. ____ Minute(s)	

* In case you are no public transport user, please note the name of the stop you would use.

Survey: Urban transport

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What transportation means did you use the last week? Estimate the number of ways t you have undertaken with the respective transport mean.

A trip is a combination of legs to reach a certain destination (e.g. workplace, shopping mall, house of friends). You use one transportation mean for one leg that constitute in a combination a trip. E.g. walking to the bus stop, public transportation, walking to the final destination.

How many trips did you last week by using					
Public transportation	Approx.	☐	Trips	☐	None
A car (also as co-driver)	Approx.	☐	Trips	☐	None
A bicycle	Approx.	☐	Trips	☐	None
How many walking trips lasted longer than 10 minutes?	Approx.	☐	Trips	☐	None

What transportation mean do you usually use for the following kind of trips presented below?
Mark the transportation mean that FIRST crosses your mind.

	By foot	Bicycle	Motor-bike	Car	Public transportation
Example: Shopping at IKEA					
Travel to work					
Excursion to the Rhine Falls in Schaffhausen					
Going to the empty glass container					
Dinner in town					
Visiting relatives in Basle					
Going to the grocery store (e.g. to get some milk)					
Post a letter					
Excursion to the zoo in Zurich					
Trip to the international motor show in Geneva					
Going to the movies					
Visiting somebody in the University Hospital in Zurich					
Excursion to Lugano					
Having a coffee in the neighborhood					

How much do you agree with the following statements about your neighborhood?

	Agree fully	Agree somewhat	No opinion	Disagree somewhat	Disagree fully
My neighborhood is well connected to relevant places for me	☐	☐	☐	☐	☐
I can reach the city center easily from my neighborhood	☐	☐	☐	☐	☐
It is easy to go out in my neighborhood	☐	☐	☐	☐	☐
My neighborhood is centrally located	☐	☐	☐	☐	☐
There are sufficient possibilities to use public transportation	☐	☐	☐	☐	☐
The neighbors are content with the frequency of public transport service	☐	☐	☐	☐	☐
Public transport provides good connections to other neighborhoods	☐	☐	☐	☐	☐
Public transport stops are well located	☐	☐	☐	☐	☐
Public transport means are often crowded	☐	☐	☐	☐	☐
The air quality is good	☐	☐	☐	☐	☐
It is a quiet neighborhood	☐	☐	☐	☐	☐
The neighborhood is dirty	☐	☐	☐	☐	☐
Traffic bothers the residents in my neighborhood	☐	☐	☐	☐	☐

Survey: Urban transport

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Below you find a list of different opposite pairs. Imagine an arbitrary TRAM and rate these attributions for this tram.
Example: If you think a tram is a rather big vehicle, then rate it as follows:

Big vehicle ☐ ☒ ☐ ☐ ☐ Small vehicle

However, if you think a tram is a very big vehicle, then rate it at the very end:

Big vehicle ☒ ☐ ☐ ☐ ☐ Small vehicle

TRAM						
Reliable	☐	☐	☐	☐	☐	Not reliable
Free flow	☐	☐	☐	☐	☐	Stop and go
Risk of accident	☐	☐	☐	☐	☐	Safe of accident
Smooth ride comfort	☐	☐	☐	☐	☐	Bad ride comfort
Attractive	☐	☐	☐	☐	☐	Not attractive
Not important	☐	☐	☐	☐	☐	Important
Difficult to use	☐	☐	☐	☐	☐	Easy to use
Valuable	☐	☐	☐	☐	☐	Not valuable
Environmental friendly	☐	☐	☐	☐	☐	Environmental unfriendly
Noisy	☐	☐	☐	☐	☐	Silent
Crowded vehicle	☐	☐	☐	☐	☐	Empty vehicle
New vehicle	☐	☐	☐	☐	☐	Old vehicle
Spacious vehicle	☐	☐	☐	☐	☐	Cramped vehicle
Easy to board	☐	☐	☐	☐	☐	Difficult to board
Inconvenient	☐	☐	☐	☐	☐	Convenient
Modern vehicle	☐	☐	☐	☐	☐	Old-fashioned vehicle
Confusing net	☐	☐	☐	☐	☐	Clearly designed net
Fast service	☐	☐	☐	☐	☐	Slow service
Low frequency	☐	☐	☐	☐	☐	High frequency
Indirect routes	☐	☐	☐	☐	☐	Direct routes
Unfavorable stop locations	☐	☐	☐	☐	☐	Favorable stop locations
Belongs to city center area	☐	☐	☐	☐	☐	Disrupt in city center areas
Goes with tower buildings	☐	☐	☐	☐	☐	Goes with single-family houses
Goes with new buildings	☐	☐	☐	☐	☐	Goes with old (historic) buildings
Goes with mansions	☐	☐	☐	☐	☐	Goes with working-class estates

For how many trips within the last two weeks did you use a TRAM?

☐ None ☐ Approx. 1- 4 trips ☐ 5-10 trips ☐ One trip per day ☐ Several trips per day

How important are the following aspects of public transport to you?

	Less important	Important	Very important
Fast travel speed	☐	☐	☐
High frequency	☐	☐	☐
Direct Routes	☐	☐	☐
Punctuality / Reliability	☐	☐	☐
Public transport stop location close to home	☐	☐	☐

Survey: Urban transport

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How important are the following aspects of public transport to you?

	Less important	Important	Very important
Smooth ride comfort	☐	☐	☐
Very high safety	☐	☐	☐
Environmental friendliness	☐	☐	☐
New vehicle (including air-condition etc.)	☐	☐	☐
Dedicated lane (e.g. bus lane, tram tracks)	☐	☐	☐
No crowing in vehicle	☐	☐	☐
Easy boarding	☐	☐	☐
Free seats available	☐	☐	☐

Imagine a CITYBUS and rate the following pairs of opposites:

CITYBUS						
Reliable	☐	☐	☐	☐	☐	Not reliable
Free flow	☐	☐	☐	☐	☐	Stop and go
Risk of accident	☐	☐	☐	☐	☐	Safe of accident
Smooth ride comfort	☐	☐	☐	☐	☐	Bad ride comfort
Attractive	☐	☐	☐	☐	☐	Not attractive
Not important	☐	☐	☐	☐	☐	Important
Difficult to use	☐	☐	☐	☐	☐	Easy to use
Valuable	☐	☐	☐	☐	☐	Not valuable
Environmental friendly	☐	☐	☐	☐	☐	Environmental unfriendly
Noisy	☐	☐	☐	☐	☐	Silent
Crowded vehicle	☐	☐	☐	☐	☐	Empty vehicle
New vehicle	☐	☐	☐	☐	☐	Old vehicle
Spacious vehicle	☐	☐	☐	☐	☐	Cramped vehicle
Easy to board	☐	☐	☐	☐	☐	Difficult to board
Inconvenient	☐	☐	☐	☐	☐	Convenient
Modern vehicle	☐	☐	☐	☐	☐	Old-fashioned vehicle
Confusing net	☐	☐	☐	☐	☐	Clearly designed net
Fast service	☐	☐	☐	☐	☐	Slow service
Low frequency	☐	☐	☐	☐	☐	High frequency
Indirect routes	☐	☐	☐	☐	☐	Direct routes
Unfavorable stop locations	☐	☐	☐	☐	☐	Favorable stop locations
Belongs to city center area	☐	☐	☐	☐	☐	Disrupt in city center areas
Goes with tower buildings	☐	☐	☐	☐	☐	Goes with single-family houses
Goes with new buildings	☐	☐	☐	☐	☐	Goes with old (historic) buildings
Goes with mansions	☐	☐	☐	☐	☐	Goes with working-class estates

For how many trips within the last two weeks did you use a CITYBUS?

☐ None ☐ Approx. 1- 4 trips ☐ 5-10 trips ☐ One trip per day ☐ Several trips per day

Many thanks for your participation! M. Scherer

A 2 Image score of bus and tram

Table 1 Difference in scores of frequent users

Attribution	T	df	Sign. (2-sided)	Mean difference
Traffic flow	12.898	328	.000	.94
Environmental friendliness	10.548	331	.000	.63
Attractiveness	7.933	330	.000	.53
Ride comfort	7.895	331	.000	.57
Reliabiliy	7.018	332	.000	.37
Net design	4.267	330	.000	.33
Danger	3.806	333	.000	.21
Routing	3.796	332	.000	.24
Space in vehicle	3.473	331	.001	.25
Loading of vehicle	3.444	331	.001	.18
Frequency	2.874	331	.004	.15
Age (vehicle)	2.345	331	.020	.14
Convenience	2.106	333	.036	.14
Safety	2.105	329	.036	.15
Ease of use	1.958	331	.051	.10
Value	1.923	333	.055	.10
Pace	-1.788	333	.075	**-.11**
Noise	-1.363	332	.174	**-.12**
Importance	1.358	330	.175	.08
Easy to board	1.249	334	.213	.08
Modernity (vehicle)	.880	333	.380	.05
Stop locations	-.608	331	.544	**-.03**

Table 2 Difference in scores of occasional users

Attribution	T	df	Sign. (2-sided)	Mean difference
Traffic flow	9.868	247	.000	.73
Environmental friendliness	8.160	251	.000	.58
Noise	-4.301	251	.000	**-.43**
Attractiveness	3.941	251	.000	.31
Reliabiliy	3.206	249	.002	.17
Loading of vehicle	2.820	251	.005	.17
Easy to board	-2.665	253	.008	**-.22**
Ride comfort	2.600	247	.010	.24
Stop locations	-2.507	247	.013	**-.16**
Age (vehicle)	-2.469	251	.014	**-.18**
Pace	-1.705	249	.089	**-.12**
Routing	1.466	247	.144	.10
Space in vehicle	1.333	250	.184	.10
Ease of use	.970	251	.333	.06
Modernity (vehicle)	-.872	250	.384	**-.06**
Importance	-.744	251	.458	**-.05**
Value	.492	252	.623	.04
Convenience	-.306	252	.760	**-.02**
Safety	-.202	249	.840	**-.02**
Danger	.113	251	.910	.01
Net design	.095	246	.924	.01
Frequency	.062	248	.950	.00

Table 3 Difference in scores of non- users

Attribution	T	df	Sign. (2-sided)	Mean difference
Traffic flow	4.558	61	.000	.68
Environmental friendliness	3.196	62	.002	.44
Convenience	-2.197	61	.032	**-.34**
Reliability	2.161	62	.035	.24
Safety	-1.673	63	.099	**-.25**
Modernity (vehicle)	-1.476	63	.145	**-.20**
Value	-1.277	60	.207	**-.16**
Noise	-1.178	63	.243	**-.22**
Importance	-.760	61	.450	**-.13**
Stop locations	-.695	60	.490	**-.10**
Danger	-.652	62	.517	**-.10**
Pace	-.603	62	.549	**-.10**
Frequency	-.505	62	.615	**-.06**
Space in vehicle	.429	62	.670	.06
Ride comfort	-.397	62	.692	**-.06**
Age (vehicle)	-.393	61	.695	**-.06**
Ease of use	.273	62	.786	.05
Routing	.195	62	.846	.03
Net design	-.169	62	.866	**-.03**
Attractiveness	.157	62	.876	.03
Loading of vehicle	.000	61	1.000	.00
Easy to board	.000	63	1.000	.00

Table 4 Mean score and standard deviation of bus and tram attributions.

	Bus		Tram	
Attributes	Mean	Std.dev.	Mean	Std.dev.
Important – not important	1.71	.972	1.72	1.023
Valuable – not-valuable	1.72	.871	**1.69**	.966
Easy to use – difficult to use	1.77	.931	1.72	.972
Reliable - unreliable	1.86	.820	**1.61**	.653
High frequency – low frequency	1.92	.875	1.88	.820
Security: Harmless - dangerous	1.98	.931	1.82	.976
Favourable – unfavourable stop locations	**1.99**	.858	2.12	.872
Easy to board – difficult to board	2.08	.932	2.07	1.007
Environmental friendly – environmental unfriendly	2.10	.992	**1.53**	.798
Direct routes – indirect routes	2.13	.997	2.00	.983
Vehicle: modern - oldfashioned	2.20	.844	2.16	.987
Orientation: Clearly designed net – confusing net	2.25	1.164	2.10	1.194
Attractive – not attractive	2.27	1.006	1.92	1.006
Vehicle: new - old	2.35	.849	2.34	.987
Safety: Safe of accident – risk of accident	2.36	1.129	2.31	1.253
Vehicle: Convenient - inconvenient	2.43	1.025	2.36	1.048
Free flow – stop and go	2.54	1.017	1.79	.817
Vehicle: spacious - cramped	2.59	.969	2.35	1.024
Fast - slow	**2.62**	.791	2.67	1.008
Silent - loud	**2.71**	1.106	2.90	1.218
Smooth ride comfort – bad ride comfort	2.82	1.106	2.48	1.094
Vehicle: empty - crowded	3.83	.815	3.62	.814
Average total	**2.26**	**.470**	**2.15**	**.532**

Scale ranging from most positive (1) to most negative (5)

Table 5 Attributions with significant different scores on bus and tram (5% level)

Attribution	T	df	Sign. (2-sided)	Mean difference
Traffic flow	15.676	639	.000	**.74951**
Environmental friendliness	13.256	645	.000	**.57200**
Reliability	7.188	645	.000	.23660
Attractiveness	6.939	646	.000	.34100
Ride comfort	6.096	642	.000	.34162
Loading (vehicle)	5.558	639	.000	.20825
Space (vehicle)	4.729	647	.000	.23495
Security	3.460	649	.001	.14941
Stop locations	-3.185	637	.002	**-.11845**
Routing	3.154	645	.002	.14126
Noise	-3.131	649	.002	**-.19192**
Net design (orientation)	2.944	644	.003	.15827

A 3 Comparison of cluster data

Table 6 Results of comparison of bus and tram clusters: Residents

Comparison of Resident numbers in bus and tram cluster		# cluster	Mean	Std. dev	Mean rank	Sign.
ZH	2 Tram	17	1961	974	17.53	0.149
	3 Bus	13	1363	688	12.85	
ZH	2 Tram	17	1961	974	14.12	0.760
	4 Bus	11	1991	677	15.09	
ZH	6 Tram	32	1015	635	21.06	0.121
	3 Bus	13	1363	688	27.77	
ZH	6 Tram	32	1015	635	18.16	0.001*
	4 Bus	11	1991	677	33.18	
ZH	9 Tram	16	1562	1074	14.25	0.853
	8 Bus	12	1542	667	14.83	
BE	6 Tram	18	1751	1719	37.89	0.000*
	3 Bus	35	823	561	21.40	
BE	6 Tram	18	1751	1719	15.56	0.749
	4 Bus	13	1506	727	16.62	

* Significant on a 5% level.

Table 7 Results of comparison of bus and tram clusters: Jobs

Comparison of job numbers in bus and tram cluster		# cluster	Mean	Std. dev	Mean rank	Sign.
ZH	2 Tram	17	782	827	16.29	0.572
	3 Bus	13	709	698	14.46	
ZH	2 Tram	17	782	827	14.88	0.760
	4 Bus	11	669	541	13.91	
ZH	6 Tram	32	881	926	23.47	0.707
	3 Bus	13	709	698	21.85	
ZH	6 Tram	32	881	926	22.34	0.759
	4 Bus	11	669	541	21.00	
ZH	9 Tram	16	809	1104	16.31	0.178
	8 Bus	12	326	348	12.08	
BE	6 Tram	18	689	519	30.89	0.189
	3 Bus	35	559	657	25.00	
BE	6 Tram	18	689	519	15.89	0.936
	4 Bus	13	661	396	16.15	

Schriftenreihe des IVT

Herausgegeben vom und zu beziehen beim Institut für Verkehrsplanung, Transporttechnik, Strassen- und Eisenbahnbau IVT an der ETH Zürich, ETH-Hönggerberg, CH-8093 Zürich.

Mit dieser Schriftenreihe werden die bis anhin separaten Reihen «Mitteilungen aus dem Institut für Strassen-Eisenbahn- und Felsbau» und «Lehrstuhl-Berichte» bzw. «IVT-Berichte» weitergeführt. Die bisher erschienen Schriften sind nachstehend aufgeführt.

Mitteilungen aus dem Institut für Strassen-, Eisenbahn- und Felsbau an der ETH Zürich

Nr.		
1	1943	Die Lüftung der Alpenstrassen (W. Wirz)
2	1944	Die Reibungskennziffer als Kriterium zur Beurteilung von Strassenbelägen (Dr. E. Zipkes)
3	1945	Beurteilung der Konstruktion, Rauhigkeit und Verkehrssicherheit von Strassenbelägen unter Verwendung der Reibungskennziffer (Prof. E. Thomann und Dr. E. Zipkes)
4	1947	Beanspruchung von Strassenbelägen durch metallische Systeme (Dr. E. Zipkes)
5	1954	Die Leistungsfähigkeit von ungesteuerten Verkehrsknotenpunkten (Dr. H. Rapp)
6	1957	Untersuchungen über die Leistungsfähigkeit von Überlandstrassen (M. Rotach)
7	1958	Das Motorrad im Überlandverkehr (M. Rotach)
8	1960	Geschwindigkeiten auf zweispurigen Überlandstrassen (M. Rotach)
9	1960	Lastwagen auf Steigungen (M. Rotach)
10	1960	Die Lüftung der Autotunnel (Prof. J. Ackeret, Dr. A. Haerter, Prof. M. Stahel)
11	1960	Fahrräder auf Zweispurstrassen (M. Rotach)
12	1960	Untersuchungen über die Ventilation von Stollen (Prof. H. Gessner, Prof. M. Stahel, H. Bühler, P. Schärer, F. Rutishauser)
13	1961	Griffigkeitsmessungen mit dem Rugosimètre (S. Bonomo)
14	1961	Das Aequivalent von Motorrädern (M. Rotach)
15	1961	Beschleunigungen von Personenwagen (C. Zuberbühler)
16	1967	Kenngrössen von Personenwagen (S. Sulger Büel)
17	1968	Richtlinien für die Anordnung und Konstruktion von Leiteinrichtungen (P. Pingoud)
18	1970	Neuere Leitschranken — Stand 1969 (P. Pingoud)
19	1970	N1: Bern — Lenzburg — Unfälle an Mittelschranken, Seilzaun — Doppelplanke (P. Pingoud)
20	1970	Die Lüftung der Tunnel während dem Ausbruch (Arbeitsgruppe für Lüftung im Tunnelbau)
21	1972	Erfahrungen mit der Ebenheitsmessung nach der Winkelmessmethode (S. Huschek)
22	1970	Die Prüfung der mechanischen Eigenschaften von Gesteinen im dreiachsigen Spannungszustand (Dr. K. Kovari, A. Tisa, E. Hasler)
23	1972	Abnützung von Strassenbelägen durch den Verkehr, unter besonderer Berücksichtigung von Spikesreifen (S. Sulger Büel)
24	1973	Schäden durch den Gebrauch von Spikesreifen (Dr. E. Zipkes und S. Sulger Büel)
25	1973	Der Rundlauf als Mittel der Oberbaudimensionierung — Vorstudien zu einem Forschungsprojekt (I. Scazziga)
26	1974	Höchstfestigkeit und Restfestigkeit von Gesteinen im Triaxialversuch (Dr. K. Kovari, A. Tisa)
27	1974	Haftvermögen von Spikesreifen auf eis- und schneefreier Strasse (S. Sulger Büel)
28	1974	Befahrbarkeitsmessungen auf Strassen nach der Winkelmessmethode — Neue Untersuchungen (S. Huschek)
29	1974	Strassenbau-Forschung in der Schweiz (Dr. E. Zipkes)
30	1975	Der Einfluss der Rillierung von Strassenoberflächen auf die Unfallhäufigkeit (Dr. E. Zipkes)
31	1975	Griffigkeit und Verkehrssicherheit auf nasser Strasse (S. Huschek)
32	1976	Erhebungen über die Beanspruchung der Strasse durch schwere Motorwagen (I. Scazziga)
33	1976	Geschichtliche Entwicklung der biuminösen Strassenbeläge (Dr. E. Zipkes)
34	1976	Vergleich von Seilzaun und Doppelplanke anhand von Unfällen an Mittelschranken (M. Klingler, U. Seiler)
35	1977	Rollgeräusch und Strassenbelag — Fahrgeräusch, quantitative und qualitative Analyse — Kausalität (E. Eichenberger)
36	1977	Flugbetriebsflächen — Grundlagen für die Dimensionierung und die Oberflächengestaltung (W. Busenhart, I. Scazziga)

Nr.		
37	1977	Internationales Kolloquium über die plastische Verformbarkeit von Asphaltmischungen
38	1977	Ebenheitsmessungen auf Strassen (S. Huschek, G. Bachner)
39	1978	Lüftung im Untertagbau (Dr. A. Haerter, R. Burger)
40	1978	Beleuchtung und Unfallhäufigkeit in Strassentunneln (U. Graf und M. Ghielmetti)
41	1979	Griffigkeitsmessungen mit dem Skiddometer — weitere Ergebnisse (R. Pelloli)
42	1979	Die Beurteilung des Verformungswiderstandes bituminöser Mischungen durch den Kriechversuch (S. Huschek, P. Staub)
43	1979	Anfahrversuche an Varianten der Seilleitschranke System British Ropes (M. Klingler)
44	1980	Mechanische Eigenschaften von Filler-Bitumen-Gemischen/Einfluss der Verdichtungsart auf die mechanischen Eigenschaften von Asphaltprüfkörpern (S. Huschek, Ch. Angst)
45	1980	Beläge mit diskontinuierlichem Kornaufbau (Dr. E. Zipkes)
46	1981	Der Einfluss der Verdichtung auf die mechanischen Eigenschaften bituminöser Schichten (Ch. Angst)
47	1981	Numerische Erfassung rheologischer Probleme in der Felsmechanik (P. Fritz)

Nr.		
48	1982	Verhalten des Strassenoberbaus unter wiederholter Belastung — Versuch Nr. 1 auf der ISETH-Rundlaufanlage (H. P. Rossner, I. Scazziga)
49	1982	ISETH-Strassenbaucolloquien, Wintersemester 1981/82
50	1982	International Colloquium - Full Scale Pavement Tests, Colloque International - Essais routiers en vraie grandeur
51	1982	Morphologische Beurteilung verdichteter bituminöser Mischungen (Ch. Angst)
52	1983	Simulation von Eisenbahnsystemen mit RWS-1 (P. Giger)
53	1983	Beurteilung der Griffigkeit auf Fahrbahnen (F. Bühlmann)
54	1983	Zum Verformungsverhalten von Asphaltbeton unter Druck (S. Huschek)
55	1985	Einfluss der Witterung auf die Griffigkeit von Fahrbahnen, ein Beitrag zur Verkehrssicherheit auf überdeckten Strecken (F. Bühlmann)
56	1984	Griffigkeit - Bremsspur - Kraftübertragung (Dr. E. Zipkes)
57	1984	Reifengeräusch und Strassenbau, Internationales Seminar, Zürich, 9./10. Februar 1984
58	1985	Verhalten des Strassenoberbaues unter dynamischer Radlast (S. Huschek)

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LSB 73/1	Motorisierungsprognosen (F. Gerber, B. Ranft)
LSB 73/2	Gesetzmässigkeiten im Verkehrsablauf von Grossparkierungsanlagen 1. Teilbericht VSS FA 8/67
LSB 74/1	Landesplanerische Datenbank der Schweiz, Liniendatei (F. Karli, Prof. C. Hidber)
LSB 74/2	Wurde als LS-Notiz 74/1 publiziert, «Aggregatzustände des Verkehrssystems» (R. Meyer, Prof. C. Hidber)
LSB 74/3	Wurde als LS-Notiz 74/2 publiziert «Über demografische Determination des städt. Personenverkehrs» (F. Gerber)
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IVT 82/4	Das Werk mit dieser Nummer wurde zurückgezogen
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