KTH Architecture and the Built Environment

Ease-of-Use in Public Transportation – A User Perspective on Information and Orientation Aspects

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Doctoral Thesis in Traffic and Transport Planning, Infrastructure and Planning

Royal Institute of Technology
Stockholm, Sweden 2008

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TRITA-TEC-PHD 08-001
ISSN 1653-4468
ISBN 13: 978-91-85539-29-1
ISBN 10: 91-85539-29-5

For Kalle K.

Preface:

This thesis consists of this summary and the following eight papers, which will be referred to by their Roman numbers.

I. Dziekan, K. (2008). The transit experience of newcomers to a city – learning phases, system difficulties and information search strategies. Proceedings of the 87th TRB Meeting, January 2008 in Washington/DC/USA

II. Dziekan, K. (in press). What do people know about their public transport travel options? Investigating the memory representation of public transport through telephone interviews in a residential area of Stockholm, Sweden. Transportation

III. Dicke, M. & Dziekan K. (in manuscript). Reducing uncertainty and supporting cognitive maps in travel information for public transport.

IV. Dziekan, K. & Sedin, S. (2005). Customer reactions to implementation of a trunk bus network in Stockholm/Sweden. Proceedings of UITP Conference 2005 in Rome/Italy

V. Dziekan, K. (2007). Influences of a new trunk bus network line on the quality of cognitive maps of public transport of residents. Proceedings of World Conference on Transport Research (WCTR) 2007 Berkeley, California, USA

VI. Dziekan, K. & Kottenhoff, K. (2007). Dynamic At-stop Real-time Information Displays for Public Transport: Effects on Customers. Transportation Research Part A: Policy and Practise. Vol. 41, 489-501

VII. Dziekan, K. & Vermeulen, A. (2006). Psychological effects of and design preferences for real-time information displays. Journal of Public Transportation. 1, 71-89

VIII. Dziekan, K. & Scholz, A. (submitted) How to Measure “Ease-of-Use” in Public Transportation? - Scale Construction and Testing

Comments on my contributions:
In the papers where I am the first author I was responsible for the main part of the work. The co-authors contributed with advice and background knowledge (paper IV), ideas and help with the structure (paper VI), the practical field work and questionnaire translation (paper VII) and in paper VIII the co-author was involved in data collection and analysis. Paper III has two main authors. We analysed literature sources and compiled the review and conclusions together.

CONTENTS

0 SUMMARY

This interdisciplinary thesis combines psychological and transportation planning knowledge. Three main questions are investigated: 1) What concepts and ideas do people have with regard to a public transportation system (cognitive user perspective)?; 2) What orientation and information factors within the public transportation system enhance Ease-of-Use and make it simpler and more efficient to use public transportation in metropolitan areas?; 3) How can Ease-of-Use of a public transportation route be measured?
A combination of qualitative and quantitative methods was used. Between 2002 and 2007 a total of nine different studies were conducted: An in-depth study on a single exchange student, an interview study with exchange students, a questionnaire study on exchange students, a before-after interview study with travellers on selected bus stops, an before-after telephone interview study on residents, an expert questionnaire study via email, a behaviour observation study on travellers, a before-after questionnaire study on travellers on a tram line, and an on-board questionnaire study.
To analyse the cognitive user perspective the term memory representation was introduced, that includes cognitive maps of and additional knowledge about a public transportation system such as service frequency. Memory representation is influenced by experience. Three learning phases in an unknown public transportation system are proposed and a general information search script is described. A new approach is presented regarding the organisation of public transportation knowledge: The ground level is that there exists a public transportation option, the next level is the identification of the mode of transport and at the highest level of the hierarchy is the code for the line. Within the second level, the public transportation mode, a hierarchical structure of public transportation option knowledge is proposed. Three factors are postulated that contribute to the extent to which a line is represented in people's memory: visibility, straight route layout and labelling.
Which orientation and information factors within the public transportation system enhance Ease-of-Use, i.e. match the cognitive user perspective? It was found that trunk bus lines enhanced Ease-of-Use and at-stop real-time information can have various positive effects. The role of good maps is explained and stretched and the importance of consistent information throughout the travel chain is also pointed out. In addition, many valuable concrete hints are given with regard to how to match the system properly with the cognitive user perspective.
Undoubtedly, an interaction exists between system and user and they influence each other. This is where the third research question comes in: How can Ease-of-Use in public transportation systems be measured? The iterative process of defining and measuring Ease-of-Use resulted in a scale that measured the defined concept well with good reliability and validity.
The final discussion highlights the contribution to science of this thesis and presents some possible paths for further research. The thesis consists of a summary and eight papers.

SAMMANFATTNING

Den här tvärvetenskapliga avhandlingen kombinerar psykologi och transportplanering. De tre huvudfrågeställningarna är: 1) Vilka bilder har människorna av ett kollektivtrafiksystem (kognitivt perspektiv)?; 2) Vilka informations- och orienterbarhets-faktorer bidrar till att det blir lättare att använda kollektivtrafiken i ett storstadsområde?; 3) Hur kan man mäta ”Ease-of-Use” för en kollektivtrafiklinje?

Kvalitativa och kvantitativa metoder kombinerades och mellan 2002 och 2007 genomfördes totalt nio olika studier: en djupstudie av en utbytesstudent, en intervjustudie med utbytesstudenter, en enkätstudie med utbytesstudenter, en före/efter-intervjustudie med resenärer på utvalda busshållplatser, en telefon-intervjustudie med boende, en expert-enkät via e-post, en beteende-observationsstudie av resenärer, en före-efter enkätstudie på en spårvagnslinje och en enkätstudie ombord.

För att analysera användarperspektivet infördes begreppet ”memory representation”. Det innehåller såväl kognitiva kartor om kollektivtrafiken som ytterliggare kunskap om systemet, till exempel turtätheten på en linje. ”Memory representation” beror av personens erfarenhet. Tre inlärningsfaser vid inlärning av ett nytt kollektivtrafiksystem introduceras och beskrivs. Likaså har ett informationssöknings-diagram tagits fram. En ny ansats rörande hierarkisk organisation av kollektivtrafikkunskap föreslås: På basnivån finns kunskap om existensen av kollektivtrafik. Nästa nivå är identifikation av ett visst färdmedelslag och högsta nivån i hierarkin är koden för linjen i fråga. Inom den andra nivån, färdmedelslaget, föreslås en ytterliggare differentiering baserad på tre faktorer som bidrar till att ett färdmedel finns sparat som alternativ i människors huvud: god synlighet, raka linjesträckningar och beteckning/namngivning av linjen eller trafiksystemet.

Vilka informations- och orienterbarhets-faktorer höjer ”Ease-of-Use” i kollektivtrafiken; stödjer det s.k. kognitiva användare-perspektivet? Avhandlingen ger många konkreta tips hur anpassningar i systemet kan underlätta för resenärerna. Stombusslinjer, realtidsinformation vid hållplatser, bra kartor och konsistent information genom hela resan är bara några exempel.

System och användare interagerar och påverkar varandra. Därför undersöks i den tredje forskningsfrågan hur man kan mäta detta ”Ease-of-Use”. Forskningsprocessen var iterativ och till slut utvecklades ett mätinstrument. Detta mäter det definierade konceptet av Ease-of-Use med god reliabilitet och validitet.

Den avslutande diskussionen visar vilka vetenskapliga bidrag den här avhandlingen givit och skissar några idéer för fortsatt forskning.

Avhandlingen består av en sammanfattning och åtta vetenskapliga ”paper”.

ZUSAMMENFASSUNG

Diese interdisziplinäre Arbeit kombiniert psychologisches und verkehrsplanerisches Wissen. Die drei Hauptfragestellungen waren: 1) Welche Vorstellungen haben Menschen vom ÖPNV System (kognitive Nutzerperspektive)?; 2) Welche Faktoren bezüglich Information und Orientierung erhöhen die „Ease-of-Use“ eines ÖPNV Systems und machen dessen Benutzung einfacher und effektiver in einem städtischen Ballungsraum; 3) Wie kann die „Ease-of-Use“ opernationalisiert und gemessen werden?

Qualitative und quantitative Methoden wurden kombiniert und im Zeitraum 2002 bis 2007 wurden insgesamt neun Studien durchgeführt: eine Einzelfallstudie an einer Austauschstudentin, eine Interview-Studie mit Austauschstudenten, eine Fragebogenstudie an Austauschstudenten, eine Vorhehr-nachhehr Interview-Studie mit Fahrgästen an ausgewählten Bushaltestellen, eine Expertenfragebogen-Studie via Email, eine Verhaltensbeobachtungsstudie an Reisenden, eine Vorhehr-nachhehr Fragebogenstudie an Fahrgästen einer Tramlinie und eine Fragebogenstudie in Verkehrsmitteln.

Um die kognitive Nutzerperspektive zu analysieren wurde der Begriff „memory representation“ (Gedächtnisrepräsentation) eingeführt. Dieser beinhaltet sowohl kognitive Karten zu einem ÖPNV System als auch zusätzliches Wissen wie beispielsweise die Fahrtenhäufigkeit bestimmter Linien. Die „memory representation“ wird von Erfahrung beeinflusst. Für den Fall des Erlernen eines unbekannten ÖPNV Systems werden drei Lernphasen vorgeschlagen und ein genereller Informations-Suche-Script wird beschrieben. Bezüglich der Organisation des ÖPNV-Wissens wird ein neuer Ansatz vorgestellt: Die Basis-Ebene beinhaltet Wissen darüber, ob generell eine ÖPNV-Verbindung besteht, die nächste Ebene ist die Identifizierung eines bestimmten ÖPNV-Verkehrsmittels und die höchste Ebene in der Hierarchie wäre der Code für die Linie. Innerhalb der zweiten Ebene, dem Verkehrsmittel, wird eine weitere hierarchische Struktur vorgeschlagen. Diese basiert auf drei Faktoren die dazu beitragen, dass eine bestimmte Linie / ein bestimmtes Verkehrsmittel im Gedächtnis repräsentiert ist: Sichtbarkeit, gerade Linienführung und Labeling.

Was sind die Faktoren im Bereich Information und Orientierung, die Ease-of-Use im ÖPNV erhöhen, also die kognitive Nutzerperspektive unterstützen? Metro-bus Linien, Echtzeit-Abfahrtsanzeigen an Haltestellen, gutes Kartenmaterial und konsistente Information während der gesamten Reisekette seien nur beispielsweise genannt. Die Arbeit gibt viele konkrete Hinweise wie das System die Nutzerperspektive unterstützen kann.

System und Nutzer interagieren zweifellos miteinander und beeinflussen sich damit auch gegenseitig. Deshalb beschäftigte sich die dritte Forschungsfrage damit, wie man diese „Ease-of-Use“ messen kann. Der iterative Prozess resultierte in einer Skala, die dass definierte Konzept zuverlässig und gültig gemessen hat.

Die abschließende Diskussion hebt hervor, was diese Arbeit Neues zum Wissenschaftsstand beiträgt und skizziert einige Ideen für weitere Forschung. Die Arbeit besteht aus einer Zusammenfassung und acht wissenschaftlichen Artikeln.

1 INTRODUCTION

This introductory chapter gives background information on this work, outlines its scope and objectives and presents the structure of this summary.

1.1 Background

Today about 80% of the world's population (UITP, 2005) and 60% of the European population live in urban areas (EC, 2007). Public transportation (PT) plays an important role in achieving sustainability, efficient mobility and high quality of urban life. However, there are many reasons why people do not use PT to its full potential. The classical factors in this context are time and money (Wardman & Waters, 2001). However, the complex question of how and when people use (or do not use) PT has also been investigated with theories and models from social sciences. Beyond utility maximization functions and rational choice paradigms some other approaches can be mentioned that try to describe, explain and predict travel mode choice behaviour.

The classical theory used to explain travel mode choice from the psychological approach is the theory of planned behaviour (Ajzen, 1991; Bamberg & Schmidt, 1993; Bamberg & Schmidt, 2003). Attitudes, social norms, and perceived behaviour control are used as predictors. Recent research suggests the enlargement of the theory of planned behaviour with two other concepts: ecological norms and symbolic-social motives (Haustein & Hunecke, 2007). Other approaches to explain travel mode choice have been reported in research areas concerning habits (Aarts, 1996; Verplanken, Aarts, & van Knippenberg, 1996; Banister, 1978; Goodwin, 1977) or important life events (Klöckner, 2005; Bamberg, 2006).

One way to create high ridership in PT is to strengthen the relative attractiveness of PT vs. the car (TCRP, 2007; Steg, 2007; Gärling & Steg, 2007). Starting points might be better supply, higher quality of service or more marketing. The City of Stockholm and the public transport authority have been working for many years with the issue of making travel by public transport more straightforward, thereby increasing traveller numbers. Trunk bus lines have been implemented in order to simplify travelling. The first three trunk bus lines, implemented in stages between 1997 and 1999, were a success: passengers preferred the new lines, leading to an increase in patronage up to 100% on them within a period of 5 years (Kottenhoff, 2002; paper IV; Dziekan, 2006). Average service frequency did not increase compared with the former, substituted bus lines, but factors concerning orientation and information were improved, for example:

Bus lines

- are operated by new blue-coloured, articulated buses,
- are equipped with real-time at-stop information displays,
- have coloured concrete to indicate stops clearly in the urban area, and
- are clearly shown in a good overview map of the system.

The positive ridership developments in Stockholm supported the hypothesis that other factors, such as clarity and easy orientation might also be important for PT in metropolitan areas. The occasion when the final line in the trunk bus network was implemented was used to investigate customer reactions in a before-after study. It was interesting to investigate the Ease-of-Use factors that had possibly led to the success of the first three bus lines. These ideas were the birth of this doctoral project.

Many disciplines are concerned with mobility and transportation aspects, for example geography, urban planning, architecture, transport planning, sociology and psychology. Transportation in general and public transportation in particular is a multi-disciplinary field. Much literature exists on transport planning, operation and innovative vehicle technology, but comprehensive knowledge about the user is rare. As Stradling (2002) describes it, focusing on aspects of the experience and thinking of the traveller is a relatively new approach in PT. This work is thus about the user perspective, combining public transport planning aspects with psychological knowledge. The focus is on information and orientation aspects that enhance the Ease-of-Use of PT systems from the user perspective.

Knowledge about what people know (or do not know) about a PT system can enable planners to devise “easy-to-understand” and ”simple-to-use” systems as well as provide essential and useful information to the customers. The scientific results presented in this thesis, when implemented in practice by operators, authorities and other actors in the PT sector, could improve the performance of a PT system in two ways: first, make it easier for users to handle the system and use it in a more efficient way; second, the results could help lower the barriers to using PT for people not used to the system, such as travellers in an unfamiliar city, younger inexperienced residents or older car drivers (Schlag, 2008; Engeln, Schlag, & Deubel, 2002). More attractive PT, focusing on the user perspective while being planned and operated, can contribute to sustainable and efficient transportation systems and to better quality of life in urban areas.

1.2 Scope and Objectives

The thesis focuses on the user perspective. But the system with its characteristics is also part of the picture. Figure 1 visualises the framework of the thesis.

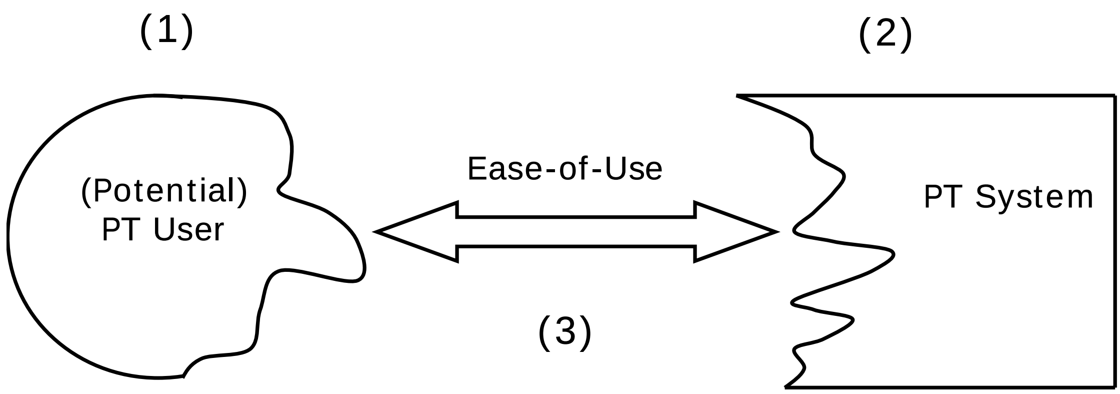

Figure 1: Thesis framework with research question areas

The central concept is Ease-of-Use. It was not clear at the beginning of the work what this term means. There were some vague speculations based on the success of the trunk bus network in Stockholm as to which factors could enhance Ease-of-Use. Primarily, these factors were assumed in the area of information and orientation. The whole work tried to determine on one hand what the core concept is and how to define Ease-of-Use, and on the other hand point out factors that enhance Ease-of-Use. Now that the work has been completed, the author still cannot give a final definition of Ease-of-Use in PT. A tentative definition is provided as follows:

Ease-of-Use is determined by the degree to which travellers spend affective and cognitive effort on a journey by public transport. Low affective effort means feeling comfortable, experiencing pleasure and convenience accompanied by feeling secure and perceiving less stress. Low cognitive effort is defined by the system being easy to learn and providing high quality information and reliable services.

There are three other concepts that are related to or can even be seen as facets of the Ease-of-Use concept: Usability, self-explanatory systems and customer satisfaction. Possible contributions of these concepts to solve the definition problem of Ease-of-Use could be an issue for further research.

Research on usability had already been done in the aviation sector (for example Tam & Lam, 2004) and in the road traffic sector (for example Weller, Schlag, Gatti, Jorna, & van de Leur, 2006) but the literature on usability in the PT sector is very sparse. The idea of "self-explanatory systems" is that well planned and designed PT systems do not need any special explanatory information; they will lead the traveller by themselves. A well known motto says: "When simple things need pictures, labels or instructions, the design has failed" (Norman, 2002). Finally, customer satisfaction is also seen as an indicator of Ease-of-Use as well. You are satisfied with a service when it is easy to use and vice versa. The problem with all of these concepts is that they do not perfectly match the Ease-of-Use concept.

It needs to be emphasised here that in this thesis the objective is to investigate the Ease-of-Use for all PT users; however, the perspective and target group also matter. The dimensioning user (see 2.1.4) in some of the papers was defined as the newcomer to an unknown PT system.

Although the concept is still a working definition it is concluded that in order to design systems with high Ease-of-Use it is necessary to know more about the user's perspective and experiences. Thus, investigating memory representations, learning processes, and experienced affective and cognitive effort while using the system constitute the approach in this thesis.

The following three main questions were chosen for study:

1) What concepts and ideas do people have about the PT system in metropolitan areas (cognitive user perspective)?
2) What information and orientation factors within the system enhance Ease-of-Use in metropolitan areas?
3) How can Ease-of-Use of a public transportation route be measured?

Metropolitan areas are conceptualised as large cities and their surrounding areas that have an extensive PT network containing at least one type of rail-bound traffic and bus services. Finally, some limitations have to be mentioned. This thesis is not concerned with ticketing in PT. Further, it concentrates on metropolitan areas in developed countries.

1.3 Structure of the Thesis

This thesis consists of an introductory part followed by reprints of eight papers. The introductory part is a summary of the findings of the papers. It can also be read on its own merits.
In this first section, a general background to the thesis is provided and the objectives are formulated. Section 2 introduces definitions of relevant concepts and terms used. Section 3 provides a brief overview of the various methods. Section 4, which presents a summary of the results, gives answers to the three main research questions elaborated above. Finally, section 5 discusses what the results contribute to science and details possible further research.

2 CONCEPTS

Since this thesis is an interdisciplinary work and includes both psychology and public transportation planning, this section is intended to define and explain the most important terms used during the course of the work, thereby giving a short introduction into related theories.

2.1 Psychological Concepts

2.1.1 Cognitive Map and Memory Representation

In general, a cognitive map is an interpretative framework of the world in the human mind, which affects actions and decisions as well as knowledge structures. In a more specific sense a cognitive map is the mental representation of the layout of one's environment (Kitchin & Freundschuh, 2000) and an internal representation of experienced environments (Golledge & Gärling, 2003). Cognitive maps have been examined for several environments, mainly large-scale environments (see Gärling, Lindberg, Carreiras, & Böök, 1986; Gärling, 1995; or Jackson, 1994 for overviews). The concept of cognitive maps was originated by Toleman (1948). Later, Lynch (1960) and Appleyard (1970) began researching spatial knowledge and urban perception and Kuipers (1982) used the term as a metaphor to describe “the map in the head” of humans.

The more general term “memory representation” also used by Gärling & Golledge (2000), describes what people know and have in their minds about certain issues or things, such as a bus line. It includes not only cognitive maps as spatial representations of the environment but also other knowledge such as knowledge about service frequencies and route options. This knowledge serves as a basis for making travel mode, route or destination choices (paper II). It is also essential for successful wayfinding and orientation.

While the traveller is interacting with the PT system, his or her memory representation is developing continuously. New knowledge, experience and insights are stored. The traveller continuously matches information from the cognitive map with information from his or her environment (Stern & Portugali, 1999). Thus, the person's prior experience of PT is important to understand travel behaviour and accessibility in cities (Mondschein, Blumenberg, & Taylor, 2006).

The term orientation (orienterbarhet in Swedish), as used in the main headline of this thesis, could be seen as a part of the concept memory representation.

2.1.2 Schemata and Script

Schemata are organized packets of information about the world, events or people, that are stored in the long-term memory. They include what are referred to as scripts and frames. While schemata describe more generally a cognitive structure of types of background knowledge that a person brings to a context, a script has a more dynamic nature; it 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. 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 & Keane, 2005).

Analysing cognitive structures such as schemata or scripts is important to understand human behaviour. These schemata are abbreviations and save cognitive resources. As human beings are cognitive “niggards” they will save effort and build up such behaviour routines based on schemata, stereotypes and scripts. This makes life easier, because one does not have to think about normal things in-depth. On the other hand, it is very difficult to change such script-based behaviour.

2.1.3 Newcomers to a City

Business travellers, tourists or new residents are typical newcomers to a city. They usually have only limited memory representation of the urban area and the PT system. However, they might have a general idea of how PT works such as is available in schemata.

It is important to focus on first-user usability in PT systems (paper I) since a system that is easy to use for people unfamiliar with the urban area and the PT will also be easy to use for any other (potential) user. The uncertainty of the newcomer should define the standards (paper II).

When the right support is provided winning a newcomer to a city as a PT user is easier - due to the situational circumstances - than breaking the habits of residents. Business travellers and tourists often arrive without a car and are not dedicated in their travel mode choice. People moving to a new city are faced with a change in their life and are also forced to think over their mobility options. Campaigns to attract more PT users among new residents can be very successful (Bamberg, 2006).

2.1.4 Design for All - The Dimensioning User

The approach "design for all" provides an inclusive design idea that could be adapted post-hoc for this thesis. It uses the concept of the dimensioning user. Facilities should empower the user with the least capability to act independently from persons. Translated to the public transportation it means that the user with the greatest need of help and support from the system should be enabled to use it. The dimensioning user could be persons with different disabilities such as persons with visual handicaps or persons bounden to wheelchairs (Westerlund, Ståhl, Nelson, & Mageean, 2000; Waara, 2001). But apart from the group of persons with disabilities older people can also be considered to be dimensioning users when designing a system (see Engeln & Schlag (2001) for PT use and Schlag (2008) for older car drivers). In the same way younger users can be considered as dimensioning users (Hunecke, Tully, & Bäumer, 2002).

Since this thesis focuses on information and orientation aspects the newcomers to a city, namely exchange students, were chosen as the dimensioning user since they have to learn to use the unknown PT system (see also 2.1.3). The approach is as follows: If the needs of the dimensioning user are met, the system is easy to use for all other user groups alike. This work concentrates not on the very extreme poles of the continuum of users with different disabilities. It rather puts the average (potential) PT user in focus and the results should be valid for the majority of people.

2.2 Public Transportation Planning Concepts

2.2.1 Public Transportation

Public transportation (PT) has many synonyms: transit, public transit, mass transit. The Swedish term “kollektivtrafik” indicates that it means travelling together and bundling individual journeys. The Germans call it “Öffentlicher Personennahverkehr” (ÖPNV), focusing on the aspect of being accessible to the public and often financed by public bodies, and on the passive transport of people.

There are many definitions of public transportation. White (2002) defined it as including all modes available to the public, irrespective of ownership. In addition to the scheduled services of bus, coach and rail operators, he included taxis, private hire buses and coaches and even the provision of school services.

The online lexicon Wikipedia (German version) says: PT is mobility and transportation services that are accessible for everybody. The main criteria are general accessibility, that the service is offered by special transport operators, and that conditions such as prices and timetables are set. Public transportation comprises all transport systems in which the passengers do not travel in their own vehicles. While it is generally taken to mean rail and bus services, wider definitions would include scheduled airline services, ferries, taxicab services, etc. — any system that transports members of the general public (Wikipedia, 2007).

The definition in Sweden (SIKA, 2008) reads: Public transportation is in advance organised, regularly operated accessible transport services that are offered to all citizens or to a selected group of persons based on given/stated rules. This definition excludes taxi journeys. The definition includes three main groups of public transportation:

1) General public transportation (allmän kollektivtrafik) that is offered to all people based on timetables and routes;
2) Special public transportation (särskild kollektivtrafik) offers services to a specific group of people (e.g. pupils, people with disabilities);
3) Tourist and charter traffic that is offered to all citizens.

It is possible to categorize public transportation into local, regional and interregional traffic. Public transportation can be operated with road-based vehicles (buses), rail-bound vehicles (e.g. trams, trains, metro), on water (e.g. ferries) or via air.

The definition and practical application of public transportation varies very much in the global perspective. Developing countries may have a different definition from industrialized countries.

For the purposes of this thesis, *public transportation* is defined as *a collective form of passenger transport that is accessible to all. The conditions such as timetable, routes and prices are set and people do not travel in their own vehicles.* It is taken to mean rail, light rail, subway, bus and ferry services, but does not include scheduled airline services, taxicab and other hired services. Local, regional and interregional traffic is included in the definition, but there is no focus on interregional traffic.

2.2.2 Public Transportation System

In this work, the term public transportation system (PT system) is used in a broader meaning. Beyond the physical system also other system components are included. Thus, not only bus and rail networks, stations and vehicles are part of a PT system but also the information and organisation. Both the journey itself and the pre-trip planning take place within the PT system. The term therefore also includes information such as in timetables, web based travel planners, announcements in vehicles or at stops or other strategically and tactical information about how to use PT.

2.2.3 User

User here means the final user of a product or service. The term is used in this thesis as being synonymous with passenger, customer or traveller. There are different ways of segmenting user groups. Usually they are categorised according to frequency of use: frequent users are people who often travel by PT, occasional users ride PT approximately once a week or less, and finally there is the category of seldom users or non-users. The cut off value for frequent users can vary: in paper V the cut off value is 2 days a week and more, while paper II uses 3 days a week and paper VII sets the cut off at 5 days due to the sample characteristics. Other ways of categorising users is by gender, travel purpose, age, education level, car availability or experience of the system such as newcomers (as in paper I) vs. being an old hand at using the PT system in a city.

2.2.4 Ridership

Ridership (also called patronage) is one performance measurement used to assess the success of a PT system on the precondition that the system capacity is sufficient. High ridership and high customer satisfaction are general objectives in public transportation planning and operation. There are several ways of generating numbers, for example how many passengers per day use a particular route. Direct counting is one method (O´Flaherty, 1997). Manual or automated counting, such as by in-vehicle automatic passenger counting systems, can be applied. Data from automated passenger counting was used in papers IV and V. There are also other methods that involve the user more and demand cooperation: traveller interviews, household interviews or questionnaires in various forms often combined with travel diaries that have to be filled in by the respondent.

2.2.5 Traveller Information

The mode of traveller information can range from the simple paper timetable and maps up to personalised, real-time journey planners. Information provides the traveller with decision making aids and with knowledge that can be used in future travel decisions. Information plays a crucial role in supporting the traveller before, during and after the trip. Recent developments allow more and more passenger information based on information technology (paper VI). One example is real-time departure time displays at stops, stations or in other places such as shopping centres or hospitals. The new generation of personalised devices such as mobile phones or PDAs also offer many possibilities for providing valuable PT information. The Internet has become more and more important as an information medium and is well suited for passenger information such as in travel planners.

2.2.6 Trunk Bus Network

Trunk bus networks have some elements of bus rapid transit (BRT). BRT is a bus-based mass transit “system” and requires coordination of a number of features including exclusive right-of-way lanes, rapid boarding and alighting, easy transfers, streamlined fare collection, clear route maps and other information, modal integration, clean vehicle technologies, marketing and customer service (Levinson et al., 2003; Takeshita, Shimizu, & Kato, 2007). However, the term BRT conceptually lies along a continuum between rubber-tyred light-rail-like systems at one end, and improved local bus services at the other end (Hess, Taylor, & Yoh, 2006). Trunk bus networks, rather, belong to the latter. A trunk bus strategy in metropolitan areas can include:

- fast, direct connections on the main traffic axis;
- a clear network structure with a few lines which are clearly differentiated (e.g. by colour);
- high frequency of service;
- long distances between stops;
- high accessibility, reliability and speed due to traffic prioritization.

Further, operation with large, high-capacity buses, visible stops and routes within the urban area, and well-designed information (e.g. maps similar to subway maps) can also characterise trunk bus systems.
These elements are implemented to various extents in European trunk bus networks. In most cases, however, only a few of these features have been realized. The idea is that a trunk bus network is perceived as something in between a bus network and a subway network. Synonyms for trunk bus are “Metro-Bus” in Germany and “stombuss” in Sweden.

3 METHODS

This chapter begins with an overview on all methods used in this thesis. After that interview and questionnaire methodology are described as the main methods and then the methods in each study are briefly described and discussed. Particular attention is paid to limitations to generalisation possibilities in order to support reflections on the results later on.

3.1 General Comments

Since the focus of this thesis is on the user perspective, methods were used that focus on the customer and reveal his or her thoughts, knowledge, experience and feelings. Both qualitative and quantitative methods were used. All methods have advantages and disadvantages. Furthermore, they focus on different parts or reveal information about different aspects of a research problem (such as the philosopher Karl Popper's searchlight theory suggests). Therefore, it is wise to combine methods to obtain a good database that allows hypotheses to be tested and conclusions formulated.

In this thesis nine different studies were conducted; three of them as before-after evaluation studies including two - and in one case three - data collection periods. Table 1 gives an overview of the nine studies and links them to the papers. The timeline is presented in Figure 2.

Table 1: Overview of empirical studies conducted for this thesis

#	Study – method	Referred to in paper
1)	Interviews with exchange students in Stockholm	I
2)	Questionnaires to exchange students in Dresden/Germany	I
3)	In-depth study on a single exchange student using method triangulation: questionnaires, interviews, wayfinding tasks with mind protocols during her first 10 weeks in Stockholm	I
4)	Before-after interviews with travellers at selected bus stops on bus line 46 / 2 in Stockholm	IV
5)	Before-after telephone interviews with residents in a residential area in Stockholm	II & V
6)	Worldwide expert questionnaire regarding IT in PT via email	VI
7)	Behaviour observation study of travellers approaching a subway entrance in Stockholm	VI
8)	Before-after questionnaire to travellers on a tram line in The Hague/The Netherlands	VI & VII
9)	On-board questionnaire to travellers on buses, trunk buses and subways in Stockholm	VIII

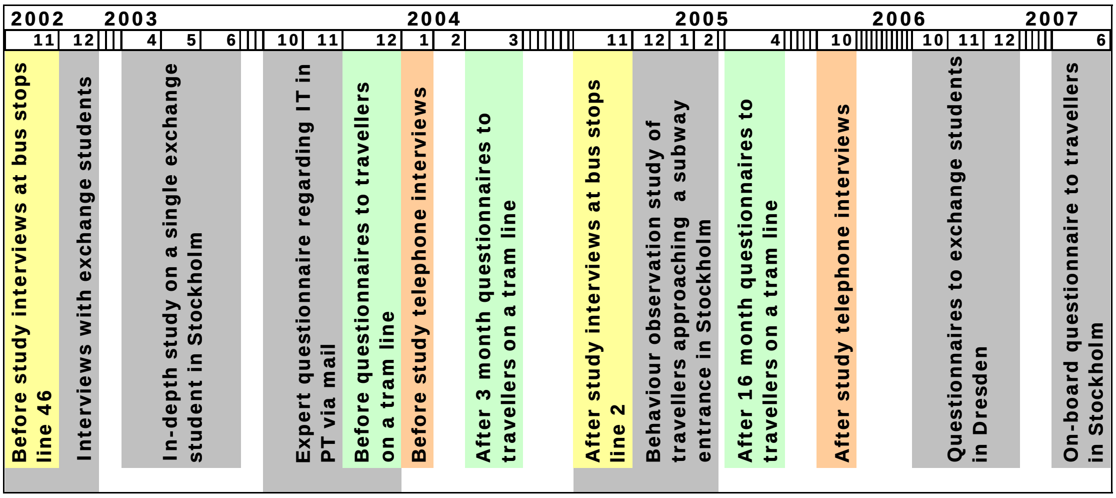

Figure 2: Timeline of the empirical studies conducted for this thesis

After some more general considerations on interview and questionnaire methodology, the methods used in this thesis are introduced and critically discussed. A detailed method description can be found in each paper.

3.2 Interview and Questionnaire Methodology

3.2.1 Interview Methodology

Using interview methodology means in general talking to selected people in a more or less structured way either face-to-face or via communication channels such as telephones. The selection, also called sampling, can be done in different ways. One method is true random sampling. It ensures that each sampling unit has an equal chance of being selected, thereby automatically producing a representative sample. Other sampling methods are systematic ordered sampling, stratified sampling and cluster sampling (O´Flaherty, 1997). Even purposeful sampling is possible (see 3.3.3). Theoretically, the sample can be single individuals but may also be a group.

The format of an interview guideline can range from a list of open questions where the respondent is asked to talk freely, to a list of questions with given answer categories, where the respondent's answers are categorised directly into the given categories. Open questions producing open answers have the advantage that more qualitative data can be collected, revealing new thoughts and providing deeper insights (Patton, 2002). But the data analysis is time consuming since the categorising has to be done afterwards by the investigator. Already categorised answers have the advantage of effective data analysis but entail the risk that the selected categories do not reflect the real answer structure. Usually, a combination of open and closed question formats is applied in interviews.

3.2.2 Questionnaire Methodology

A questionnaire is a list of more or less structured questions that is given personally or via (e-)mail to selected people, who fill it in using pen or pencil, or computer-based, for example a web questionnaire. Many other data collection techniques can be incorporated in a questionnaire such as stated preference experiments (Ortúzar & Willumsen, 1996) or critical incident technique (Flanagan, 1954; Friman, 2000).

Open questions require the respondent to write down his or her own answers and closed questions provide either answer categories such as "yes", "no" and "do not know" or a scale is provided on which a value for the answer should be rated. There are many different kind of scales and the most appropriate scale for the purposes of the questionnaire must be selected (Bortz & Döring, 1995).

Questionnaires can be more effective than interviews since the data analysis is faster, but not all aspects can be investigated in this way. For instance, if unbiased knowledge about PT options is of interest to the researcher it should not be possible for the respondent to check information sources other than their own memory before answering. This cannot be guaranteed with a mail back or web questionnaire.

3.3 Methods by Study

3.3.1 Interviews with Exchange Students in Stockholm (Paper I)

The aim of this study was to investigate newcomers to a city regarding their experiences with the unknown PT system and the problems that occurred when using the system (Dziekan, 2003). Since this issue had not been investigated the interview method was used. Exchange students as a representative group within newcomers to a city were chosen as study subjects due to the fact that almost all of them used PT in their guest city. Thus they were able to report events and describe experiences. Further, English had up to that point in time been the only means that the thesis author had of communicating fluently.

The recruiting was done by posters and through an exchange student mailing list. A small gift was awarded in return for an interview regarding their first experiences with their guest city. This was not true random sampling but since the students did not know the real background of the interview (namely PT) an interest-biased sampling was avoided. In total thirty-one complete face-to-face interviews were conducted with exchange students who had arrived in Stockholm approximately three months before. Each interview took between 45 and 60 minutes. Both qualitative and quantitative questions were used. One quantitative closed question was for example if the student knew the best travel option by PT from their place of study (KTH) to Odenplan. The free-associated answers were categorised afterwards and included in the constructed knowledge score. A qualitative example is the open question “Can you remember and describe difficulties, especially with the PT system, that you faced during your first days in Stockholm?” All interviews were audio recorded and transcriptions were made for subsequent analyses.

The sample of exchange students can be seen as representative for exchange students in Stockholm but of course exchange students are different in many aspects from other newcomers to a city such as tourists. They often have language problems, they stay longer than a couple of days, and they are usually captive PT riders. However, they can be considered as the dimensioning user (see 2.1.4) and a generalisation about experienced problems and improvement options for the PT system is thus possible.

3.3.2 Questionnaire to Exchange Students in Dresden (Paper I)

The purpose of this study was to gain additional knowledge on problems of exchange students with PT systems at the very beginning of their experiences and to add a sample from another country. The interviews in Stockholm (see 3.3.1) that had more a qualitative and explorative character served as reference and source of inspiration for developing the questionnaire.

Since it was found that the primary learning of the PT system and the most critical incidents happened during the first weeks, the target population in the Dresden study was defined as exchange students who had arrived in Dresden four weeks at most before the study and who had already experienced PT in their guest city. The questionnaire contained closed questions with given answer categories regarding knowledge of the PT system and information search strategies for PT use, a scale to measure customer satisfaction, and some questions to elicit statistical indicators. Open questions on positive and negative critical incidents in given problem fields were also included. The entire questionnaire, available both in English and German, took about 10 minutes to complete.

The sample was recruited at social gatherings of exchange student associations. Due to personal contact when distributing and collecting the questionnaire the rejection rate was very low and therefore the sample can be seen as representative for the defined target population since nearly all students participated in one or another of the visited social activities. Again, as already stated above, exchange students are only one sub-group in the group of newcomers to a city. But when considering them as dimensioning users the derived results could be generalised to some extent to all newcomers – both visitors and residents who had never travelled by PT in their city – and help to improve PT systems to be more attractive to them.

3.3.3 In-depth Study on a Single Exchange Student (Paper I)

In order to study the process of how to learn an unknown PT system in more detail and to focus on weak points in the system regarding Ease-of-Use an in-depth study was conducted. It followed a qualitative research approach. However, quantitative methods were also included (Dziekan, 2007).

One exchange student was investigated during her first 10 weeks in a new city. The in-depth study consisted of three questionnaires, 34 route discovery tasks performed while writing mind protocols, and eight interviews. This method-triangulation gave valid, deep insights into the information search and orientation strategies, knowledge about the PT system and its development, and critical incidents showing weak points in the system. By method-triangulation is meant that the same aspects or questions are investigated by different methods. An in-depth study (also called case study) is a common way of acquiring more qualitative details about a cognitive process (Yin, 1994; Stake, 1995; Strauss & Corbin, 1990). It allows the researcher to collect wide ranging qualitative data to investigate how the process works in general and to capture the phenomenon, in this case of using an unknown PT system. However, the method is time and resource consuming and should only be used to investigate unsought questions (Denzin & Lincoln, 2000), which was the case here.

Purposeful sampling (Patton, 2002) was used: The 23-year-old female study subject that volunteered came from Germany to Stockholm to do an internship. As a psychology student she was used to methods such as mind protocols and self-observation and was therefore a suitable study object. Further, her own study project dealt with the question of difficulties in an unknown PT system and she was highly motivated to perform the various tasks seriously. However, the subject represented an average exchange student or a person from abroad without any knowledge of the urban area or the language spoken there.

Generalisations can doubtless be made for all newcomers to a PT system (either visitors or newcomers to a city and non-PT users in their city) regarding the weak points discovered in the PT system. But for the different learning phases and information search strategies there are greater inter-personal variations possible due to learning styles or different information channel preferences.

3.3.4 Before-After Interviews with Travellers at Bus Stops (Paper IV)

The objective of this study was to evaluate the effects of the introduction of the new trunk bus line number 2 in Stockholm on customers. One key aspect in evaluation studies is to define and specify the indicators. It was concentrated mainly on two indicators: the development of traveller numbers and the experienced Ease-of-Use of the new line.

Traveller numbers were measured by automated passenger counting (APC) and in the interviews questions were included about user frequency to that date and one year before to complement the APC data analysis.

Face-to-face interviews with travellers at stops on the old and the new bus line were conducted in the same week of the year (the last week in November) before and after implementation. A structured interview guideline was used and each interview took between 3 and 10 minutes. The same method was used for both sets of interviews. The trained interviewers contacted waiting passengers at four different stops along this particular bus line between 13.00 and 18.30 on all days during that particular week.

The majority of the questions were closed questions such as travel frequency, type of journey, travel mode and frequency of the same route one year before, ownership of monthly pass, gender and age. Further, a special scale to measure Ease-of-Use was constructed and applied in this study (see also 4.3.1). One additional open question was put in the after test on the experienced differences between the former red bus and the new blue trunk bus.

In the before-test sample 541 persons were interviewed and 368 in the after-test one year later. Analysis showed that all sample parameters were similar, so the samples were comparable. The target population of this study was travellers on this particular bus line. For organisational reasons and due to the length of the interview on-board interviews were not chosen as the method. Since four stops were selected and all waiting passengers were asked, this was cluster sampling (O´Flaherty, 1997). The sample analysis showed that a wide range of passenger types were included. Generalisations regarding trunk bus effects can only be made for this specific situation in Stockholm. But for the tested Ease-of-Use scale the sample can be considered as average PT users on a normal inner-city bus line.

In the study on trunk bus effects the interviews with travellers were only one part – interviews with residents completed the picture (see the following section, 3.3.5).

3.3.5 Before-After Telephone Interviews with Residents (Paper II and V)

This study had two objectives. The first was to evaluate the effects of the introduction of the new trunk bus line number 2 on the memory representation of residents. The second objective was to investigate memory representation of PT of residents in an urban area in general.

When looking at effects of an implementation of a new trunk bus line, ideally the same sample is used for the before and the after study to omit sample biases and each individual can act as his or her own control group. This means that the personal variables and characteristics do not change. A further extension could be a time line (Bonate, 2000; Ortúzar & Willumsen, 1996) that includes several time-lagged before measurements and several time-lagged after measurements to study effect sizes and even long-term effects. For cost reasons only a simple before-after testing on the same sample was done in this study.

A residential area close to the future trunk bus line was selected. This inner-city area had good PT accessibility in general. When checking knowledge it is necessary to ensure that people do not consult other sources for their answers, thereby producing bias. Thus, only direct interview methods like face-to-face or telephone interviews could be considered for this study of memory representations (Bortz & Döring, 1995; Lavrakas, 1993). The latter was chosen for reasons of cost and efficiency.

The interview guideline was semi-structured. Since computer-aided telephone interviews were used, some questions could be designed in such a way that they were formulated as open questions but the interviewer categorised the answers directly into the data file.

For the area, 399 private telephone numbers were officially registered and accessible, and 279 of these numbers were randomly called in the before test phase. 27% of the people who answered the phone refused to participate in the study. Only people above the age of 15 were asked to answer the questions. Moreover, only people who had been living in the area for more than half a year were included in the sample because it was necessary for them to have enough time to familiarize themselves with the public transportation options in their area.

The interviews were conducted in January 2004 and October 2005, between 17.00 and 21.00 on weekdays. Each interview lasted between 10 and 25 minutes. In the before test the person who answered the telephone was asked to answer the questions. 197 persons agreed to participate in the after test and were contacted for the after interview. 121 persons participated in both the before and the after test (response rate 60%). The 83 prospective respondents lost were 45 people who refused to participate, 34 who moved from the area, and 4 who passed away. The comparison of the characteristics of the drop out sample and the final analysed sample showed no significant differences for the variables of gender, employment, level of education, mode choice for commute trips, car availability, and frequency of public transportation use. Only the age variable showed a significant difference. People in the remaining sample used in the after test were older on average than people in the drop out sample.

The subsequent analysis showed that the sample was representative for the residential area in terms of age, gender, employment rate, and level of education. But the area was one of Stockholm's wealthier areas whose residents have a higher level of education than the average Stockholmer. However, the results regarding the quality of the memory representation of PT can be generalised to residents in urban city centres with good PT accessibility. Some of the results found can even be generalised to all people living in metropolitan areas.

3.3.6 Expert Questionnaire (Paper VI)

The aim of this study was to gain more information and insights on the question of how IT-based PT information influences the real behaviour of people. This was an explorative study of a qualitative nature. It was used to review actual knowledge and experiences on the question in the field and in the industry. An expert panel was conducted using the mean of E-mail. Experts in the field were identified in the literature review (Dziekan, 2004). Further persons participating in selected meetings (UITP conferences on PT information 2003 in Gothenburg, EIRASS workshop in Eindhoven 2003) were included in the expert list.
A formal letter of request and a questionnaire with mainly open-ended questions were sent out to the experts.
The main questions were:

1. How do you think IT-based PT information systems influence the real behaviour of people?
2. Do passengers use the information to make their journey more efficient?
3. Do you believe that current IT systems are efficient, and sufficiently match user needs? Please give positive or negative examples.
4. How does the customer assess the reliability of an IT-based information system?
5. Do people trust the PT information they obtain from IT-based PT information systems?
6. Do these systems "create" new passengers for PT systems? Do they encourage the occasional users to change to more frequent PT use, or frequent users to adopt a more efficient travel pattern?

Answers from 11 experts were analysed. Their background included PT authorities, PT companies, consultancies, research institutions and universities. They had experience in research and implementations of IT applications in PT, such as mobility portals on the Internet and real-time information delivery to customers. The experts came from Austria, Germany, The Netherlands and Sweden. This qualitative study was a good starting point for compiling a state-of-the-art report (Dziekan, 2004; paper VI) to that date, but as soon as new technologies and applications appear and new evaluation studies are conducted the results are outdated. However, since the focus was on the user and the behaviour reactions in general some of the results are of more durable character and can be generalised to a wider extent.

3.3.7 Behaviour Observation Study (Paper VI)

The objective of this study was to experimentally test the effects of at-stop real-time departure information at subway entrances on the walking speed of approaching travellers. A behaviour observation as a non-responsive method was chosen.

The main criterion for observation was whether or not users ran as they headed towards the escalators, down to the subway. “Runners” were loosely defined as those who run, walk rapidly, have hurried looks on their faces, or quicken their pace as they approach the escalators (Dziekan, Weinstock, & Rutherford, 2006).

Since the concept of “normal walking and “running” is difficult to define, it becomes a subjective measure when observed. Thus, in order to obtain valid data, two observers were used. The observers always remained together, so that data could be verified in the analysis stages. However, in order to maintain the integrity of the data, they did not discuss or view each other’s results during the observations. The observer consistency ranged between 0.8 and 0.9, for most of the cases. These were very satisfying correlations. The average of the observers’ data was used in the data analysis.

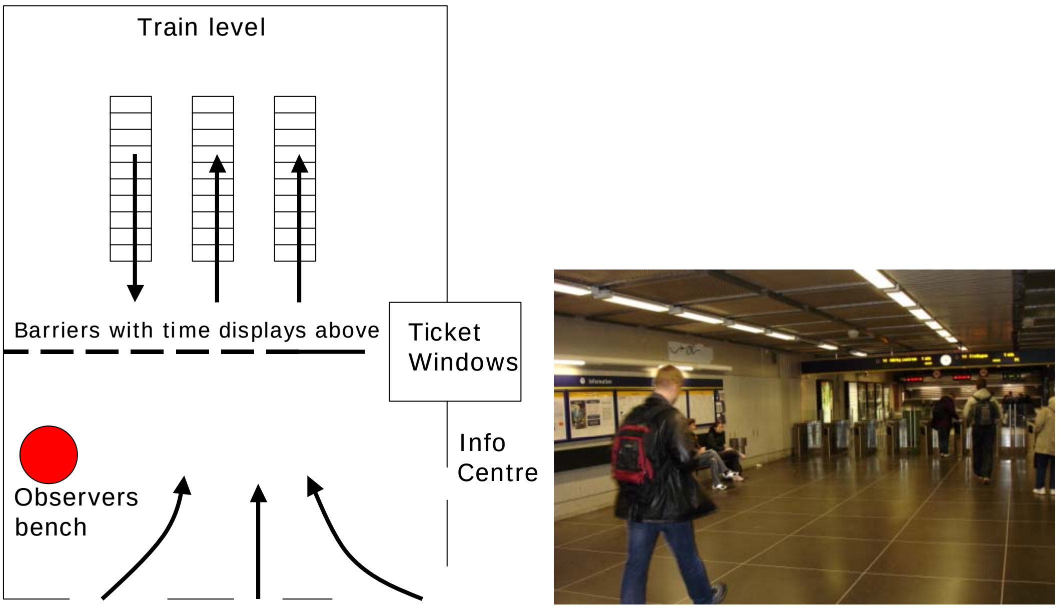

Figure 3: Schematic view of the observation places at the subway station “Tekniska Högskolan”

The observers sat on the bench located at the mezzanine level and made observations as users crossed their paths (Figure 3). In this way, the real-time information, when switched on, was available to the observers, as well as to the system users. For a period of one hour, the observers continuously recorded the number of minutes before the arrival of each train as well as the number of “walkers” and “runners” in each period. When the signs were switched off, observers recorded the time of day and the corresponding numbers of “walkers” and “runners,” at every minute, to later be matched with subway schedules.

This personnel intensive method was preferred to video observation due to the fact that it was not possible to record the traveller flow

appropriately in a way that each traveller could be followed the whole way from entrance to escalators.
For comparison, the displays in the selected subway station were turned off for one day. This quasi-experimental situation allowed the hypotheses to be tested.
Three one-hour observations were conducted under each condition: one during the morning peak hours, one in the middle of the day, and one during the afternoon peak hours. It was assumed that travel patterns differ among these periods and thus, it was important to capture data at each of these times. All observations were conducted on a Tuesday, Wednesday, or Thursday, so as to minimize any abnormalities that may be present on Friday through Monday. Table 2 shows the start time and date of each observation as well as the observed number of people in each sub-sample (N).

Table 2: Overview of all behaviour observation samples based on time period, date, and observed numbers of people

Time period observed	Morning 7:45 - 8.45		Day 12:50 – 13:50		Afternoon 16:30-17:30	
	Date	N	Date	N	Date	N
Sign on	Wednesday, Dec. 1st, 2004	1660	Thursday, Nov. 11th, 2004	881	Wednesday, Dec. 1st, 2004	1926
Sign off	Wednesday, Feb. 2nd, 2005	867	Tuesday, Feb. 1st, 2005	842	Tuesday, Feb. 1st, 2005	2135

The subway station “Tekniska Högskolan” was chosen because it contains real-time information signs pertaining to next train arrival (countdown) at its mezzanine and ground levels. The noise from arriving trains, that could bias the effect of the displays, cannot be heard from the entrance level. Further, only one subway line (red line) serves this station and the trains in both directions depart approximately at the same time.
While KTH (=Tekniska Högskolan) is a university, the sample population for observations was not limited to students. This is because the station also serves as a major transfer point between a large commuter rail line (Roslagsbanan) and the core Stockholm subway system. Therefore, the observed population was quite varied. The general results (but not the exact numbers) of this study can be generalized to all PT systems in metropolitan areas.

3.3.8 Before-After Questionnaire to Travellers on a Tramline (Paper VI and VII)

The objective of this study was to evaluate the effects of the installation of at-stop real-time departure information displays at stops on a tramline in The Hague/The Netherlands. One month before the implementation 840 questionnaires were distributed to individual travellers at selected tram stops. Travellers were asked to complete and return the questionnaire to the local PT operator. By returning the questionnaire, travellers were given the chance to win a prize of EUR 20. A total of 370 questionnaires were returned (return rate of 44%).

The before questionnaire consisted of closed questions with given answer categories and some rating scales. It was short in order to encourage people to fill it in completely. Questions concerned boarding time for the respective journeys, use frequency per week for the line in question, age and gender. Further, the perceived security at the boarding stop was to be rated by the respondents from one (very bad) to ten (very good). The perceived average wait times at the stops on line 15 were to be stated in minutes. The question here was: “How long do you have to wait, on average, for a tram on line 15?”. Finally, the Ease-of-Use was evaluated (see 4.3.1).

The 175 persons who indicated their addresses in the before-questionnaire for participation in an after-test, received a letter and a mail-back questionnaire three month after the implementation of the displays. It was assumed that people who still live in the same place will not have changed their boarding stop or their user frequency. For evaluation and comparison, the questions regarding perceived security, wait time, and Ease-of-Use were asked again. Further questions were added regarding highest level of education, car availability, use of the displays, and evaluation of the line’s reliability.

Based on a detailed comparison of sample characteristics (Dziekan & Vermeulen, 2004), it was shown that apart from the five years’ higher average age in the after-test sample, both samples can be considered comparable. Therefore, it can be assumed that the after-sample is a representative selection of the before-test sample. Hence, the data from the people who participated in both the before-test and the after-test (N=53) were the basis for the before-after analysis of the effects of the real-time information displays in paper VII.

A detailed non-respondent analysis was conducted for the sub-groups of participants who returned the before survey but did not receive the after survey and the participants who received the after survey but did not return it. There were no significant differences between the non-respondents and the 53 participants in the after survey in the characteristics of gender, boarding stop, boarding time, user frequency, mobile phone ownership, and internet access. Only the average age was different. The participants in the after sample were, on average, four to eight years older than the non-respondents. The higher average age may thus have led to some biases in the measured impacts.

The same questionnaire as in the after test was sent out again with a new letter 16 months after the implementation to test the long-term effects. From 175 questionnaires 81 were returned (a response rate of 46%). Again, the non-respondents were younger on average but all other characteristics were comparable. The total number of people who answered all three questionnaires dwindled down to 32 respondents.

Although the people in the sample were older than the average PT user tentative generalizations can be made and part of the results might be transferable to all PT users in metropolitan areas.

3.3.9 On-Board Questionnaire (Paper VIII)

This study had two objectives: first, to test a developed Ease-of-Use scale in practise, and second to look for support for hypothesised differences in Ease-of-Use between different PT modes (subway, trunk bus line and inner-city bus line). The questionnaire consisted of the Ease-of-Use scale (see 4.3.2) and other closed questions concerned the purpose of the trip, user frequency on the particular route and socio-demographic data.

The standardised instructions consisted of a verbal part when the travellers were approached and a written part in the introduction to the questionnaire. The participants were asked to tick the answer that best matched their actual trip on the vehicle they were actually travelling on. The questionnaire was easy to handle due to its small format and the thick paper used. The time to fill in the questionnaire was about 3-5 minutes.

A quasi-experimental design was used. All persons were tested in just one condition (mode). The three public transportation modes/routes in the Stockholm PT system (subway, trunk bus and inner-city bus) were chosen to be comparable and representative of the entire system. They all served Stockholm's inner city from north to south along approximately the same axis. Two interviewers who distributed the questionnaires to travellers did the on-board tests. The survey period was from 7.30 to 17.30 on five consecutive weekdays in June 2007. Each mode was tested both in morning and afternoon peak hours and during the day.

On the buses all passengers were approached and on the subway everyone in a pre-defined zone was asked to fill in the questionnaire. The questionnaire was filled in during the journey and collected by the interviewers before the passenger left the vehicle.

The sample can be considered to be representative for Stockholm inner-city PT users. Generalisations regarding the effects of the three different modes should be made with caution but generalisations about the aspects measured with the Ease-of-Use Scale can be drawn in a broad perspective.

3.3.10 Literature Review (Paper III)

The purpose of the literature review was to obtain a state-of-the-art picture of the selected topic of traveller information in PT.

The literature was retrieved from databases and Internet searches and through personal communication with people in the research community and in the PT industry. A literature review can only present the knowledge of the authors to that date and it will be outdated as fast as new research on the topic is published. Nevertheless, it is a valuable summary of the knowledge in this field and can serve as a basis to develop new projects and investigations.

4 RESULTS

This section aims to answer the three research questions outlined in the introductory chapter by using the results from the papers included in the thesis. Table 3 gives an overview about the different contributions.

Table 3: Overview contributions of papers within this thesis to the three main questions

	1)	2)	3)
Paper I Transit experience of newcomers to a city – learning phases, system difficulties and information search strategies	X	X	
Paper II What do people know about their public transport travel options?	X	X	
Paper III Reducing uncertainty and supporting cognitive maps in travel information for public transport	X	X	
Paper IV Customer reactions to implementation of a trunk bus network in Stockholm, Sweden		X	X
Paper V Influences of a new trunk bus network line on the quality of cognitive maps of public transport of residents	X	X	X
Paper VI Dynamic At-stop Real-time Information Displays for Public Transport: Effects on Customers		X	
Paper VII Psychological effects of and design preferences for real-time information displays.		X	X
Paper VIII How to Measure “Ease-of-Use” in Public Transportation? - Scale construction and Testing.		X	X

1) Cognitive user perspective; 2) Factors enhancing “Ease-of-Use”; 3) How can Ease-of-Use of a PT route be measured?

4.1 Cognitive User Perspective

4.1.1 Previous Experience and Experienced vs. Occasional Users

Knowledge of a new system depends on experience of other cities or hometowns. If one had previously learned how the PT system in a metropolitan area works, learning a new (similar structured) system was much easier (paper I).

Experience of the public transportation system enhances knowledge and increases the quality of the memory representation of the public transportation system. But, as shown in paper II, even people who do not use public transportation know quite a bit about the main characteristics - at least in well-known transport corridors in their city. This contrasts with the assumption that non-users have to be considered newcomers without any knowledge of the public transportation system.

Only PT users experienced a change in memory representation from the trunk bus implementation (paper V). The users mentioned the trunk bus route to an inner-city destination more often than non-users and they also estimated the service frequency for the trunk bus on weekdays more correctly. In the before-after test of residents in paper V users found it easier to use the new trunk bus line. However, when it comes to the perceived Ease-of-Use measured on the Ease-of-Use scale (EUS) developed in paper VIII, occasional users found it easier to use public transportation then frequent users did. Prior knowledge might influence the perceived Ease-of-Use by forming a schema (paper II) and occasional PT users had not yet experienced the difficulties of this system, such as delays and unreliability. They might have expected more effort for their journeys due to the fact that they do not use the route so often and that then matched the effort that was really spent on a journey. However, frequent users might have underestimated the effort needed and therefore indicated the options as not so easy to use.

4.1.2 Learning Phases and Information Search Script

The three phases of the learning process as presented in paper I could be considered to some extent to be universally valid for anyone arriving in an unfamiliar metropolitan area and learning a new PT system.

Phase 1: The “alert phase”, in which the newcomer is grasping for all available information, is characterized by a high rate of assimilation and substantial cognitive effort while using the public transportation system. For this reason, complicated routes or public transportation modes are avoided.

Phase 2: In phase two, the individual has built up considerable background knowledge as well as reference points within the city. Although mistakes still occur, the individual feels more confident using the public transportation system and begins to habitualize and seek out “best” routes.

Phase 3: The third phase is characterized by more relaxed pre-trip planning and a greater trust in the information that will be offered by the system. It is assumed that such a cognitive process is generally similar for

everyone familiar with the industrialized world and some experience of urban public transportation systems, although the time span may vary.
A general information search script for using PT as developed from the results in paper I is presented in Figure 3. It starts with the precondition that travel mode choice is already set and the person has a valid ticket. The script includes some parts of the whole travel chain.

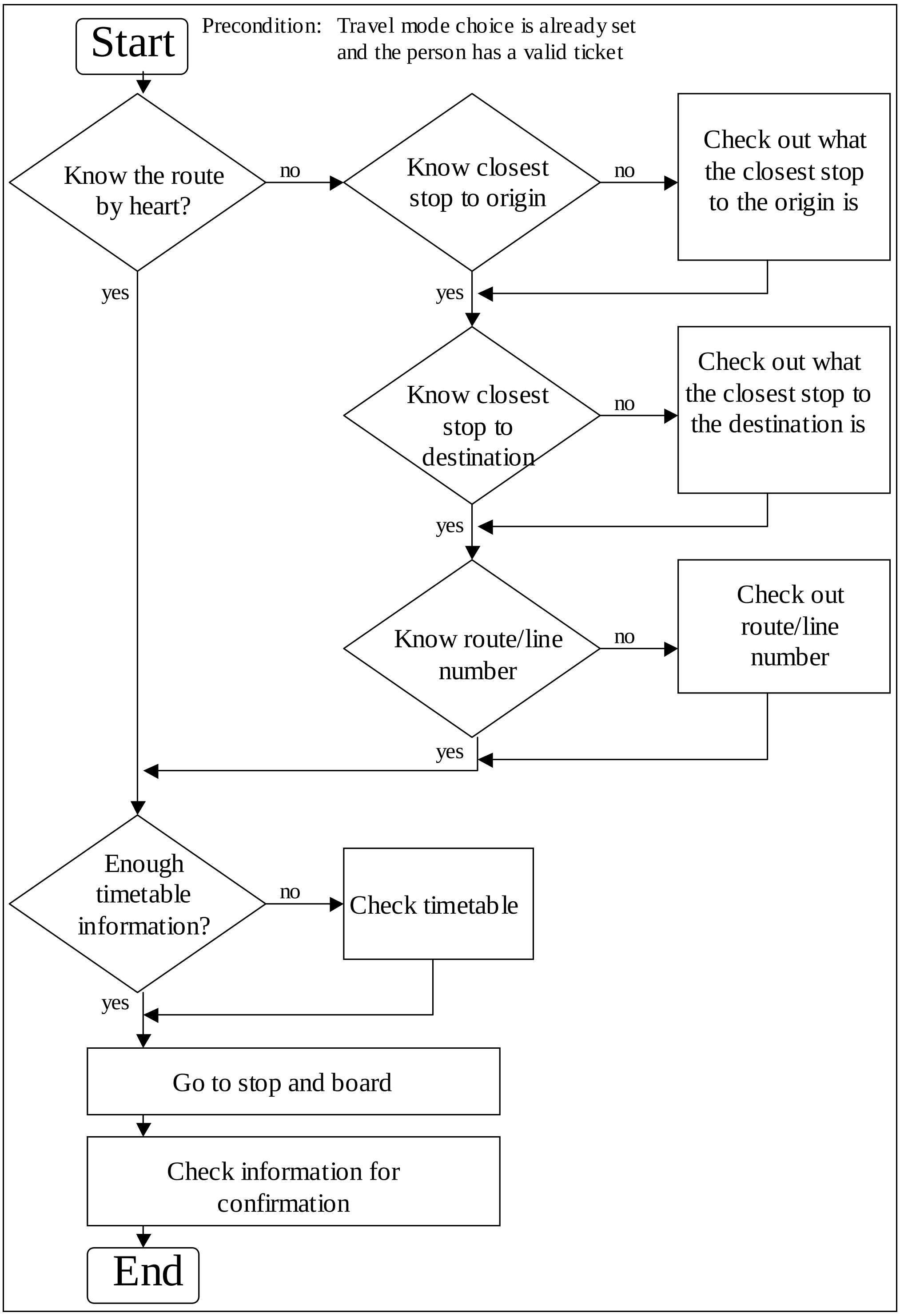

Figure 4: Information search script for pre-trip planning and using public transportation (adapted from paper I)

4.1.3 Human Information Processing and its Limits

Perception of information is selective. Since processing of information is generally sequential, not too much information should be provided at the same time. The limited capacity to process information leads to the use of heuristics and simple rules. Due to limited working memory capacity, the traveller cannot remember too much information in a short period of time. According to Miller (1956) we can store 7±2 items in working memory. Anderson (1995) states that 4 or 5 items can be stored in the visual image memory.
Four cognitive ergonomic principles were described in paper III and applied to PT practice: conspicuity, legibility, comprehensibility and credibility. When adapting a system to humans' abilities for information processing, these four principles must be considered (see also chapter 4.2.6).

4.1.4 Organisation of Public Transportation Knowledge

In this thesis a psychological approach was chosen to investigate the memory representation and to explore how knowledge regarding PT options is structured in the human mind. Derived from the results in paper II, the following hierarchical structure of knowledge (Figure 5) has been derived:

– The ground level (mostly general knowledge) – and the first step - is to know that there exists a public transportation option.
– The next step is the identification of the mode of transport, such as a metro line for this route. This level was explored in depth in paper II and a hierarchy for the Stockholm case was presented as follows: commuter trains and metro were better represented than buses.
– The last step, at the highest level of the hierarchy, is the "code" for the line, such as a bus number or the colour of the metro line. People often remember that "there exists a public transportation option to get from A to B" but they less often memorise the numbers of the lines (paper II). However, the colours are often better known than the numbers.

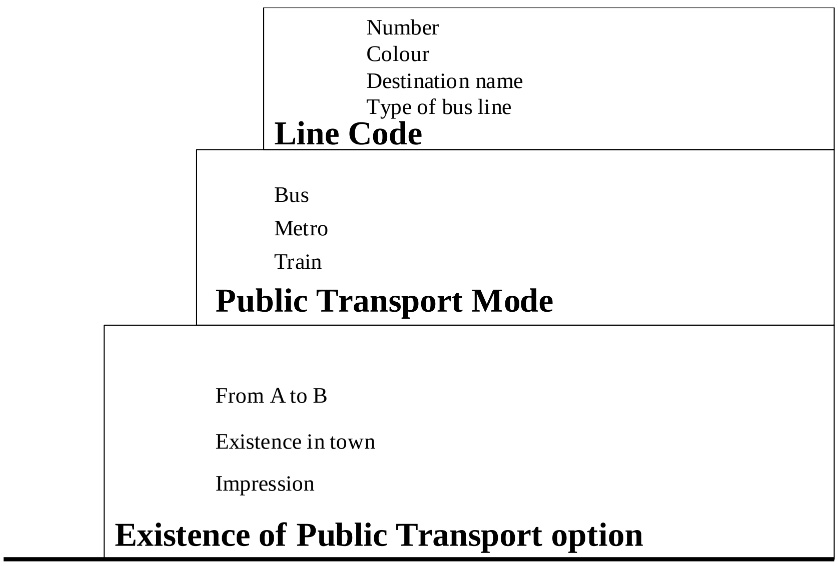

Figure 5: Proposed hierarchy of public transportation option knowledge (paper II)

People can only choose from options of which they are aware (Gärling & Golledge, 2000). For public transportation it seems to be enough to know roughly that there is a public transportation option at all. It may even be enough to have the impression that there exists an option. It is probably more important for the traveller, when choosing the travel mode, to be convinced that there will be a comfortable public transportation option than to know the exact details of the option, such as the bus number.

Based on the hierarchical structure of the memory in general and the assumption that Kitchin & Blades (2002) made for their integrated model of cognitive mapping, it is possible that a hierarchy exists for the organisation of knowledge about public transportation lines and connections. Apart from service and accessibility factors, three factors were proposed in paper II which contribute to the extent to which a line is represented in people's memories.

1) A line in an urban area is remembered both by its stops and stations and by the stretches in between (visibility in the urban area).
2) A straight route layout serving main roads is easier to memorise than sinuous or crooked lines that travel on minor streets.
3) Lines that are labelled and/or serve important and well-known destinations are easier to memorise than lines without labels since the destination is already anchored in the cognitive map. The name of the served area can act as a label. Single digit route numbers could also act as labels since the easy-to-remember number becomes a label.

The results in paper II support the explorative hypothesis that public transportation lines that are more visible in the urban areas, travel on straight lines/main roads and are labelled are easier to retrieve from memory. Some evidence was found in the case of Stockholm of a hierarchy of different public transportation modes: commuter train, metro and bus. However, there was also a hint that the hierarchy of the travel modes is also influenced by the options provided – lines that run close to where a person lives are better represented in their memory.

4.1.5 Memory Representation

It is widely recognised that people's perception of public transportation is generally pessimistic (Bonsall, Firmin, & Beale, 2004; (Goodwin, 1997). Journey times and waiting times are usually overestimated while frequencies and network penetration are often underestimated (Lacy & Bonsall, 2001). Accordingly, residents in paper V underestimated the service in peak hours as well as on Sundays. But PT users estimated the service frequency of the trunk bus line more correctly in the after test; they came significantly closer to the real service frequency.

In paper II it was shown that residents have a good picture of the public transportation options in the well-known transport corridors. Almost all knew where the closest bus stop was located, whereas only every second person could correctly name it. The other people described the location by using their local reference system. This more vague kind of identification is called relational (Golledge, 1999).

Route knowledge within well-known transport corridors is very good and better than for lesser-known corridors. People know more travel options in well-known transport corridors than in less-known ones. It can be concluded from paper II that all residents in an inner-city area have some basic knowledge of public transportation options.

The effects of the new trunk bus line implementation on memory representation can be seen quite fast but this does not automatically effect the patronage. In paper V, for instance, the trunk bus line had some initial effects on customer perception before patronage impacts were seen. It takes people some time to learn the new line and to integrate it into their memory representation and show revealed actions.

4.2 Factors Enhancing Ease-of-Use

4.2.1 Trunk Bus Line Effects

An initial trigger of this thesis was that a trunk bus implementation increased traveller numbers and the aim was to find out why.

The results in paper IV showed that the customers did, in fact, appreciate the trunk bus network and traveller numbers increased. Patronage of the trunk bus line implemented last in Stockholm rose by 10% - a result that is similar to the reported success of trunk bus networks in other European cities. The measurements implemented in the Stockholm case were, for example, one-digit route numbers, differentiated colour, and a clear network without many turns and loops. Further, stops in the urban area, made more visible with red concrete, and real-time information contributed to better user orientation and clarity of the trunk bus network.

Nevertheless the Stockholm transport planners expected an even higher increase in patronage. This was not the case and several possible reasons are given in paper IV, such as increased ticket prices and a lack of marketing actions.

In line with other research results travellers evaluated the trunk bus as easier to use compared to the former bus network (paper V); it was found that people who travel by PT more than 2 days a week perceive the trunk bus as significantly easier to use than the former bus line. In general it was found that the awareness level increased from 90% up to 96% when people were given a trunk bus line serving the area where they lived.

However, in paper VIII, where an Ease-of-Use Scale (EUS) was developed and tested, no differences in Ease-of-Use were found between the three investigated PT modes subway, trunk bus and inner-city bus. One reason for this might be that Stockholm has a very good and well coordinated PT system and all three of the investigated PT options were in fact simple to use. The general Ease-of-Use score did not vary between the modes. However, differences occurred in the perceived reliability: the subway and the trunk bus were perceived as more reliable than the inner-city bus. Furthermore it was shown in paper VIII that trunk bus was perceived as more secure then subway.

The testing in paper VIII was an in-between design while the before-after study in paper V was conducted as a repeated measurement on the same individuals. This may also explain the different results. Nevertheless, it can be concluded that a trunk bus implementation has positive effects, especially on attracting PT users.

4.2.2 Effects of At-Stop Real-Time Information Displays

When in operation reliable, at-stop real-time information systems can have many positive effects on customers. Paper V shows that the real-time displays installed at the trunk bus stops supported enhanced memory representations and knowledge of service frequency. Paper VI gives a comprehensive overview of effects of at-stop real-time information displays and seven main effects were described:

A. reduced perceived wait time,
B. positive psychological factors, such as reduced uncertainty, increased Ease-of-Use and a greater feeling of security,
C. increased willingness-to-pay,
D. adjusted travel behaviour such as better use of wait time or more efficient travelling,
E. mode choice effects,
F. higher customer satisfaction,
G. better image (Figure 6).

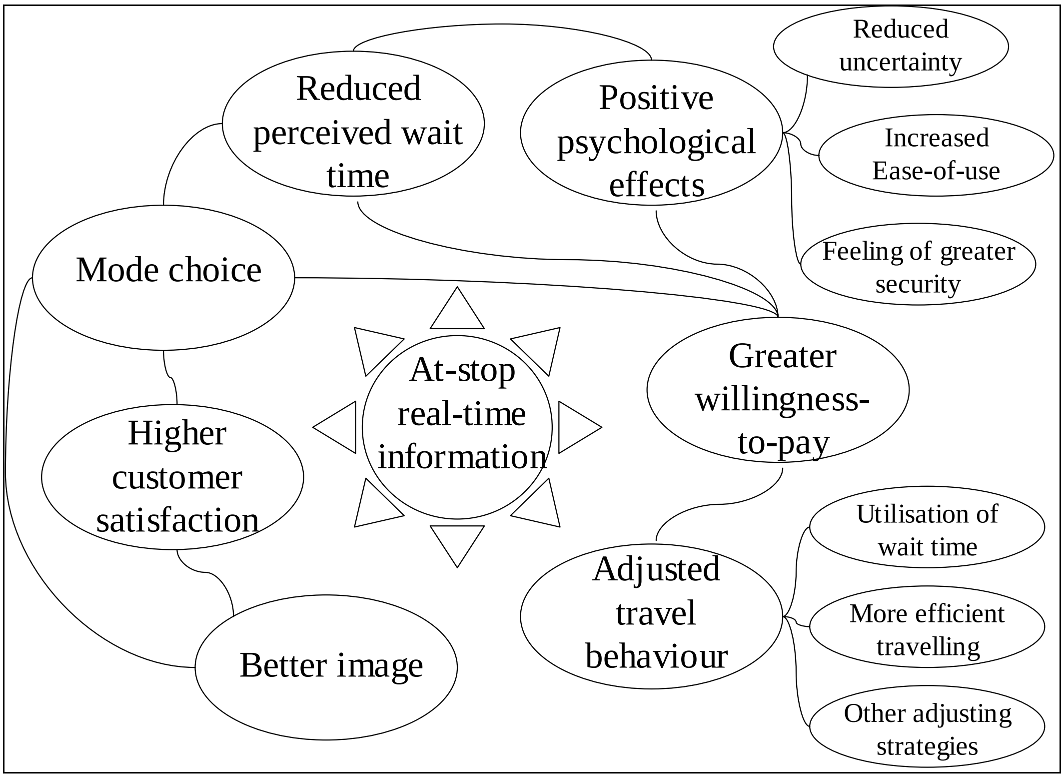

Figure 6: Mind map of possible effects of at-stop real-time information displays (paper VI)

Two studies are presented in paper VI. Study I (described in more detailed in paper VII) supports and proves that perceived wait times can be reduced by 20% with at-stop real-time information displays. A before-after implementation evaluation study with questionnaires on a tramline was employed to study this effect. The decrease in perceived wait time remained unchanged even after 16 months. Study II shows the effects of real-time displays on behaviour in the form of adjusted walking speeds, by using a behaviour observation method in a subway station. People sped up significantly when the display showed two minutes or less left until train departure.

4.2.3 The Role of Maps

It is necessary to support the development of a cognitive map with good physical and/or digital maps. Good maps are essential since route (second-level knowledge) and survey knowledge (third-level knowledge in cognitive map acquisition process) happen later (paper I). Newcomers can only obtain this information through external sources. The map should also contain major landmarks and all PT modes within the entire metropolitan area. This holds for both conceptual/schematic maps and maps with an underlying street network.

Landmarks are salient objects in the environment that help the user understand the space and find out where he or she is. They are reference points of a kind and support the navigation process by identifying decision points. Landmarks should be included in all maps and especially in stretch-maps for a particular line. Stretch maps should also show all stops on the line and travel times between stops. Furthermore, salient landmarks should be used to indicate the direction of exits from a transportation system.

One special type of map, the so called you-are-here map, is good at complex terminals and stations and for overview in the vehicle. Paper III lists strategies for good you-are-here maps where the alignment and the forward-up principle were proposed.

An integrated map that also indicates stops and subway entrances in the urban area is both user friendly and a good marketing instrument. Further, maps for the surroundings at stops and stations help the traveller find the final destination.

Ideally, maps should always accompany travel information and be readily available at all times. The Internet is then a natural choice for distributing information via mobile devices that support the use of interactive and always updated maps.

4.2.4 Information Throughout the Travel Chain

Travellers need information throughout the travel chain, from door to door. Multi-channel information and redundancy are key terms in this respect. Information must be available about all alternatives for travelling from home to the first public transportation stop and all alternatives for travelling from the last public transportation stop to the destination. The information need is highest before a trip, such as which route to take in which direction at what time. Later, on the trip, this information needs to be confirmed (paper I). All information provision has to be reliable and adequately presented throughout the travel chain. Next stop announcements, stretch maps and overview maps inside the vehicle are essential as on-trip confirmatory information. Travellers need information about where to alight and what connections are possible on arrival. Information about the next stop must be given early enough to give the traveller time to respond.

Information is important throughout the travel chain but is even more essential if something disrupts the regular traffic. Such irregular traffic situations may be planned, such as construction work, or may be caused by unexpected events, for example technical breakdowns. In paper I it was also reported that newcomers had problems with route changes between night and day schedules.

Reliable information provision is the basis for trust in the system and thus for reduced uncertainty (paper III). In order to support the traveller one should provide information about available services and mandatory actions (such as reservations) and provide static and dynamic travel information (e.g. travel time, delay, alternatives, platforms when changing, arrival information). There is a need for redundancy in the system. It is advisable to have information available through different channels (such as oral and visual announcements) and confirmatory information throughout the entire travel chain. This confirmatory information can reduce travellers' feelings of uncertainty and it is therefore good to replicate information.

Internet-based travel planners and SMS information systems are beginning to complement and even replace the traditional printed paper timetable. They also offer the possibility to give even better advice and information tailored to the individual traveller throughout the whole travel chain.

4.2.5 Design of Stops and Stations

Visibility of PT stops and stations in urban areas is a key factor in making PT cognitively more accessible to people. Some factors supporting Ease-of-Use can be illustrated from papers I, II and III.

Stops with identical names should be located close to each other and both directions should be situated close to each other as well. Stop names should be short, clear and simple – preferably landmarks that are nearby and not names of long streets where it is hard to locate the stop on the street.

Factors that enhance Ease-of-Use are avoiding splitting branches or making the splitting point very clear to the user, naming the final destinations significantly differently (e.g. different word length, different initial capital). Short transfer distances and clear signage of transfer points are other important factors when planning stops and station design.

Waiting connections at central stops in a PT system enhance Ease-of-Use.

The residents in metropolitan areas, regardless of whether they are public transportation users or not, know their closest access point to the system (paper II). Every single stop in the system thus needs to be considered an entrance portal and should therefore be well equipped with information about the system, making it possible to use the entire system properly.

For all kinds of stations orientation and guidance from the built environment and from signs inside stations are very important.

4.2.6 Design and Layout According to Cognitive Ergonomic Guidelines

When designing and planning a PT system and the information to this system the limits of human information processing have to be taken into account. One should make sure that design and layout conform to cognitive ergonomic guidelines, applying the four ergonomic principles presented in paper III:

Conspicuity refers to the extent to which information can draw attention. Travel information displayed in a form that is expected by the traveller will be more likely to attract attention and processed further. Visual information should therefore be displayed where the traveller will expect to find it. Information sources should be clearly visible and recognisable (e.g. specific design and colour for the departure displays). The surrounding environment should not distract. Advertisements and routing signs should be separated. A balance between object and environment concerning colour and luminosity should be accomplished. Light boxes and reflecting materials increase conspicuity.

Legibility determines how easily a sign can be read. Factors to take into account include: reading speed, combination of colours, contrast, font, font size, contrast between thick and thin strokes of the letters, character width, letter spacing, word spacing, line spacing, capitals vs. lowercase letters, and pictograms vs. text. All these components need extensive deliberation in deciding their use as their effect will depend on the context of use.

Comprehensibility refers to how easily the traveller can understand the displayed information. A high level of comprehensibility implies that the relevant information should be comprehensible to travellers with different cognitive abilities and travellers from different countries. The use of pictograms instead of text messages is advisable.

Credibility refers to the extent to which travellers believe that a message or advice is true and applies to them. This type of confidence is highly dependent on confirmation, so information providers should ensure that messages are correct and reliable. When a message is not judged to be credible, travellers will ignore it.

4.2.7 Special Support for Newcomers and Other Factors

There are “cultural” specialities in every PT system that need to be communicated to newcomers. Examples of such specialities, described in paper I, include: mandatory pressing of the stop button in the vehicle for alighting, train traffic on the left-hand side that causes misunderstandings, and the restriction that boarding buses is allowed at the front door only. Language problems were often reported by foreign newcomers; it is therefore a good support to also provide key information in an appropriate foreign language (e.g. English, German, French or Spanish).

A further factor enhancing Ease-of-Use is frequent services in PT, that means that people do not need to think about the timetable: they just go to a PT stop and there will be a service arriving soon.

The presence of friendly and helpful PT staff in the system enhances Ease-of-Use. Even the presence of fellow travellers, apart from over-crowding situations, can be a support.

Finally, standardization is a key issue: from system planning to information provision. One solution could be international or at least national standards for planning, designing and operating PT so that the user is presented with the same kind of interface wherever he or she would like to use PT.

4.3 Measurement Methods of Ease-of-Use

4.3.1 Early Ease-of-Use Concept and Scale

During the course of the work on this thesis several ideas and methods were developed and tested to define and measure Ease-of-Use. In addition to saving time and money, people want to save effort when using PT. Stradling (2002) names three types of effort: physical effort, cognitive effort, and affective effort. While physical effort concerns the physical activity on a journey, cognitive effort is expended on a journey via information gathering and processing for route planning, navigation, progress monitoring, and error correction. Affective effort is the emotional energy expended on a journey in dealing with uncertainty regarding safe and comfortable travel and timely arrival at intermediate and final destinations.

Further, it is known from service research that a product recommended to others tends to be of relatively high quality. Reichheld (2003) suggested using the recommendation question to measure customer satisfaction reliably and efficiently.

Paper IV includes the first attempt to measure Ease-of-Use. Three scales were tested with rankings for cognitive effort, emotion and recommendation on a 5-point agreement scale (Figure 7). The cognitive effort was measured with three questions while emotion and recommendation were measured with one question each.

I agree	1 Not at all	2 Nearly not	3 Neither nor	4 Nearly fully	5 Fully	Do not know
It takes a lot of mental effort to plan my trip with the bus line in question						
I have to figure out when the bus will leave and calculate when it will arrive at my destination	**Cognitive effort: 1=low cognitive effort 5=high cognitive effort**					
While on the bus, I have to continuously reorient myself and be ready to get off						
The ride on the bus line in question feels strenuous and influences my mood negatively	**Emotion: 1=not negative 5=negative**					
If another person should have to make the same trip as I am right now I would recommend going by the bus line in question	**Recommendation: 1=not at all 5=very much**					

Figure 7: Early Ease-of-Use scale used in paper IV

The majority of travellers interviewed at bus stops on the new trunk bus line and the former bus line found it very easy to use the bus line, meaning it involved little cognitive effort. Further, riding the bus did not negatively influence many travellers' moods. Finally, the recommendation rate was very high.

In paper VII scales similar to those in paper IV were used, but in a shortened version. The scales in paper VII were used to show the effects of an at-stop real-time information display installation on Ease-of-Use on a tramline. Only two aspects of Ease-of-Use of a PT journey, namely the

cognitive effort and the recommendation rate, were measured with the following questions included in the before-after questionnaire:
"For the statements below, please indicate how strongly you agree, on a five-point-scale:
- It is hard to determine when exactly tram 15 departs.
- If somebody else has to make the same trip as I am making right now, I would recommend that they choose line 15."

The answer categories were: fully agree (1), agree (2), neutral (3), disagree (4) and fully disagree (5).
No significant differences between the before-and-after situations could be reported for cognitive effort and for the recommendation willingness factor.

In both studies (papers IV and VII) the values in the before tests were already so positive that ceiling effects were observed. That means that if something is already rated as very easy-to-use in the before test it will not be possible to improve the Ease-of-Use value further. Thus, the after test showed the same values.
Further, it seemed that people, when they already had decided to use a travel mode (like waiting at the bus stop), were quite positive towards this travel mode and also very confused about the ("silly") questions put to them. Thus, there was a need for further development of a measurement method.
In paper V residents were asked directly if they found the newly implemented trunk bus line easier to use than the former normal bus line. This was a post-hoc evaluation on a scale from 1 to 5 (from more difficult to much easier). Since measurement was made post-hoc, a real comparison was not possible.

4.3.2 The Ease-of-Use Concept and Scale in Paper VIII

None of the trials reported above (papers IV, V and VII) produced satisfactory results for measuring Ease-of-Use. Another study (paper VIII) was therefore conducted to define Ease-of-Use clearly from the user perspective and develop a scale to measure the concept. The definition of Ease-of-Use in paper VIII reads as follows:
Ease-of-Use is determined by the degree to which travellers spend affective and cognitive effort on a journey by public transportation. Low affective effort means feeling comfortable, experiencing pleasure and convenience accompanied by feeling secure and perceiving less stress. Low cognitive effort is defined by the system being easy to learn, providing high quality information and reliable services. Ease-of-Use is when it simply fits with people's imagination of travelling. The effort that has to be spent matches the effort people are willing to spend for their journey.

The developed Ease-of-Use Scale (Table 4) was tested in a field experiment in Stockholm where 432 travellers were interviewed on three different modes: the subway, a trunk bus line and an inner-city bus line.

Table 4: Items in German, Swedish and English from the Ease-of-Use Scale in paper VIII

#	Swedish	English	German
1	Jag kan lita på det här färdmedlet.	I can rely on this public transportation option.	Ich kann mich auf dieses Verkehrsmittel verlassen.
2	Den här resan är avkopplande.	I find this journey relaxing.	Diese Fahrt finde ich entspannend.
3 i	Jag tycker att den här resan är krånglig.	I find this journey difficult.	Ich finde diese Fahrt schwierig.
4	Jag är lugn och avslappnad under den här resan.	During this journey I am calm.	Bei dieser Fahrt bin ich ruhig und gelassen.
5	Jag får den information jag behöver.	I can find the information I need.	Ich bekomme die Informationen die ich brauche.
6 i	Det tog lång tid tills jag kände mig hemma med det här färdmedlet.	It took me a long time to become acquainted with this transport option.	Es dauerte lange bis ich mich mit diesem Verkehrsmittel auskannte.
7	På den här resan mår jag bra.	During this journey I feel comfortable.	Bei dieser Fahrt fühle ich mich wohl.
8	Jag kan njuta av den här resan.	I enjoy this journey.	Ich kann diese Fahrt genießen.
9	Om någonting är oklart, hittar jag information som hjälper mig.	If something is unclear I can find enough helpful information.	Wenn mir etwas unklar ist, finde ich ausreichend helfende Informationen.
10	Den här resan tycker jag om.	I like this journey.	Diese Fahrt gefällt mir.
11	Under den här resan känner jag mig trygg.	During this journey I feel secure.	Bei dieser Fahrt fühle ich mich geborgen.
12 i	Jag tycker att den här resan är onödig komplicerad.	I think this journey is unnecessarily complicated.	Ich finde diese Fahrt unnötig kompliziert.
13	Jag kan utnyttja restiden på ett bra sätt.	I can use the journey time in a good way.	Ich kann die Fahrtzeit sinnvoll für mich nutzen.
14	Jag tycker att den här resan är behaglig.	I find this journey convenient.	Ich finde diese Fahrt angenehm.
15	När jag inte kan orientera mig, vet jag att jag enkelt kan få information.	If I am unsure, I would be able to reorientate myself with the help of the given information.	Wenn ich unsicher bin, weiß ich, dass ich mich mit Hilfe der gebotenen Informationen neu orientieren kann.
16 i	Den här resan är ansträngande.	I find this journey tiresome.	Diese Fahrt finde ich anstrengend.
17	Om någon annan person skulle behöva göra den här resan skulle jag rekommendera honom/henne att använda detta färdmedel.	If another person has to do the same journey, I would recommend this public transportation option to him or her.	Wenn eine andere Person dieselbe Reise machen müsste, würde ich ihr/ihm dieses Verkehrsmittel empfehlen.

i = inverted items (were not included in the final analysis)

An explorative factor analysis with principal component analysis and VARIMAX rotation suggested a two-factor solution (Table 5), which explained a variance of 57.4%. The Ease-of-Use score as a summarising

value was calculated for each dataset by adding up the scores in each of the items divided by the number of items and subtracted by 1. The analysis showed that the Ease-of-Use Scale, including 12 items and providing two subscales “pleasure and convenience” and “reliability and information”, was a reliable instrument (internal consistency: Cronbachs alpha .88; average item correlation .38) to measure Ease-of-Use for a particular PT route.
The final 12 Items in the developed Ease-of-Use Scale measured affective effort (pleasure, convenience, relaxation and security) and cognitive effort (reliability and information quality).

Table 5: Factor solution and item characteristic (paper VIII)

#	Item	Factor 1: Pleasure and Convenience (PC)	Factor 2: Reliability and Information (RI)	Mean	Devi-ation	Selec-tivity
1	Reliability	.242	**.524**	3.84	0.93	.40
2	Relaxation	**.782**	.150	3.43	1.09	.66
4	Calmness	**.650**	.160	3.84	1.11	.55
5	Useful information	.168	**.742**	3.68	1.10	.47
7	Comfort	**.762**	.178	3.87	1.10	.65
8	Enjoy	**.847**	.142	3.43	1.14	.71
9	Helpful information	.132	**.842**	3.46	1.14	.49
10	Pleasure	**.793**	.193	3.49	1.07	.69
11	Security	**.556**	.363	4.03	0.92	.58
13	Useful journey time	**.556**	.213	3.47	1.13	.52
14	Convenience	**.811**	.202	3.51	1.05	.72
15	Reorientation	.169	**.776**	3.54	1.18	.48
17	Recommendation			4.19	0.96	.53

4.3.3 Further Development of the Ease-of-Use Scale

The developed and tested Ease-of-Use Scale in paper VIII is still of an explorative nature and further research is greatly needed.
Further development could include attitudes towards PT since this is a strong variable in travel mode choice models. Replications, the development of norms, further item development and revision are also possible. Another improvement might be to measure not only the amount of experienced effort but also the acceptance of this effort, thus allowing analysis of the results in an importance-acceptance diagram that can give PT operators direct indications as to where to begin improvements.
Investigation of public transportation solutions in other metropolitan areas and other more differing PT modes such as tramlines vs. feeder buses might reveal differences in the Ease-of-Use scale.

5 DISCUSSION AND FURTHER RESEARCH

What was new? What was the contribution to science of this thesis? The psychologist may miss the theory based experimental designs to describe, explain and predict behaviour. The transport planner may wonder why it is so important to look at the cognitive user perspective when well known rules of thumb and presumptions were merely justified by the research reported here. Some parts and results seem to be self-evident but they have been investigated and proven in a scientific way using valid methods, so they are now good as reliable arguments. Psychology and transport planning approaches were combined in this interdisciplinary work and the new contributions to science are reported below:

- The focus was on a cognitive user perspective. The author had not found any evidence of such a focus in the international literature regarding public transportation. The concept memory representation was introduced, described and explored.
- An in-depth study was developed and conducted for investigating the learning process in an unknown PT system.
- The focus on newcomers to a city, such as exchange students, is unique, except for a few references. Newcomers had, based on the literature accessible to the author, never been investigated in this quality. Since this target group discovers weak points in the system fast and needs most support, the results derived from the studies allow improvement of the PT system for newcomers to a city and other potential PT users alike.
- Applying the concept “Ease-of-Use” to PT is innovative and during the course of the work an Ease-of-Use Scale was developed and tested with the intention of measuring the fuzzy concept and producing a figure that could – apart from well-known customer satisfaction – constitute an indicator of the state of the PT system as regards Ease-of-Use.
- The approach of looking at the match between the (potential) user and the PT system by exploring the cognitive user perspective and system characteristics regarding orientation and information aspects could also be considered new.
- A hierarchy of PT option knowledge was proposed with three levels: existence of PT option, PT mode and line code. For every level sublevels were suggested.
- In addition, visibility, straight route layout and labelling were proposed as factors that contribute to the extent to which a PT line is represented in people’s memory.
- Finally, the in-depth exploration of the effects of at-stop real-time information displays presented a comprehensive summary of possible effects including both “soft” effects such as psychological effects and effects on perceived wait time.

The answers to the three research questions presented in this thesis are not complete and stimulate new questions that can be addressed in further research.

Proving and verifying the three phases of a learning process in an unknown PT system is an interesting question for further research. The new approach regarding the organisation of PT knowledge should be tested as well. The three factors (visibility, straight route layout and labelling) that were postulated to contribute to the extent to which a PT line is represented in people's memory can also be a topic for further research. With the Ease-of-Use Scale the reliability and validity criteria were met, but further research (as already outlined above, chapter 4.3.3.) should continue to develop the scale and to get more results to base conclusions on and allow more generalisations.

The research scope could be extended to smaller cities and rural areas. Further, replication of some of the studies would provide a broader, more reliable data basis to interpret the results on. Further research could include all kinds of difficulties concerned with ticketing; this was totally excluded from this thesis but is indeed a very problematic field, especially for occasional PT users and newcomers to a city. A long-term panel study with newcomers could prove the three learning phases proposed here with a broader sample of subjects. Visitors, tourists, and even residents who do not use PT would be interesting subjects for future investigation.

Derived from paper III, the literature review, there is a need for field studies, which allow for existing ergonomic guidelines to be transferred into practice and made applicable for engineers and transport planners. More evaluation studies of trunk bus implementations in other cities could use parts of the methodology developed in this thesis such as before-after interviews with travellers, before-after telephone interviews with residents and the Ease-of-Use Scale developed in paper VIII. In further research it might be possible to enhance the test design even more and incorporate two control groups in the evaluation: one without treatment (the implementation of a new bus line) and one without before-test sensitizing. The market effects accompanying a trunk bus implementation on the non-user should be investigated in future research. Marketing probably has the potential to increase knowledge and enhance the memory representation even more.

One unsolved question that also needs to be considered is if the following statement is true or not: People do not use PT due to lack of knowledge about the options. If this is true, more marketing and better information can enhance knowledge and thereby lead to higher modal split of PT. If this is wrong, it means that people know about options and probably have enough information but even so do not use PT. The focus should therefore be on better travel demand management in general, including attractiveness-enhancing measures in PT.

This thesis constitutes a first draft of what success factors for a trunk bus system could be. Nevertheless, there is still a need for further studies to determine which characteristics are most important for creating attractive bus networks, for example the characteristics of the route/network layout. Further, research on information in service disruption cases or other information of interest to customers that could be shown on real-time information displays at stops and stations is also encouraged. A topic for further research can be how to put the costs and effects of real-time at stop displays into socio-economic cost-benefit analysis models. How to translate Ease-of-Use in general and even the cognitive user perspective in particular into computer models is also an interesting question.

Beyond that all aspects that have not been within the scope of this thesis but could be potential influences on Ease-of-Use can be studied in further research. For example: public transportation fare collection, physical accessibility such as walking distance or physical barriers, or other accessibility factors such as travel time and service frequency.

In a PT context, it is desirable to focus more on the customers and their needs than on the technical challenges. Effects on the customers can act as sensitivity indicators of the success of improvements such as service changes or new information systems. Development should always begin and end with the customer firmly in focus. The author would like to stimulate more applied and even classical basic research in this important field to contribute to better PT. Attractive PT plays and will continue to play an important role in achieving sustainability, efficient mobility and high quality in urban life.

6 GET STARTED – A TO-DO-LIST FOR SL

This additional chapter is not part of the official scientific summary of my work. It is a possible answer to the question from practitioners after listening to my results: “WHAT should we do in practice?”
I have compiled a top-ten list, presented below, of measures that could enhance Ease-of-Use in Stockholm’s public transportation system. It starts with the actions that are probably most easily and quickly implemented. This analysis was not conducted in a scientific way and is my own subjective ranking. So, let’s get started on making public transportation more attractive ...

1. A good schematic map of the entire system, including salient landmarks and all public transportation modes should be placed at stops and stations. The current bus map (red-coloured bus lines in a street network) is too hard to understand when looking for a specific bus line. A map of the surroundings at the stop/station would be nice as well.
2. Consider each single stop as an entrance to the public transportation system: provide all necessary information to be able to use the entire system at each stop.
3. Provide more information inside buses: for instance, a system overview map and route/stretch map.
4. Indicate in the timetables at the stop all stops on a line and the time that will be needed to reach them.
5. Promote your Internet travel planner better. It is very good but not everyone knows about it – more marketing!
6. Stick to your information strategy: standardised consistent information throughout the system, multi channel information and disruption information.
7. Plan and implement a tourist strategy: ensure that public transportation information is properly included in all material that is distributed to tourists (free tourist maps, Internet), provide brochures in different languages, post signs in English, and make announcements other languages in addition to Swedish (during the tourist season for example).
8. Invest in youth marketing: revitalise for example your “SL kompis”-club to train, involve and commit children and teenagers to using public transportation. Experience matters!
9. Develop or continue with a newcomer strategy for people moving to Stockholm: provide a welcome package with information about the public transportation options in the new area and perhaps a free ticket to test the service.
10. Cooperate with major travel destinations such as shopping or leisure centres or big employers: they should indicate the closest public transportation stop in their advertisement/travel description and have a link to the SL travel planner on their websites.

7 ACKNOWLEDGEMENTS

If I had to start this work again I would do many things in a different way. I learned that this is the process of becoming a PhD – the process of realising that behind every apparently solved question 1000 new questions arise. The work that is presented in this thesis mirrors a process and shows the results of this research journey. Tek. Dr. Karl Kottenhoff was the most important travel guide during this journey. He was the person who made it possible for me to come to Sweden as a PhD student. Kalle, a very encouraging person, shared my enthusiasm about public transportation and without him this work would have never been done in this way. He can also take the credit for the inspiring and supporting meetings with the reference group for my research project. I would like to thank all the people who have been involved in this reference group over the years for their valuable input. Of course I must also thank my principal supervisor Prof. Karl-Lennart Bång for supporting my work, giving valuable comments, asking critical questions and leading me through the jungle of administration. I would like to thank my second co-supervisor Prof. Bernhard Schlag, Chair of Transportation Psychology at Dresden University of Technology for discussions of the psychological parts in this work and always prompt responses to my questions.

I thank all my co-authors: Arjan Vermeulen, Sten Sedin, Matthijs Dicke-Ogenia and Agnes Scholz – it was always a pleasure to work together with you! I owe special thanks to Sten who made the illustration on the cover of the thesis for me.

I would like to thank Sofia Lundberg (for teaching me Swedish and being my best friend at work), Ines Thronicker (for being my case study subject and my friend), Annie Weinstock (for English improvements, behaviour observation results and being a good friend) and Tony Burden (for being an inspiring mentor in the "Technologia" program 2005/06).

I would like to thank all my former and present colleagues at the division of Transportation and Logistics for their support and all the pleasant, informative and stimulating discussions in the coffee room and during lunch breaks.

Without all the persons who participated in my studies this work would not have been possible. In all, 2,114 people donated their time to my research (this number does not include the 8,311 people whose behaviour was observed). When calculating the average interview time and time to fill in a questionnaire I come to the (non-scientific) conclusion that I was given 411 working hours - Thanks to all the anonymous people who contributed to my results!

Financial support by Vinnova – The Swedish Governmental Agency for innovation (project 22329-1), Banverket – The Swedish Rail Administration and Vägverket – The Swedish Road Administration (project "Behavioural response to IT-based traveller information in public transport") is thankfully acknowledged. Further I was glad to receive a WCTRS fellowship and a travel grant from Ragnar och Astrid Signeuls Stiftelsen in 2007.

Finally, but most importantly, I want to thank my family Thomas, Alexander and Elisabeth for their patience.

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APPENDIX