THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

Effects of long-term access to ICT-mediated travel information services

- Users' assessments and reported behavioural changes

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Abstract

Great optimism has for some time framed the potential effects that access to ICT-mediated travel information services (ICTIS) have on travellers. Little has however been known about real-life long-term effects of access to ICTIS. The aim of this thesis was thus to create a basis for understanding the role of ICTIS in urban transport of people. The focus was on changes in travellers' assessments of ICTIS; the changes in travel experiences from having access to ICTIS; and behavioural changes such as changes in choice of travel mode and route choice from having access to ICTIS. All in all, more than a thousand respondents participated in four studies investigating changes over time periods between six months and twelve years. The results show that travellers' pre-exposure expectations on benefit and impacts are larger than what is experienced from use. The results also showed that travel experiences changes from access to ICTIS, and that access to ICTIS does have potential to change travel behaviour. Magnitudes of behavioural changes were however found to be limited. It is suggested that a larger focus on the travellers' benefits, time perspectives, and the travellers' possibilities to act could increase intended changes from access to ICTIS.

Keywords: ITS - Intelligent Transport Services and Systems; ICT-mediated traveller information; Navigation; Traffic information; Real-time information systems; Travel Planner; Co-modal Travel Planner; Multi-modal Travel Planner; Public transport; Transit; Behavioural change; Assessments; Action spaces

Preface

This PhD thesis is the result of a need to know more about the effects of ICT-mediated traveller information. The research project has been a part of the Swedish National ITS (Intelligent Transport Systems) Postgraduate School. It was partially funded by the Swedish Transport Administration and Sweden's innovation agency, Vinnova. Some of the research has been done as part of Seventh Framework Programme project co-funded by the European Commission DG Information Society and Media within the strategic objective "ICT for Cooperative Systems".

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I am also grateful for having good friends and family that skilfully combined the art of trusting in me while at the same time trying to avoid asking me the forbidden questions.

Finally, I would like to thank Nina for holding on. It might have been a longer journey than you expected and I'm happy that you never lost hope. Now, let's go to New Zealand!

Berlin, Germany, August 2014

Included publications

Karlsson, MariAnne; Skoglund, Tor (2012)

ICT-mediated information services in public transport: Travellers' use, assessment and long-term effects. Submitted to Travel Behaviour and Society.

Skoglund updated, reformulated and restructured the questionnaire, performed the information collection, carried out the statistical analysis, and wrote parts of the paper.

Skoglund, Tor; Karlsson, MariAnne (2012)

Appreciated – but with a fading grace of novelty! Traveller's assessment of, usage and behavioural change given access to a co-modal travel planner. Proceedings from Transport Research Arena - Europe 2012, pp. 1-9.

Skoglund formulated the questionnaires, collected the information, carried out the statistical analysis, and wrote most of the paper.

Skoglund, Tor; Karlsson, MariAnne; Wallgren, Pontus (2014)

Drivers' use and reported effects of access to in-vehicle navigation systems. Findings from a long-term inter-European field operational test. Submitted to IET Intelligent Transport Systems

Skoglund contributed to formulation of questionnaires, constructed web-survey, contributed to focus groups, carried out the statistical analysis, and wrote parts of the paper.

Skoglund, Tor; Wallgren, Pontus; Karlsson, MariAnne; Franzén, Stig (2014)

Users' perception and reported effects of long-term access to in-vehicle traffic information services mediated through nomadic devices - Results from a large-scale inter-European field operational test. Submitted to Transport and Telecommunication Journal.

Skoglund contributed to formulation of questionnaires, constructed web-survey, contributed to focus groups, carried out the statistical analysis, and wrote most of the paper.

Additional publications

Skoglund, Tor; Karlsson, MariAnne; Franzén, Stig (2009)
Realtid ur ett organisationsperspektiv: motiv, införande, effekter. Transportforum 2009

Skoglund, Tor; Karlsson, MariAnne; Franzén, Stig (2009)
Real-time traveler information from an organizational perspective: Driving forces, implementation issues, and deployment effects. Proceedings of the 16th world congress and exhibition on intelligent transport systems and services, (3830)

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1 Introduction

The purpose of this section is to describe the background and motives for the research. It will briefly mention the importance of transport and some contemporary and possible future challenges connected to the area. The expectations surrounding ICT-mediated traveller information services are presented, followed by a description of the existing knowledge on the observed effects of introducing such services.

1.1 Transport systems – enablers and problem creators

A well-functioning transport system is an important foundation of societies. Economic development and sustainability are connected to the transport of goods and people (Steininger, 2002; Limani & Lubishtani, 2013). Good communications contribute to a high quality of living and can facilitate a development towards a more sustainable society. However, the challenges associated with shaping tomorrow's transport systems are numerous as the way transport of people is constituted is unsustainable (Gudmundsson & Höjer, 1996; Banister, 2005). Two examples of areas connected to transport of people that need to improve are energy demand and spatial use. Transport is an increasingly inefficient (cf. Peake, 1994) energy demanding human activity. In 2009, close to all transport (95%) was reported to be dependent on non-renewable petroleum (International Energy Agency, 2009). Transport energy demand is expected to decline somewhat in OECD until 2040, but is expected to stay the same on an international level (U.S. Energy Information Administration, 2013).

Transport of people is an important part of the transport sector. The transport of people is moreover increasing and is expected to double by 2050 (International Energy Agency, 2009). Some indications of potential decline in the use of energy consuming modes of transports have been reported. A slight decline in car passenger kilometres per capita has, for example, been noted for young adults in industrialised countries (Kuhnimhof et al., 2013). A strong decline in the share of the comparatively energy efficient travel modes such as rail and bus is nevertheless expected for urban travel internationally (International Energy Agency, 2009). An accelerated urbanisation and the relative density of urban areas are thus no guarantees for energy efficient transport of people.

A number of negative environmental effects have moreover been linked to the transport sector (cf. Hoban & Tsunokawa, 1997; Sharma, 2003; Chester & Horvath, 2009). One such concern is that of an increase in carbon emissions. Road transport is the transport subsector with the largest contribution to global warming (Fuglestvedt et al., 2008) and land transport has been reported to contribute to more than one fifth of the total anthropogenic carbon emissions in CO_2 equivalents (Uherek et al., 2010). Such a large contribution makes a reduction of transport related carbon emissions desirable and relevant.

Spatial limitation in urban areas is another challenge. The world's urban

population grew from 220 million to 2.8 billion during the 20th century and more than half of the human population now lives in cities (United Nations Population Fund, 2007). Such a concentration of the population demands a spatially efficient transport system. The number of cars on roads, a spatially demanding mode of transport, could, according to International Transport Forum (2011), double from year 2010 to 2050 with a possible fourfold in global passenger-kilometres travelled (ibid.). Although statistically valid data on the performance of traditional investments in infrastructure is lacking (Flyvbjerg et al., 2005) and difficult to assess (Lakshmanan, 2011), traditional infrastructure investments have been argued to no longer be profitable from a public economy perspective (Hulten & Schwab, 1991; Banister & Berechman, 2001; Brännlund et al., 2013). Additionally, although also difficult to assess (Grant-Muller & Laird, 2007), the costs of congestion are claimed to increase and have in Europe alone been assessed to cost 1% of the gross domestic product (European Commission, 2011a). The costs for congestion in Europe would, if the projected trends continue, rise by 50% to €200 billion annually in 2050 (ibid.). Solutions for more spatially efficient urban transport of people are thus needed.

1.2 Long-term confidence and optimism

Choices made by individuals have the potential to affect the transport system. Changes in travel mode, travel frequency, or route choice are examples of choices that on an aggregate level affect the transport system at large. Measures designed to motivate individuals to voluntarily change towards a more sustainable travel behaviour have thus been discussed as a potential solution (e.g. Cairns et al., 2008; Richter et al. 2009, 2011). Special interest has been shown in the potential of Information and Communications Technology (ICT) mediated travel information services (ICTIS). *ICTIS denotes services where travel related information is presented to the individual through ICT*. It does not denote the technical systems as such. The expectations of the effects of ICTIS have been high for some time. Statements from the very beginning of the millennia until 2013 indicate the persistence in expectations on impacts of ICTIS by important institutions. The Commission of the European Communities stated in their White Paper from 2001 that "information services provided before or during journeys […] should help greatly to alleviate the effects of road network saturation" (Commission of the European Communities, 2001, p. 122). The Transportation Research Board in USA stated similarly in 2000 that "information technology [...] provides the single greatest opportunity to enhance the quality of the travel experience" (Transportation Research Board, 2000, p. 15). The historically positive expectations of the effects of having access to traveller information services in the transport sector extended to the Transport Research Board Committee on User Information Systems going so far as to *define* their area of interest as stimulus that "aids the user to better complete a trip or perform a trip-related operation" (Dewar et al., 2000, p. 1). However, in the same document, the Committee also noted a lack of knowledge about the effects, stating that "the effects of [advanced traveller information systems] on travel are largely unknown and will need to be addressed in the new millennium" (ibid, p. 5).

The belief in using ICT-based systems as a problem solver is persistent and the focus on information-based solutions, and in particular ICT-mediated traveller information, is still years later said to "...make a significant contribution to improving environmental performance, efficiency, including energy efficiency, safety and security of road transport, including the transport of dangerous goods, public security and passenger and freight mobility" (European Parliament, 2010, L207/1 (4)). Based on this claim, the European Commission presented, in their whitepaper for competitive and resource efficient transport system, initiatives such as establishing a framework for a "European multimodal transport information, management and payment system" as one of the ten goals for a competitive and resource efficient transport system (European Commission, 2011b). Similar beliefs were simultaneously expressed by the US Department of Transportation (2010), including ICTIS as part of system efficiency strategies. The Swedish Government has likewise claimed that ICT systems applied to the transport area make users better informed and in this way make the use of infrastructure safer, better coordinated and more efficient (Swedish Government, 2013, 3§).

The confidence in positive effects of introducing systems for ICT-mediated traveller information is correspondingly reflected by influential non-governmental institutions like the Institution of Engineering and Technology, stating that "Information and communication technologies can make various modes of transport more efficient while minimising the negative effects on health, the environment, the economy and quality of life" (2011, p. 4). The same rhetoric regarding information and information services has also been acknowledged on a local public transport level. Groth et al. (2011) presented for example transport information services as a means for increased market share. Also public transport planners speculate on the transformative power of ICTIS in for example supporting wider stop spacing through reducing departure time uncertainty (cf. Walker, 2012).

The fact that representatives of such different levels of society for decades have shared these great expectations about systems for ICT-mediated services points to a need to know if these expectations are based on real-world facts.

1.3 Confirmed effects of access to ICT-mediated travel information services

Transport of people could be described as consisting of at least one of two contexts. The first context includes private modes of transport. ICTIS can, in this context for example, include travel planners, navigation support, and traffic information. The second context includes public transport modes. ICTIS can, in a public transport context, for instance include public transport planners, real-time information in terms of minutes left until next departure, information on disturbances and delays, and other travel-related information. An example of an ICTIS that applies to both private and public modes of transport is a co-

modal travel planner[1] that has the ability to combine travel options from public and private modes of transport.
Effects of access to ICTIS can be both behavioural and related to how the traveller experiences the travel situation. These experiences can be related both to factors, such as the level of comfort or stress, and to performance related factors, such as efficiency. Several empirical studies show that ICT mediated information services in public transport are appreciated and generate positive reactions by users (e.g. Sekara & Karlsson, 1997a; Sekara et al. 1997; Sekara & Karlsson, 1997b; Sekara & Karlsson, 1998; Dziekan and Kottenhoff, 2007; Dziekan & Dicke-Ogenia, 2010; Ferris et al., 2010). Literature reviews on short-term studies of ICTIS in public transport have supported this (e.g. Schweiger, 2003). There are some indications that expectations of the impacts of real-time travel information are exaggerated regarding travel behaviour (Nijkamp et al., 1996) and mode choice (Dziekan & Kottenhoff, 2005). Furthermore, Van Wee et al. (2013) claimed that the impact pre-trip travel information has on comfort is relatively under-researched. Studies on effects of long-term access to ICTIS related to public transport are however scarce. Long-term here denotes a timeframe long enough to enable the individual to *adopt the service and incorporate it into daily life*.

ICT mediated information services targeting users or private cars include traffic information and navigation services. The effects of drivers' access to in-vehicle navigation support have been studied for some time. As early as 1985, Streeter et al. presented a short-term study of navigation support, finding that voice guided support got the participants to the destination in shorter time, with fewer navigational errors, while driving a shorter distance than if they used a physical map. Attention was later turned to the cognitive demands associated with the interaction with these systems. Dingus et al. (1989) studied for example, visual distraction from a safety perspective, as have more recent studies such as a comparison of physical maps with navigation service on mobile phones by Lee and Cheng (2008). Empirical data on the effects of long-term access to such systems are, in the case of navigation support, limited. There is moreover a scarcity of studies on mature in-vehicle navigation support products, as most research has been done on pre-market solutions. One exception is Girardin and Blat (2010) who, in a retrospective study, investigated the long-term effects of introducing ICT-mediated navigation support in taxis. Much of the research on the effects of traffic information to car drivers has been based on simulator studies or on use of stated preferences. There are however some studies based on field tests. Zhang and Levinson (2008) studied for example the short-term (only a few trips were done by each participant) effect that traffic information had on path choice. Koller-Matschke et al. (2013) followed on the other hand participants with access to a variety of traffic information services over a period of eight weeks. The study found among other things that drivers had a strong main route preference. No large-scale studies on nomadic device based in-vehicle traffic information or navigational

[1] A co-modal travel planner combines private and public modes of travel. Kenyon and Lyons (2003) used the term Integrated Multimodal Traveller Information (IMTI) to denote the type of information presented by a co-modal travel planner.

support for non-professional use have however, to the author's knowledge, been done in real traffic over time periods longer than two months.

Several reviews and compilations of effects of traveller information services have been presented. Lyons et al. (2007) presented a review regarding demand, choice making, and consequences of travel information on individuals. They found for example, that there was not enough empirical insight about the behavioural consequences of information use, and highlighted a need to know more about the impacts of long term use of in-car travel information. Chorus et al. (2006a) concluded in their literature review on Advanced Traveller Information Services (ATIS)[2] (with a dominant focus on pre-decisional information about departure times, routes and mode choices) that there is a lack of empirical knowledge concerning the effects of ATIS on the travellers' perceptions and beliefs regarding, for example, travel alternatives. Van Wee et al. (2013) stated moreover, a lack of knowledge on the potential of navigation systems to induce a travel demand through decreased inconvenience and travel times.

[2] "Advanced Traveller Information Systems" (ATIS), a phenomenon closely related to ICTIS, has been defined as "systematic application of information and communications technologies to the collection of travel related data and the processing and delivery of information of value to the traveller" (McQueen et al., 2002)

1.4 Aim and research questions

The inadequate level of knowledge about the real-life effects of introducing ICTIS described in the previous section needs to be addressed. This thesis aims to create a basis for understanding the role of ICTIS in urban transport of people from an individual – user – perspective, in particular the effects that the effects that access to ICTIS these systems have on travel behaviour and the travellers' experiences of the travel situation. Understanding the effects that long-term access to ICTIS has on the transport system has to be based on an understanding of how the individual is affected (cf. Camacho et al., 2013).

Effect here denotes both behavioural changes of the traveller and changes to how the traveller experiences the travel situation in terms of for example comfort and stress.
Long-term here denotes a timeframe long enough to enable the individual to adopt the service and incorporate it into daily life.

The effects that long-term access to ICTIS has on individuals can be described as (i) changes in assessment of the benefit of ICTIS, (ii) in assessments of travel options, or (iii) changes in travel behaviour.

Assessment here denotes the individual's evaluation or opinion of experience, often indicated through rating.
Benefit denotes an advantage as assessed by the individual.
Behaviour here denotes travel behaviour, i.e. the individual's choice of when and how to travel, choice of travel mode, route choice, etc.

The aim of the thesis has been addressed by intending to answer the following questions:

- How do travellers assess having access to ICTIS?
- What are the perceived benefits of access to ICTIS?
- Do travellers' assessments of benefits change over time, i.e. does long-term access influence their assessments?

- What are the perceived effects of users' access to ICTIS?
- Are there changes in travellers' assessments of transport options from having long-term access to ICTIS? If so, what are these changes?
- Are there any changes in travellers' travel behaviour due to users' access to ICTIS? If so, what are these changes?

1.5 Thesis structure

This thesis is organised into six main parts.

Part one, Introduction, presents the background and the challenges related to the studied area. It shortly describes how transport is important to society, and also describes some challenges related to transport of people. It moreover points to a gap between expressed expectations on the effects of introducing ICT mediated traveller information services in solving these challenges, and the actual knowledge about long-term effects on travellers and traveller behaviour.

The second part, Framework, explains the theoretical basis through which the empirical data later is interpreted. It emphasises some factors influencing how decisions made by travellers are formed by the design of the transport system and information services connected to it.

The third part, Research implementation, describes the overall research approach and, in general terms, how data was collected and analysed in each of the four studies that constitute the basis for this thesis.

The fourth part, Summary of Studies, presents a short summary of the aims of the respective studies, a more detailed description of how each study was executed, the most important results from each study, and the main conclusions from each of the four studies. Each study corresponds to one of the appended papers (A-D). There is however also some information that would be unsuitable if included in the appended paper, but important to the thesis. Such information was thus included in thesis but not the corresponding paper.

Several types of information services, mediated via a multitude of systems, to a variety of different types of users were investigated in the included studies. Effects of introducing ICT mediated traveller information services to travellers using public transport, to travellers using private modes, as well as to travellers potentially combining public and private modes of transport were studied. The studied services were used for a variety of reasons and with different time perspectives. The investigated systems included online websites, publicly placed information boards, and in-vehicle devices. Results from investigations of such a variety of users, services, time perspectives, and systems opens up for discussing the role of ICT mediated traveller information services. Such discussion, and conclusions from said discussion, is presented in the fifth part, Discussion and conclusions.

The last part, Development of Future Research, offers suggestions on what could be fertile and/or important perspectives for future research based on the results of this thesis.

2 Framework

A multitude of factors influence the effects that access to ICTIS may have on travellers. Different research approaches have consequently been applied to the studies of such effects. The effects originate in the behaviour of individuals and successful research is likely to be human centred. The effects of individuals having access to ICTIS stem more specifically from the relationship between the individual and the systems involved. It is thus important to use an approach that also addresses this relationship. Such a relationship includes the human, the systems, and the context in which this relationship exists. One research tradition, with a focus on the relationship between human and technology is the tradition of Human factors. The scientific discipline of Human factors is "concerned with the understanding of interactions among humans and other elements of a system […] in order to optimize human well-being and overall system performance" (International Ergonomics Association, 2014). For this purpose, Human factors is employed as a tool that includes ideas and research perspectives from cognitive science, design, and sociology but also takes an interest in the design and application of the artefacts and systems that the individual interacts with. This trans-disciplinary research perspective opens up for a broader understanding of the effects of introduction and access to technology than have approaches with more narrow research perspectives.

2.1 The systems

The transport system constitutes the area of application for this thesis. The transport system includes what frequently has been referred to as Intelligent Transport Systems and services, ITS. The area of ITS includes in turn the ICT mediated services that have been in focus and will therefore be presented together with a short description of the role that information plays for the transport system and the human actors involved.

2.1.1 The transport system

Transport systems are complex systems that include several types of actors, technologies, and time horizons. The breadth of research possibilities given in the area of transport has thus attracted attention from a variety of research perspectives. Sjöstedt (1995) described some central aspects of transport research as illustrated in Figure 2-1.

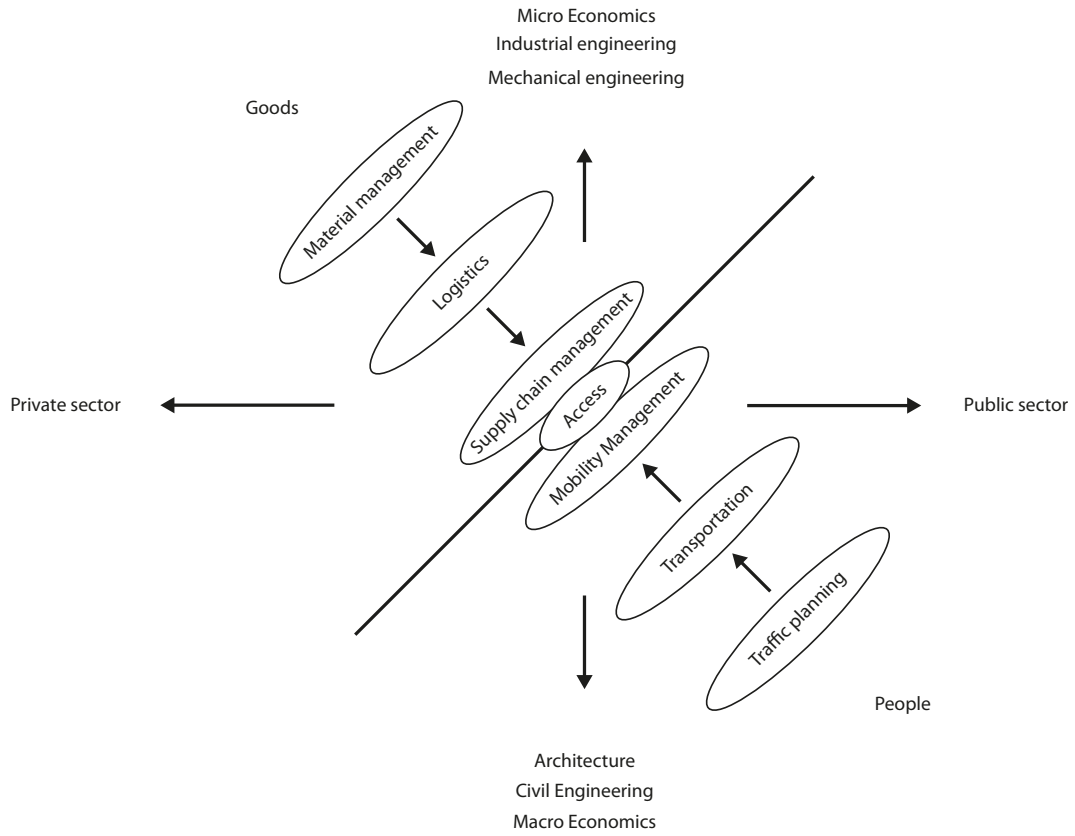

Figure 2-1 Illustration of transport research categories. Based on Sjöstedt (1995)

The foci of transport research can in this way be argued to exist on intersections of the axes Micro-Macro; Public-Private; People-Goods. The research presented in this thesis can be argued to exist in the sphere of Micro-based research focusing on transport of people along the Public-Private axis. More specifically the thesis focuses on the people side of the People-Goods axis. Transport of people is an inherent part of the lives of people and thus relates to cultural, social, and psychological factors (cf. Gudmundsson & Höjer 1996).

The thesis is intended to, from a micro perspective, create a basis for a macro perspective. Potential changes from access to ICTIS are thus studied from a micro perspective, investigating effects on individuals in terms of changes to assessments of travel experiences as well as behavioural changes. The number of studied individuals is in some cases large and the data might thus be used also for a macro perspective potentially supporting policy decisions. The thesis does not however, cover factors such as economic policies or infrastructures. The focus has been on individuals without professional interest in transport of people. Other potential user categories such as authorities, politicians or drivers of buses and trams have not been studied[3].

Information needs, and consequently information services, are present throughout the whole transport system. This thesis focuses on *information services intended to support private and public urban transport of people*.

[3] For more information on the organizational effects of introducing systems for real-time traveller information services in public transport organizations see Skoglund (2012).

2.1.2 Information and the transport system

Information is a basis for understanding and services offering information are thus likely to be important to the use and perception of transport systems. Services for transport of people do not function without information flows. The information services studied here would, correspondingly, be of little value short of a transport system.

The relationship between the individual and the transport system is created via information and information services. If the transport system is described as a system that enhances accessibility to activities through mobility services; information services is what gives the user access to this mobility. Information can both give access to and add subjective advantages in terms of, for example, increased comfort and feeling of security.

Traveller information services offer information related to many types of travel modes and can include a variety of types of information. Traveller information can for instance include information on costs, or environmental impact etc. The information can be static: printed timetables and maps, or it can be dynamic: real-time information at stops, traffic information updates, or navigation support adapting to the user's position. Traveller information services also vary in the way they inform: The information can be reassuring, counselling as well as descriptive, leaving the conclusions to the individual. This width and diversity of the area of traveller information and traveller information services point to a need to context specific examination with wide-ranging perspectives in attempting to understand the effects.

The opinion that a traveller has of the transport system might not just be related to the properties of infrastructure, vehicles, and the information services per se but also related to the process through which the traveller uses these services. Rexfelt (2008) described that the relation that a user has with a technology-mediated service is an indirect relationship where the total outcome of the use of a service is affected by the interaction that the user has with the technology content of the service (Figure 2-2).

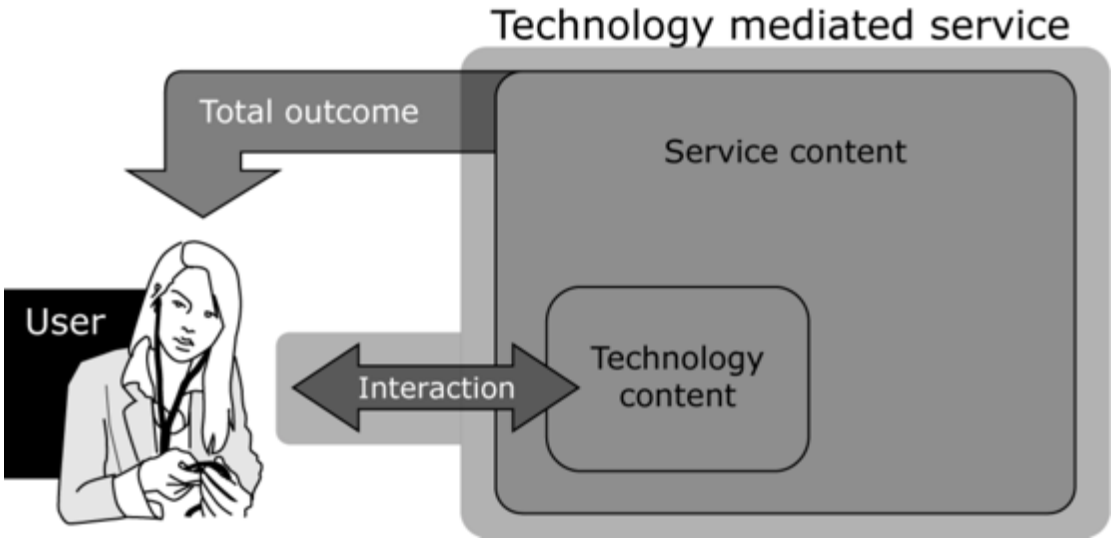

Figure 2-2 A technology-mediated service (Source: Rexfelt, 2008)

A traveller's assessment of an ICT-mediated traveller information service would thus be affected by both the presented information and by the way the information is presented. The transport service in general would in a similar way by affected buy how the information services, being a part of the total service content, is presented. From this perspective it is reasonable to assume that ***information services might make a considerable difference to assessment of the transport system at large***.

2.1.3 ICT and Intelligent Transport Systems and Services

Information and Communications Technology (ICT) is a transformative power and ICT mediated services have, since the seventies, been argued to hold a potential to substitute physical mobility (Wiesner, 1973; Kenyon et al., 2003). Such a substitution has however been more moderate than expected (e.g. Salomon, 1998; Zhu, 2013). A more specialised type of ICT mediated services, the ICTIS, are a set of services more directly connected to the mobility system related to the transport of people. Access to ICTIS can consequently be expected to affect individuals using the transport system more directly.

ICTIS are moreover, part of a set of transport investment areas categorised as Intelligent Transport Systems and Services (ITS). ITS has been described as "advanced applications which without embodying intelligence as such aim to provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed and make safer, more coordinated and "smarter" use of transport networks"(European Parliament, 2010). A common denominator for this area is the application of ICT in the transport sector (Miles & Chen, 2004). Those working with ITS therefore direct a special interest not only to the transport of people but also the transport of information. Information can be transferred between machines, between machines and humans, and between humans. This thesis focuses on services based on information transferred to travellers through ICT.

Technology is central to ITS and ICT but all technical systems also need human actors to function (cf Vicente, 2006). This applies to ICTIS even if the traveller is disregarded. The information that is the basis for a service has, for example, at some point to be chosen to be communicated. This can be done in two ways. The information can have been chosen to be communicated directly by an individual (e.g. information about traffic jams chosen by traffic control officer), or the information can have its origin in machine-generated information only indirectly chosen by an individual (e.g. so-called real-time public transport information chosen during the design process). Both these types of information can be communicated through ICT and can thus be argued to belong to the area of ITS.

The advocates for ITS solutions have for some time however, referred to ICT-mediated travel information services as a coherent space in which solutions to transport related challenges can be found. Although the uniting factor, the use of ICT in the wide area of transport, is somewhat weak. Chorus (2012) points for example to a need of common language and concepts in order to describe and measure needs and efforts. There is moreover a lack of literature

describing and comparing effects of having access to ITS solutions from a user perspective. These shortages highlight weaknesses of what ties the ITS industry together and could thus have the potential to, in the long run, dissolve the unity of an industry.

2.2 The human

The travel behaviour of individuals affects the transport system. An individual's travel behaviour will here denote that individual's choice of travel mode, when or if to travel, route choice, etc.

A number of theories on behaviour and behaviour change has been have used in order to explain travel behaviour decisions, including for instance the Theory of Reasoned Action, Habit Formation Theory, Value Belief Norm Theory, Norm Activation Theory, and Goal Setting Theory (for an overview, see e.g Adjei and Behrens, 2012).

The Theory of Reasoned Action, TRA, (Fishbein and Ajzen, 1975) and its extension, the Theory of Planned Behaviour, TPB, (Ajzen, 1991) are perhaps the most common and have been applied in various travel behaviour studies and experiments to explain factors affecting choice. TRA argues that a person's behaviour can be predicted by the strength of intention. Intention is in turn determined by attitudes towards the behaviour and subjective norm. TPB introduced a third determinant, perceived behavioural control, i.e. the perceived difficulty (or ease) of performing behaviour. The role of information could in relation to this theory be to influence a person's attitude towards behaviour, for instance a traveller's attitude towards travelling by public transport. In relation to the overall aim of the thesis, TRA and TPB hence provide limited support.

Another factor that has been introduced in travel behaviour studies is habit. Theories, such as the Habit Formation Theory, differ compared to TRA and TPB in that they do not intend to explain what factors affect choice-making but rather to explain how choices are made. Habit, defined as a repetition of past behaviour without deliberating or forming an intention, has been argued to be of importance in travel choices (e.g. Gärling & Axhausen, 2003) and its importance has also been confirmed in several studies (e.g. Fujii & Kitamura, 2003; Schlich & Axhausen, 2003). Interventions to break habits include provision of information on alternatives but habitual behaviour is in general not affected by such information as information is not used to form decisions once a habit is established (see e.g. Verplanken *et al.*, 1997). Habit thus potentially limits the effects of access to ICTIS why it is necessary to consider the role of habit in interpreting the results of the studies included in the thesis.

Investigating the role that information has in a transport system requires however a more systems approach than what the mentioned theories offer.

2.2.1 Information and decision-making

Information flows are important in systems where multiple actors arrange their actions. The transport system is no exception and transport of people in urban

areas involves a multitude of actors acting as decision-makers. Franzén (1999) presented a conceptual model for evaluation of public transport including information flows and hierarchies. The model is based on cognitive systems engineering and a simplified version of this model is depicted **Figure 2-3** below.

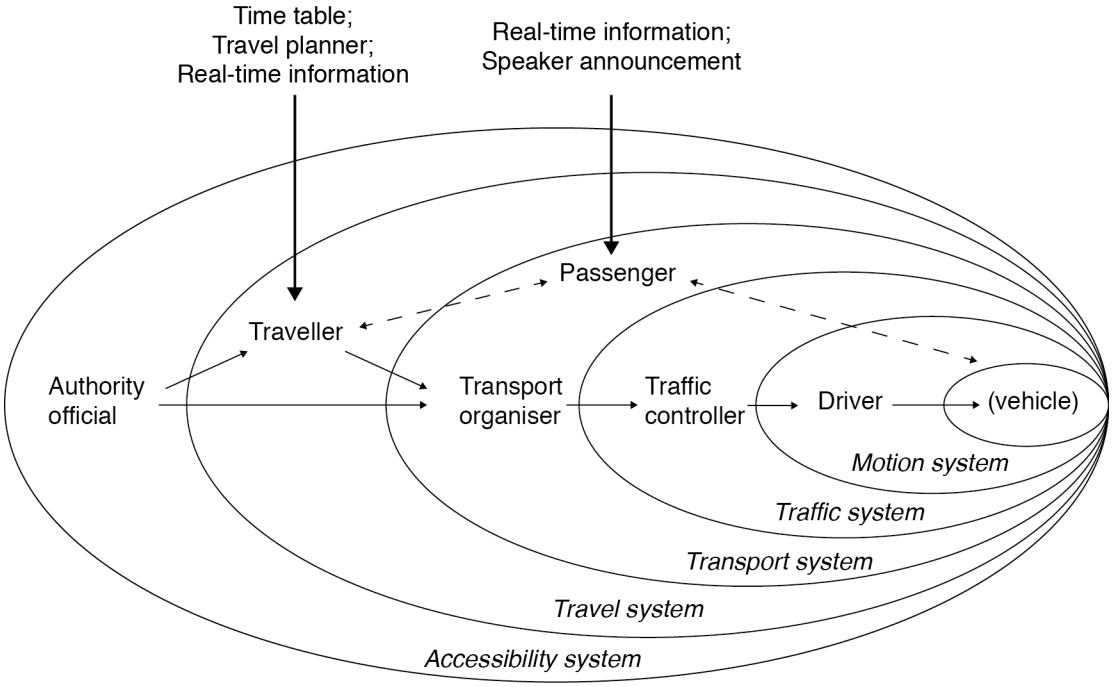

Figure 2-3 Simplified version of the ideal public transport process as described by Franzén (1999)

The model was developed for understanding information and information flows in public transport, but might be possible to use as a base for traveller information in general. In this model the individuals are described as having different roles as decision-makers at specific levels in a hierarchy. The hierarchy, with levels ranging from the Accessibility system to the Vehicles, indicates the different action spaces available for the individuals at a specific level. Vertical arrows indicate examples of inputs for decisions available through ICTIS. Non-vertical arrows indicate examples of potential influences between actors. Travellers using for example, the public transport system (and at this point in time potentially being passengers) receive input from a number of sources. An individual can moreover, have different decision-making roles simultaneously. A traveller can for example, be both passenger and driver of the same vehicle. An individual might also quickly shift level inside the model. A pedestrian can for example, enter the (public) transport system level from the travel system level through choosing to wait at a bus stop. Such a shift from one system level to another is a consequence of a decision. The decisions taken by the individual at a specific system level have the potential to affect actors on other levels of the system. The behaviour of travellers for example, affects transport organisations/authorities and decisions by transport organisations/authorities affect travellers in turn. Information is a basis for decisions and access to information services on one level and therefore has the potential to affect the transport system at large through, for example, affecting decision-makers on other system levels.

The set of possible decisions that an individual can chose between is affected by the position of the individual in the hierarchy. The information that is available, and the information that is relevant, also varies between positions on different levels. Other factors that vary between the different levels in the hierarchy are physical or geographical constraints. Different kinds of decisions are thus possible on different levels. An individual might, as mentioned, change level and thus gain, or lose, possibilities to decide and act. Decisions might moreover not always lead to action, as the set of possibilities, perceived or actual, might be limited.

2.2.2 Objectives and opportunities

The objectives of using information services differ between decision-makers at different levels in the transport hierarchy. A person that is positioned in the motion system (i.e. on a bus) has for example already decided on travel mode and is unlikely to ask for information on timetables. A person that is about to decide on whether to enter the transport system or not, might on the other hand not use information services informing them about the speed of vehicles.

Optimization for the individual is moreover not necessarily attained in parallel with optimization from a transport network perspective (cf Liu et al., 2013). Use optimization of a system by an individual might for instance counteract societal goals. This illustrates how complex systems sometimes include parts that are operating in ways that are inefficient for the common best of the system. The reason might lie in that the individual travellers are more than just part of a transport system. Travellers are also mothers, brothers, lovers and hedonists. The objective of most travel is to "meet a friend, earn income, attend school or purchase a good, not movement per se" (UN, 2013, p. 198). Consequently, the objective of an individual does not necessarily match the objective of the system at large.

Measures solving the problem with parts that act inefficiently from the perspective of the common best of the accessibility system, could include removing those possibilities from actors, or to make those actors work towards the common best of the system. The first option might, in the case of a transport system, require removal of certain, now much appreciated, spatially inefficient transport modes. Such an action could prove to be politically challenging. The second option, to make actors change behaviour, might be attempted through information provision. This is what ICT-mediated traveller information services are often created to do. Another, third, type of solution could be to adapt the transport system to better fit the goals of the actors in the system. These types of action may, if information services are as regarded part of the transport system, also include offering ICTIS.

To increase the overall system efficiency might however not be the only reason for the existence of an ICTIS. The effects of offering a service are then likely to not only include changes in line with the objective of the transport system at large. It is for example possible, if profit is the main objective for offering a service to the traveller, that the service is more successful (i.e. profitable) if the service is primarily designed to benefit the individual traveller than if the

service was primarily designed to benefit overall system efficiency. Improvement of transport system efficiency is not likely to be successful by asking travellers in general to change behaviour to something that is less beneficial for the individual (cf. Olson 1965; Hardin, 1968).

2.2.3 Activity theory

The description of the roles of actors as decision-makers in the transport system hierarchy does not by itself offer a comprehensive explanation of the role of ICTIS as tools used by individuals in an activity in order to reach their personal goals. Kaptelinin and Nardi (2006) stated for example that understanding the effects of technology needs to "be based on analysis of its role and place of in activity" (p. 28). Activity theory approaches activities as relationships between tools; subjects; and objectives. In Activity theory an activity is described as purposeful interaction, oriented towards an objective that the subject needs to attain. An activity is mediated (and both limited and facilitated) by a tool. The relationship between subject; objective; outcome; and mediating tool, can be illustrated as in Figure 2-4.

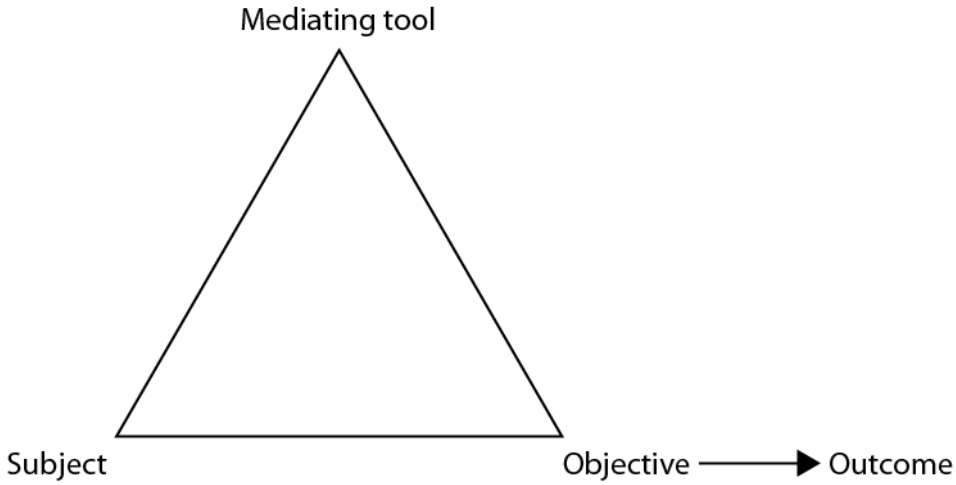

Figure 2-4 The relations between the Subject, Objective, Outcome, and the Mediating tool in a basic Vygotskian triadic representation of action as described by Engeström et al. (1999).

Mediating tools can represent a physical tool or a sign. The similarity of signs and (physical) tools in mediating (psychological/physical) activity was for example discussed by Vygotsky (1978) who used the term "sign" for a psychological tool used in describing internalisation of understanding gained in social interaction. Seeing signs as mediating tools could be argued to be closely related to an understanding of use of traveller information services as tools used for travelling. An individual traveller could in this way be described as a subject using an ICTIS as a tool with the objective of enjoying an activity at a specific location. The outcome could then be a decision to travel by a specific mode at a specific time, or it could be to not travel and enjoy the activity from home instead. The effects of travellers' access to ICT-mediated traveller information might best be understood by regarding these ICTIS as mediating tools used by the traveller to attain an outcome.

2.3 The context

The effects of access to traveller information has been claimed to be context specific. Lyon et al. (2007) claimed for instance that the infrastructure and vehicle availability are fundamental to the effects of information services. Some contextual factors relate to the possibilities and limitations set by the physical transport system and the understanding the individual has of this transport system. Other factors relate to the time perspective of access to, and use of, the ICTIS.

2.3.1 Perceived and actual action space

Decisions made by individuals affecting the transport system depend on several factors. One factor is the action space each individual is restricted to. *Action spaces here denote the set of possible actions that can be performed as a result of a decision*. Action spaces can be perceived or actual. Whereas actual action space depends on contextual factors such as time; geography; economy; etc., the limits of perceived action space are formed by the perceptions and understanding that the individual has of the available options. Mokhtarian and Salomon (1993; 1996a; 1996b) described for example, how decisions about telecommuting were not only dependent on what the individual preferred but also on what was possible. They categorised the factors that prevented or hindered individuals to telecommute into external (including awareness, organization, and job-related), and internal (psychosocial) constraints. Moreover, they referred to perceived constraints, for example a lack of awareness, as actual constraints, but highlighted the difference by finding that individuals had chosen options that were not "possible", i.e. telecommuting despite having reported it as not possible for one or more reason(s). Strömberg (2013) described in a similar way that considerations of both the individuals' perceived, and actual, action space affected the outcome of green driving. The actual action space for green driving proposed by Strömberg (ibid.) was to be limited by both internal and external objective constraints. It is the overlapping intersection of perceived and actual action space that enables decisions that may lead to desired outcomes (Figure 2-5).

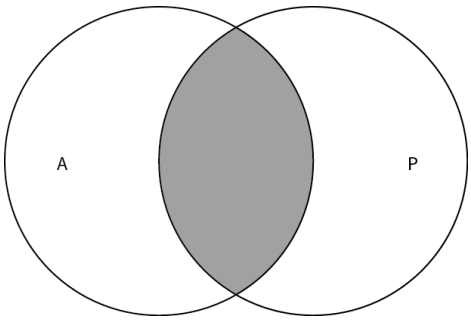

Figure 2-5 Overlap of perceived and actual action space that enables decisions that may lead to desired outcomes

A preferred choice of an individual traveller is not just governed by what the traveller would like to do but also limited by the actual and perceived action space. Actual action space is not in itself affected by an increased understanding and change in the perceptions that an individual has of the potential travel options. Perceived action space might on the other hand change with information, and a set of possible actions that can be performed as a result

of a decision might then shift from existing only in the sphere of actual action space into the intersection between actual and perceived action space. Introducing an ICTIS that informs an individual of an opportunity, or gives an individual the impression that alternative behaviour is effortlessly attained, could thus expand the perceived action space. Such expansions, potentially resulting in an increased overlap between actual and perceived, enabling decisions that may lead to desired outcomes, could be illustrated as in Figure 2-6.

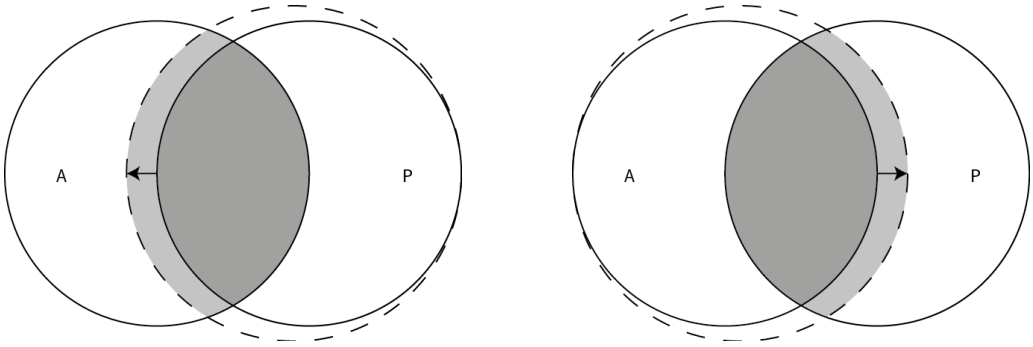

Figure 2-6 Left: Expansion of perceived action space, P. Right: Expansion of actual action space, A.

The size of the overlapping area, where actual action space and perceived action space intersect does not necessarily expand with an increase of the set of possible actions that can be performed. The individual also needs to perceive these activities as viable possibilities. An alteration to the action spaces (for example through access to an ICTIS) could decrease the overlap and thus limit the amount of decisions that may lead to, what the individual user of the ICTIS perceives as, desired outcomes. This could for example happen if an ICTIS reports incorrect information that decreases the perceived action space. In a similar way it is also possible for example a public transport service operator or a road operator to experience undesired outcomes as a result of travellers gaining access to ICTIS that demonstrate limitations of the offered transport service.

2.3.2 Time

The functional levels of the conceptual model of the ideal public transport process by Franzén (1999) illustrated in Figure 2-3 relates to time. This has been illustrated as in Figure 2-7.

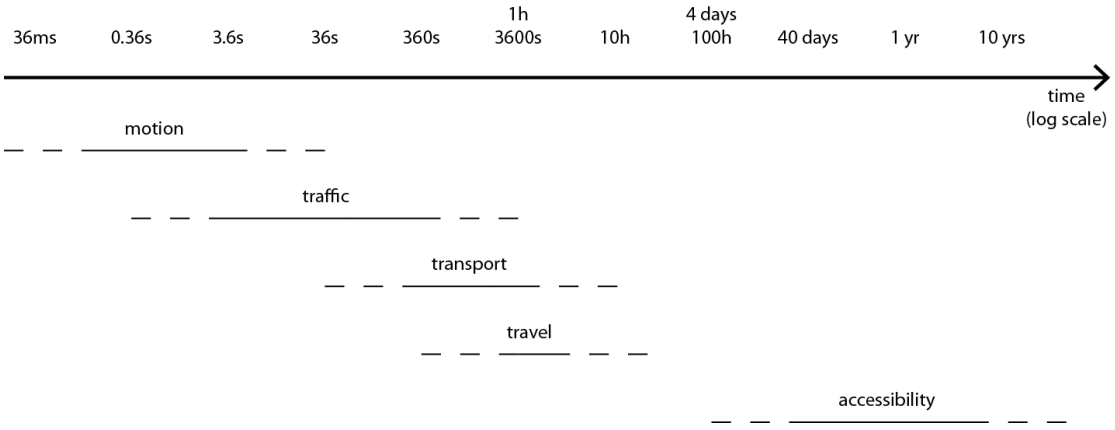

Figure 2-7 Time horizons of the functional levels in the conceptual model (Franzén, 1999)

It can be noted that the time horizons increase with higher functional levels. The time horizons of traveller information services can be assumed to increase in a similar way with higher levels.

Adoption and use frequency are two other factors that relate to time. Rogers (2003) showed that the process of adoption of innovations is affected by time and that different types of potential users adopt innovations at different tempi. Chorus et al. (2006a) stated that short-term access could render different effects than long-term influence, causing "indirect effect that may in the long-term influence next-generation ATISs' use and effects" (p. 129). Examples of such effects could be changes in destination choices and activity patterns. Time would consequently be a factor that ought to be considered in the study of effects of ICTIS. In addition, longer time periods might be needed for a critical mass of travellers to aggregate large enough changes for secondary effects to develop. A change in shopping behaviour with increased shopping at transfer points and terminals in the public transport system would for example demand a large enough customer base. Such a behavioural change might in turn affect the travel needs of the shoppers.

The model described in Figure 2-3 could be argued to include a time perspective. Decisions made on lower levels in the hierarchy, for example at the motion system level, could be claimed to be shorter-term decisions and thus potentially be more immediately affected by input compared to decisions made on higher levels like for example, at the accessibility level in the system.

The type of control employed by a decision-maker, i.e. an individual in the access system, also relates to time. Engström and Hollnagel (2007) described the functional characteristics and type of control involved with driver support functions when a traveller is on the motion level of the accessibility system (i.e. when the traveller is driving a vehicle). It is possible that the actions decided upon by the traveller above the transport level (i.e. in the travel level) could be described in a similar way. These control levels differ in frequency and when, in relation to a (potential) trip, the service is used. ICTIS might thus also be characterised by the frequency of use and the type of control that the use is

relating to in a similar way as the duration characterisations of driver support functions have been described by Engström and Hollnagel (ibid.).

Table 1 Description of functional characteristics of layers similar to ECOM layers described by Engström and Hollnagel (2007) applied to driver support functions. The column describing Demands of attention and Typical duration have been removed as they were been deemed irrelevant for non safety critical systems.

Control level	Type of control involved	Likely frequency of occurrence	Time in relation to trip
Targeting	Goal setting (incl. mode choice)	Low (mostly pre-trip, < 10/day)	Before and during
Monitoring	Condition monitoring	Intermittent (traffic, fuel economy)	During
Regulating	Anticipatory		
Tracking	Compensatory		

Table 1 indicates a similarity between expected Frequency of use and intended Time in relation to a potential trip: The closer to the actual physical movement of a trip, the higher the likely frequency of occurrence. There might also exist a difference between what can be assumed to be the time perspectives of the intended use by the creator/sponsor and the time perspectives of actual use. Positioning ICTIS in a hierarchy, as in Table 1, might increase the understanding of the different time perspective and consequently what kinds of decisions that could be affected by different ICTIS. Such knowledge is likely to be of importance to policymakers and developers.

3 Research implementation

The overall aim of this thesis was to create a basis for understanding the role of ICTIS in urban transport of people. This required studies of several types of services in different contexts. This thesis is based on four studies, of which one (Study A) investigated the effects of access for more than one service:

- Study A investigated use and effects of access to public transport related traveller information services. The study included the replication of a twelve year old survey.

- Study B investigated the attitudes towards, and effects of access to, co-modal travel planner, combining both private and public modes of transport. The study included surveys repeated over a nine-month period after introduction to the planner.

- Study C investigated effects on travellers of having half a year access to mature nomadic in-vehicle device mediated solutions for navigation services for car drivers. The study included Field Operational Tests[4] (FOT) and surveys repeated over a period of nine months.

- Study D investigated effects of half year long access to mature nomadic in-vehicle device mediated solutions for traffic information services for car drivers. The study included Field Operational Tests and surveys repeated over a period of nine months.

These studies are described in more detail in Section 4. The services that have been studied are described in Section 3.1. This is followed by a description of the methods for collecting and analysing data used in the included services.

The overall aim of the thesis, i.e. to create a basis for understanding the role of ICTIS in urban transport of people, was moreover attended to through synthesis and analysis of the results of the included studies. The analysis was attempted to identify factors common to the results of the respective studies. Objectives, setup, and included services differed between the studies why direct comparisons between the results of the studies were avoided. Synthesis and analysis was thus instead attempted with a holistic approach, reviewing and probing for patterns in the collected data from the perspectives presented in Section 2. The patterns are discussed in Section 5.

3.1 Studied services

The perceived need for information, and consequently the perceived need for ICTIS, has been argued to in generally be small (Peirce & Lappin, 2004; Lyons, 2006). Chorus et al. (2006a) concluded moreover that much of the analysis of "decision strategies and information use" applied to ATISs have been using

[4] A FOT is a "test run under normal operating conditions in the environment typically encountered by the subjects and the equipment being tested. Normally a FOT involves a larger number of users using the systems and services in their daily life in actual use conditions" (Franzén & Karlsson, 2009, p. 14)

cost-benefit types of approaches. The perceived cost of accessing traveller information needs thus, if this approach is correct, be low if it is to be consulted by the user. The perceived cost of accessing traveller information is higher if the information has to be actively sought or if it is more "automatically" presented. This thesis has investigated both information services that the user has to actively decide to acquire pre trip, such as travel planners, as well as information services that present information requiring a less active decision to acquire, such as for example traffic information in nomadic devices.

The different services that have been studied could also be categorised according to intended modes of transport, according to the kind of decision-maker that the traveller is when using the ICTIS, and according to the media through which the information is brought to the traveller.

3.1.1 Categorisation according to travel modes

The studied systems can be described as belonging to the following three main categories, depending on the type of travel mode expected to be employed by the typical service user.

- Public transport information service
    - Studied systems informed travellers about public transport services. Typical information included: Departure times, routes, service frequencies, prices, traffic disturbances, availability of services for disabled, etc.
- Information services for private car use
    - Studied nomadic in-vehicle systems informed car user of routes and directions, speed limits, road traffic system status etc.
- Multi-modal travel information service
    - Web-based planner informing travellers about trips combining several types of travel modes, both public and private. Typical information included: Annual cost, annual emission, and service frequency for each travel mode combination.

3.1.2 Services in relation to roles of travellers

The studied ICTIS target individuals in different roles as decision-makers in the travel system. Figure 3-1 illustrates, using a similar approach to Franzén (1999), examples of potential roles that individuals can have as decision-makers when targeted by studied ICTIS related to public transport.

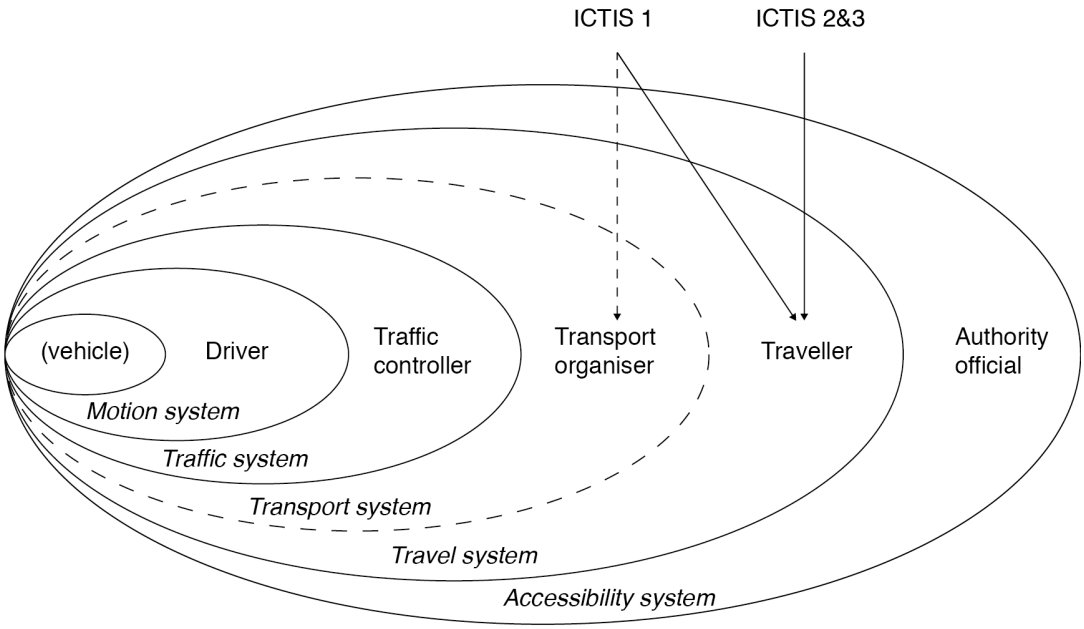

Figure 3-1 Positions of possible roles of individuals in the accessibility system using public travel modes targeted by the studied ICTIS. ICTIS 1 indicates a co-modal travel planner; ICTIS 2 indicates real-time information for public transport; ICTIS 3 indicates a public transport travel planner.

The co-modal travel planner targeted individuals making decisions before a trip at a stage where potentially also strategic decisions about future travel will be taken. Such strategic decisions could be made in a period of grater change for an individual, for example when moving or changing work place. The real-time information for public transport could be used for decisions immediately before or during a trip. The public transport planner could be used before a trip. The role of the transport organiser was in the model presented by Franzén (1999) mainly understood as a decision-maker separated from the traveller. The role of transport organiser is in Figure 3-1 however expanded to also include an individual organising future transport options for him-/herself. All three ICTIS targeted individuals on the Travel system level.

The ICTIS related to the private sector of the transport of people (i.e. including transport above the transport diagonal in the model by Sjöstedt (1995) illustrated in Figure 2-1) could analogously be illustrated as in Figure 3-2.

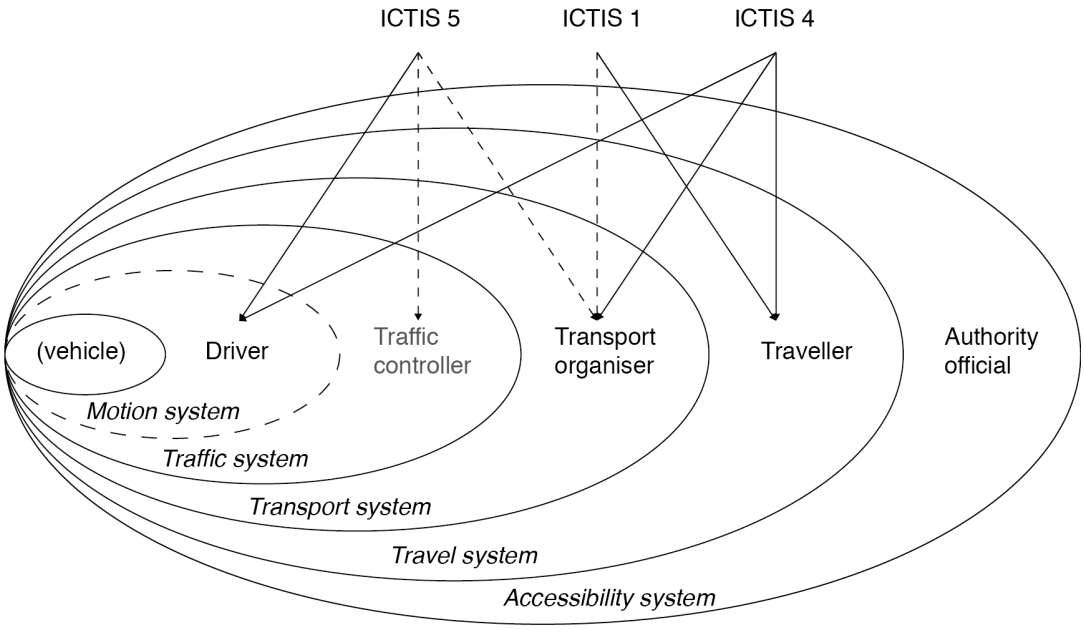

Figure 3-2 Positions of possible roles of individuals in the accessibility system using private travel modes targeted by the studied ICTIS. ICTIS 1 indicates a co-modal travel planner; ICTIS 4 indicates a nomadic in-vehicle device based navigation service; ICTIS 5 indicates a nomadic in-vehicle device based traffic information service.

The navigation support is here indicated as targeting individuals at three different levels in the transport hierarchy and the service could be used for decisions before, during, and potentially even after a trip. The traffic information service is on the other targeting individuals during a trip/driving but could also be used before a trip for organising a trip. The roles transport organiser and traffic controller are in the case of private transport modes partly included in the role of traveller. The ICTIS target individuals in the role of being travellers (i.e. not as employed traffic controllers, employed transport organisers, or employed drivers). The role of traffic controller is for a traveller normally limited to supervision with limited abilities to affect other vehicles. The scope of ICTIS does not reach outside of the travel system (to the accessibility system) but might still affect choices made outside the travel system.

3.1.3 Categorisation according to media and time

Categorising services according to the mediating technology might seem counterintuitive from a user perspective, as it could be argued that it is the service that matters to the user and not the mediating technology. Zito et al. (2011) found for example that the type of system that provides public transport travel information was reported to be less relevant to users than the price of the information service and type of information that was provided. The user does, in the case of technology-mediated services, not interact directly with the service but with an artefact, for example through a phone or an in-vehicle navigator. The interaction that the user has with the artefact is part of the total service content (Rexfelt, 2008). To not regard the (design of the) mediating technology as a factor with potential to influence the effects of a service offer is thus likely to considerably limit the understanding of the users perspective.

The services in Study A used a broad range of mediating technologies; audio-based services via telephone and speakers, variable information boards, several types of web-based services but did not include device-based information solutions (see Table 2). The system in Study B offered services that were internet-mediated and required a web-browser. The systems in Study C and Study D were device-based nomadic in-vehicle systems.

Table 2 Description of services considered in included studies. Categorisations, according to the type of targeted types of travellers, the time perspective of the offered services, and mediating technology.

		Mode type users		Typical use (*=time before trip; **=1/time during trip)				
		Public transport users	Private transport mode users	s	min	h	day	>month
Online public transport real-time information	Study A	✓		✓*	✓*	✓*		
Public transport real-time information at stops		✓		✓*	✓*	✓*		
Public transport travel planner		✓			✓*	✓*	✓*	
Co-modal travel planner	Study B	✓	✓		✓*	✓*	✓*	✓*
Navigation support	Study C		✓		✓**	✓*	✓*	
Traffic information service	Study D		✓		✓**	✓*		

Table 2 described in a way similar to the timeframes of the roles of the individual found in Section 2.3.2. Not only did the time perspectives differ between the service types, but the time perspective of the mediating systems also differs within the categories of services.

3.2 Studied systems

The choice of systems to study was initially guided by the project description as defined by the Swedish National ITS Postgraduate School[5]. The focus was in the beginning therefore on ICTIS connected to public transport. The systems that were studied first were information systems for public transport in Gothenburg and Stockholm, Sweden. The systems that were studied in Gothenburg were a variety of systems that had been available to the travellers for several years and which had been investigated earlier from a traveller perspective[6]. A repeated survey could thus give data on long-term effects. The systems for public transport information that were studied in Gothenburg were later complemented with a system in Stockholm that offered a new type of

[5] The research school includes researchers and postgraduate students from six Swedish universities. Founding organisations include among others The Swedish Governmental Agency for Innovation Systems, The Swedish Rail Administration, and The Swedish Road Administration and ITS-Sweden. More info can be found on http://its-sweden.se/forskarskolan/its-postgraduate-school-nfits/

[6] As part of the Quartet Plus project

service, a co-modal travel planner (http://reseplanerare.trafiken.nu). The co-modal travel planner was at that point in time unknown to the general public.

During the latter part of the project, the focus changed from investigating services aimed for travellers (potentially) using public transport to services aimed for travellers driving cars. The investigations were carried out as part of the TeleFOT project[7] which defined the devices to nomadic devices and the services to mature services including green driving support, traffic information, navigation support, and speed alert/speed information. This thesis did however not investigate effects of speed alert/speed information systems or green driving support.

3.3 Data collection and analysis

Effects of users' access to ICTIS depend on the relationship between ICTIS and individuals. How the users experience and assess this relationship can best be understood by asking the individuals. The four studies included in this thesis are thus all based primarily on data collected through different kinds of surveys even though individual interviews and group interviews also have been carried out. Table 3 describes the key characteristics of the four studies.

[7] The TeleFOT project was a Large Scale Collaborative Project under the Seventh Framework Programme, co-funded by the European Commission DG Information Society and Media within the strategic objective "ICT for Cooperative Systems". (http://www.telefot.eu)

Table 3 Characteristics of included studies

		Number of participants	Data collection method	Sampling type		Time between questionnaires			Questionnaires			Test type		Geo-graphic area
				Randomised	Subjective	weeks	months	years	Within subject	Between subjects	Repeated	(Semi) Controlled	Field operational test	
Public transport	Study A	494	Postal survey	✓				✓		✓	✓			Gothenburg
Co-modal	Study B	115	Web survey		✓	✓	✓		✓		✓			Stockholm
Private car	Study C	582	Web survey		✓	✓	✓		✓		✓	✓	✓	Europe-wide
	Study D	510	Postal survey		✓	✓	✓		✓		✓	✓	✓	Europe-wide

In all studies, travellers' assessments of the benefits of ICTIS, travellers' assessments of travel experiences, and perceived effects of access to ICTIS including changes in travel behaviour, were investigated by asking respondents about their reactions and actions by the means of questionnaires. The effects of having access to public transport related traveller information services were investigated in the two most populated cities in Sweden, Gothenburg and Stockholm. The effects of having access to nomadic in-vehicle device mediated traveller information services were assessed in different cities in Finland, Germany, Greece, Italy, Spain, Sweden, and the UK (for more detailed information, see e.g. Pagle et al., 2013).

3.3.1 Study A

Data collection was in Study A performed through postal questionnaires with both closed and open-ended questions that were sent to over a thousand randomly selected inhabitants of specific postal code areas in Gothenburg, Sweden, during 1997 and 2009. The questions that were asked in the questionnaire that was sent out in 2009 were chosen to mimic the questionnaire sent out 1997.

Statistical analysis was performed using IBM SPPS Statistics 17-20 for OS X. The collected data were in many cases ranked alternatives, which gives ordinal data. Median values have in these cases been used for descriptive analysis and non-parametric methods such as the Mann–Whitney U test, the Wilcoxon signed-rank test, and Spearman's rank correlation have been used for significance testing (cf. Siegel, 1957; Conover, 1980). Cut-off level for statistical significance was chosen to 0.01. Correlations <0.2 have been deemed weak (cf. Cohen, 1969) and thus ignored. Results from open-ended questions were analysed using thematic analysis and used primarily for better understanding of the quantitative data.

3.3.2 Study B

Study B included surveys carried out during the first nine months after the introduction of a new co-modal travel planner, combining both private and public modes of transport in the Stockholm region, Sweden. A web-based questionnaire was answered by over a hundred respondents at the beginning of the study, and over fifty respondents at the end of the study. The questions that were asked in the questionnaires were chosen based on thorough literature review and in co-operation with project research partners.

Statistical analysis was performed in the same way as in Study A (see Section 3.3.1 above). Results from open-ended questions were analysed using thematic analysis and used for greater understanding of the quantitative data.

3.3.3 Study C

Study C was based on Field Operational Tests where over five hundred car drivers from five EU countries tested different systems for nomadic in-vehicle solutions for navigation services over a period of about six consecutive months during 2011/2012. The participants tested the services in the vehicles of their own choice and were asked to use the devices as if it had been their own. The questions that were asked in the questionnaires were chosen through a process

of literature review, pilot studies, and in cooperation with transport researchers in seven European countries.

Data was collected through questionnaires and focus group interviews. Some behavioural changes, such as for example changes in route choices and travel speeds, were also compared to results from loggers, both in the form of travel journals and devices placed in the vehicles. Twenty individuals (out of 96) that were part of the Swedish site took part in focus group interviews. Three focus groups were carried out after the last round of questionnaires had been answered. The topic guide focused the discussions to the respondents' opinions, their use, benefits, and the device functionality. The focus groups were recorded and key statements were noted. Answers from open-ended questions in questionnaires were (when applicable) translated and all open-ended questionnaire data was compiled. The qualitative data collected in focus group interviews and questionnaires was iteratively analysed and organized through thematic analyses, such as KJ analysis (cf. Merton et al., 1990; Fern, 2001; Kvale, 1997) to further elucidate the understanding of the results from the questionnaires.

Statistical analysis was performed as in Study A and Study B. The cut-off level for statistical significance was however chosen to $p=0.05$ in order to reflect the significance level in the larger project of which Study C and D were parts. Correlations <0.2 was deemed weak (cf. Cohen, 1969) and thus ignored. Results from open-ended questions and interviews were analysed using thematic analysis and used primarily for better understanding of the quantitative data.

3.3.4 Study D

Study D was based on Field Operational Tests similar to those in Study C. Over five hundred car drivers from three EU countries tested a variety of systems for nomadic in-vehicle traffic information services over a period of about six consecutive months during 2011/2012. The participants tested the services in the vehicles of their own choice and were asked to use the devices as it had been their own. The questions that were asked in the questionnaires were chosen through a process including a literature review, pilot studies, and in cooperation with transport researchers in seven European countries.

Data was collected through questionnaires and focus group interviews in the same way as in Study C (see Section 3.3.3 above). Data analysis was also performed in the same way as in Study C, strengthening the analytical homogeneity of the thesis.

4 Summary of studies

This section summarises the four studies accomplished within the scope of this thesis.

4.1 Study A

Study A is a replication of a survey study performed in 1997 investigating public transport related traveller information systems.

4.1.1 Aim

The study aimed to elucidate what the potential long-term effects are on travellers and travelling of the introduction of a system for ICT-mediated traveller information for public transport. The study's main objectives were to:

- investigate travellers' attitudes towards, assessment of, and their use of ICT-mediated information services such as real-time information and travel planners;
- investigate the use of different media (computers, mobile phones) for accessing ICT-mediated information services;
- investigate if any changes in the choice of information channel(s) can be noted over time; and
- investigate the self-reported influences of travellers' access to ICT-mediated services.

Detailed information about the specific characteristics of the study can be found in paper A.

4.1.2 Method

Study A was a replication of a survey study performed in 1997 and was therefore deliberately designed to reflect the first study as exactly as possible (see Sekara et al. 1997; Sekara & Karlsson, 1997b). Postal questionnaires were sent to a random sample of households in the same 13 postcode areas of Gothenburg, Sweden, as in the study completed in 1997. The response rates were, after one reminder, 38.7% in 1997, and 48.3% in 2009 (see Table 4).

Table 4 Response rate

	Survey I (1997)	**Survey II (2009)**
Number of questionnaires sent out	1053	1022
Number of responses after one reminder	407	494

The questionnaires contained approximately 35 questions on topics such as technology use, use and assessment of transport modes, use and assessment of sources for information on transport, problems related to transport or traveller information, and demographics. Some questions on antiquated technology were removed (e.g. whether the displays of the computer owning respondents' computers were mono- or polychrome) and replaced by questions concerning more contemporary technology (e.g. whether the respondents owned a so called "smart phone"). The questionnaires were collected before travel

information software solutions specialized for usage in nomadic devices[8] had been widely accessible. The questions were mainly of a 'multiple-choice'-type in order to attain as high a response rate as possible.

4.1.3 Results

The respondents' rating of how well the public transport system (PT) fulfilled their requirements had, on a scale ranging from 1 to 10, increased from a median value of 7 in 1997 to 8 in 2009. Furthermore, the respondents' car ownership had decreased and the usage of public transport had increased between 1997 and 2009. The increase in number of trips with PT between 1999 and 2009 was more than twice as large in the region than the increase in the number of inhabitants was in the same area (28% vs. 11%).

Usage

Computer usage had, as expected, increased considerably since the first survey. Computer use was, however, still lower amongst older respondents and respondents that had reported a lower household income compared to other groups.

Computer-based web-browser mediated information services had become established for a large majority of the respondents (77%, n=494) and the most common way to acquire information about public transport had shifted from paper-based media and phone in 1997 to computer-based web browser in 2009. Computer-based real-time information had also become an established information service, as well as highly appreciated, whereas information mediated through web browsers on mobile units (for example over the phone) was still not established in 2009.

Assessments and reported effects

The reported benefit assessment of having access to a *web-based travel planner* had, on a scale ranging from 1 to 10, increased from a median value of 7 in 1997 to 9 in 2009 (n_{1997}=21; n_{2009}=220). This was in line with an increase of respondents that reported to experience more efficient travel (from 9% to 41%; n_{1997}=45, n_{2009}=329; p_{Fisher}<0.01) and shorter waiting times (from 9% to 30%; n_{1997}=45, n_{2009}=329; p_{Fisher}<0.01) as a consequence of having access to the web services. There was also a significant increase in the number of respondents that claimed to travel more often with public transport as a consequence of having access to web services compared to 1997 (from 2% to 19%; n_{1997}=45, n_{2009}=329; p_{Fisher}<0.01).

Overall benefit had moreover increased regarding real-time information on the web ($p_{MannWhitney}$=0.002, $n_{Survey1/Survey2}$=16/297) and at stops ($p_{MannWhitney}$<0.0005, $n_{Survey1/Survey2}$=149/459).

The benefits of *real-time information at bus/tram stops* were looked into in

[8] Here, "nomadic devices" refers to smartphones or other hand-held mobile devices. A software solution optimized for a mobile device offering, among other things, real-time information was released to the public in the middle of April 2009.

detail and followed a similar pattern. The travellers rated in general access to real-time information at bus/tram stops as providing maximum benefit (median value ten, on a scale from one to ten, where ten indicated maximum benefit and one indicated no benefit, n=459). No question was asked regarding the travellers' trust in the real-time information at bus/tram stops specifically, but some answers to open ended questions regarding the services indicated that the provided information was not entirely trusted "*[I] do not perceive monitors as trustworthy but [I] still read them*".

Regarding reported effects, between fifteen and forty-eight per cent of the respondents (n=465) reported in 2009 that they experienced:

- less stress (23%),
- shorter perceived waiting time at stop (23%),
- more efficient trips (37%),
- easier to choose route (48%), and/or
- feeling safer (15%)

as a consequence of having access to real-time information at stops. These effects are likely to contribute to that 17% of the respondents (n=465) in 2009 reported to travel more frequently with public transport because of having access to real-time information at stops. This was a significant ($p_{Fisher}<0.01$, $n_{Survey1/Survey2}=228/465$) increase from just below 2% in 1997.

Respondents were also asked about *real-time information on the web*. In 2009 between 8% and 41% of the respondents (n=329) stated they experienced:

- less stress during trip (16%),
- shorter perceived waiting time at stop(30%),
- more efficient trips (41%), and/or
- feeling safer (8%)

as a consequence of having access to web-based travel information. Almost every fifth respondent (19%, n=329) reported in 2009 to travel more with public transport because of having access to web-based real-time information. This was a significant ($p_{Fisher}=0.009$, $n_{Survey1/Survey2}=73/460$) increase from about 2% in 1997.

A statistically significant correlation between Trust (here indicated by rating of how well the respondents agreed with the statement that the communicated information often was erroneous) and experiencing one or more effects was found to be weak ($\rho=-0.155$, $p=0.021$, $n=219$) for public transport web services.

4.1.4 Conclusions

One aim of the study was to determine potential changes in attitudes towards and usage of ICT-mediated traveller information services over time. The results show that the assessments and attitudes towards real-time traveller information and travel planner services had remained positive over time. This indicates that its importance to travellers remained, lasting beyond the first exposures in

which the traveller can be expected to rate such services highly as a consequence of a positive change or an unexpected bonus to the basic service of transport.

Another aim was to investigate the effects on travellers of introducing systems for ICT-mediated traveller information. There was a large increase in the number of respondents who stated to travel more frequently with public transport as a consequence of having access to the public transport web services and the real-time travel information at stops. This might partly be explained by increased access and increased quality of the services. Other reported effects, for example feeling less stressed, decreased waiting times, and more efficient travel, could be assumed to have a positive effect on the perception of the total public transport service and can thus be a potential factor for an increase in use of public transport.

From a technology adoption perspective, the threshold to use real-time information available in displays at bus/tram stops is low – if not non-existing. The threshold to use real-time information and travel planner services on the web can be anticipated to be slightly higher. The results show that computers had been adopted by a large part of the population by the time of the second survey, but there were still those that did not own or used the technology needed for accessing offered services.

4.2 Study B

Study B included a survey carried out during the first nine months after the introduction of a new co-modal travel planner, combining both private and public modes of transport in Stockholm. The introduction of the co-modal travel planner was made in an attempt to influence travellers to find shorter, more energy efficient and cheaper ways to travel in the Stockholm area through increased knowledge and understanding of for example, annual costs and emissions associated with daily commuting trips.

4.2.1 Aim and objectives

The study aimed to create a basis for understanding the potential effects that introduction of a co-modal travel planner has on travellers and travelling. The two key objectives of the study were to investigate

- travellers' assessments of and attitudes towards travel planners in general and the described travel planner in particular; and
- if access to the travel planner resulted in any changes in the travellers' behaviour in terms of, for example, choice of travel mode.

4.2.2 Method

The study was set up as a web-based survey repeated after nine months. Two groups of respondents were included in the study. Respondents from the first group had previously registered an interest to answer questions about travel information systems in the Stockholm region. Respondents from the second group were to be subjected to an office move and were handed an invitation to answer the questionnaire outside their workplace. Those individuals that answered the first questionnaire were sent a second, similar questionnaire after

nine months in order to detect any possible change of behaviour or attitude.

The questions that were asked covered areas such as trust in the information, opinion of the service, perceived benefit, and potential effects on travel behaviour. A slightly modified van der Laan acceptance scale (van der Laan et al., 1997) with nine items assessed on a five-point semantic scale ranging from +2 to -2 was used. Demographic data like gender, age, occupation and distance to workplace/study place was also collected.

4.2.3 Results

Altogether 115 individuals answered the first questionnaire and 71 of those respondents also answered the second questionnaire.

Usage

In order to answer the first questionnaire, the participants had to visit the web site at least once. Less than 40% (n=58) of the respondents had re-visited the web site within the nine month period. More than three out of four (77%, n=22) of those respondents that had returned to the web site reported on the other hand to have visited the site at least once per month over the same period.

Assessment

The travellers' assessment of the planner was initially positive but decreased over time in terms of "value" and "desirability", despite no changes having been made to the planner (n=58, $p_{Wilcoxon}$=0.035). Statistically significant negative changes were also found in the respondents' assessment of the value and desirability of this specific planner (n=34, $p_{Wilcoxon}$=0.007 and $p_{Wilcoxon}$=0.0049 respectively) while no statistically significant change was found for acceptance as defined by the van der Laan scale.

The respondents were asked to what extent they trusted the presented information on Travel times; Emissions; and Costs. Information on Travel times was the least trusted type of information, with about one in ten respondents stating it to be "more or less incorrect" or "completely incorrect" (7%, $n_{Survey1}$=97; 9%, $n_{Survey2}$=22). No statistically significant changes in the respondents' level of trust in the information presented by the planner could be found between the surveys.

Anticipated and reported effects

Both changes to behaviour and changes in assessment of travel experience were found. In the second questionnaire, five per cent (n=58) reported to have felt less stressed as a consequence of having had access to the planner and ten per cent (n=58) claimed that travelling had become more time efficient as a consequence of having had access to the planner.

The reported changes in behaviour were not clearly in line with what could be assumed to be the intent by offering the planner. Nine per cent of the respondents (n=58) reported to have increased their use of public transport but only one (n=1) individual reported to also have travelled less often by car as a

consequence of having access to the travel planner. None of the individuals from the group subjected to a move of their workplace reported to have changed their travel behaviour, despite being part of an explicitly mentioned target group.

Moreover, no correlation could be found between ex-ante anticipated change in travel behaviour and ex-post reported changes in travel behaviour, as a consequence of having access to the travel planner. Neither could attitudes towards the planner be found to correlate with changes in travel behaviour. In addition, neither assessment of the travel planner, nor how valuable the given information was said to be, could be found to correlate to a stated change of travel mode. This is most likely due to the small number of respondents stating a change of travel mode.

4.2.4 Conclusions

The travellers' assessment of the planner was positive but decreased over time in terms of "value" and "desirability", despite no changes having been made to the planner. The relatively rapid negative change in some of the variables in the assessment of the co-modal travel planner could be due to respondents in the first survey having rated the *idea* of a co-modal travel planner rather than the *actual* travel planner itself.

Few travellers reported to have changed travel behaviour as a consequence of having access to the travel planner. An increase in reported use of public transport was noted, but this increase did not seem to be accompanied by a decrease in the use of private cars. Nevertheless, even though a majority of the travellers did not report a change in their travel behaviour, a small minority claimed to have done so as a consequence of having access to the planner. Thus, the study implies that the co-modal travel planner could have an effect on people's travel behaviour. None of the reported cases of increases in use of public transport or private bikes did however at the same time include a decrease in car use. These results are based on a small sample and further long-term studies are needed in order to determine the effects.

The benefit of the service offered by the planner did not seem large enough to motivate revisit. A lack of motivation, or perceived need, to use the service rather than e.g. lack of trust or a negative attitude, could explain the low use of the planner. Motivating usage of an information service, such as a travel planner, is thus a challenge and a reason why a more proactive approach and promotion should be discussed.

4.3 Study C

The previously presented studies focused on public transport or on private and public transport modes. Study C and the subsequent study, Study D, focus instead on changes that long-term access to travel and traffic information services might cause in car drivers. Study C, concerned the long-term effects on travellers of access to travel and traffic information services presented by nomadic in-vehicle devices; specifically mature nomadic in-vehicle solutions for navigation services. This means that the information provided is not only for

the driver during a trip, but can also be used before the decision to drive has been made.

4.3.1 Aim and objectives

The aim of this study was to investigate the influences of long-term access to mature nomadic in-vehicle solutions for navigation services on car drivers. More specifically, the main objectives of the study were to:

- investigate travellers' long-term use and assessments of the benefits of mature nomadic in-vehicle solutions for navigation services;
- investigate factors influencing travellers' long-term assessments of mature nomadic in-vehicle solutions for navigation services; and
- investigate the self-reported effects from long-term access to mature nomadic in-vehicle solutions for navigation services.

4.3.2 Method

Field operational tests (FOTs) were performed over a period of nine months with 582 participants from five EU countries. Three different nomadic in-vehicle solutions for navigation services were tested (see Table 5).

Table 5 Number of participants; Tested systems; Distribution sites; Approximate number of inhabitants in the populated place where the system was distributeds

	n	System	Distribution site	Approximate no. of inhabitants
Greece	148	Sygic Nav sw for Samsung Omnia II (WinMob 6.1)	Athens	3 700 000
Italy	141	BLOM Ndrive Touch XL	Reggio nell'Emilia	170 000
Spain	120	BLOM Ndrive Touch XL	Valladolid	420 000
Sweden	94	Garmin Nüvi 205 WT	Göteborg	950 000
UK	79	BLOM Ndrive Touch XL	Loughborough	60 000

Participants were recruited through advertising. They were instructed to use the services as if they had acquired the system themselves. Paper or online questionnaires, in the participants' native languages, were answered before, during and after the test period. In addition, two focus group interviews were held (in Sweden) in order to generate more in-depth understanding of the questionnaire data.

4.3.3 Results

Usage

The results showed that the frequency of use was in general less than 25% of the total number of trips (reported by 51%, n=455). Several reasons were given for the low usage. Difficulties in using were reported "*I only used it ones, as I had difficulties preparing it before it was possible to use*"; "*I found it difficult to use the device*", as well as deficient system properties "*The device hangs every time it is started and is often unusable. Once one has gotten it started it almost always works. The life length of the battery is extremely short*". The frequency of use was not found to correlate with the number of car trips of the driver. The most common use for the system was in relation to trips where the

route/destination was unknown (reported by 69%, n=395): “I use it to reach unknown places and to leave the known cities”.

Assessments

In general, the users rated their pre-trial reactions to the system as positive or very positive (83%, n=456): This rating was significantly ($p_{Freidman}$<0.0005; n=421) lower in the post-trial questionnaires where 65% rated their reactions to the system positive or very positive. The rating differed however between the test sites ($p_{Kruskal-Wallis}$<0.0005; n=450).

The degree of trust that the participants had in the provided information was in general not found to change during the test period. The information provided by the system was however expected to be trusted by a larger portion of the respondents before testing than who did after: 92% (n=494) of the respondents expected pre-trial to trust the information to a moderate degree, a large degree, or completely. The number of respondents with that level of trust in the information had decreased ($p_{Freidman}$<0.0005; n=209) to 71% in the post-trial questionnaires.

Assessment of the overall benefit from having access to the navigation system was in general not found to change during the test period. The anticipated benefit of access was however higher pre-trial than the assessment of benefit reported after the test period: Overall benefit from having access to the system was, in the pre-trial questionnaires, anticipated to be as “large” or “very large” by a majority (66%, n=577) of the participants. This proportion was significantly ($p_{Freidman}$<0.0005, n=426) lower (45%) in the post-trial questionnaires.

Improved comfort was, next to improved possibilities to choose the optimal route according to preferences, the most reported benefit: *“I drive more relaxed because I know that sooner or later I will arrive.”* Uncertainty was such a comfort related factor: “[The system] *largely takes the uncertainty out of my journeys when they are unfamiliar*“, assurance was another: “*The certainty that the journey will reach its final destination is enhanced, especially in unfamiliar parts of the journey where getting information from any different means is impossible*”; “*The navigator makes the journey more comfortable because the driver besides the opportunity to plan journey routes, can also follow step by step the projected route and view a map of the broader journey area. Observing and controlling the journey as such ensure that the driver (especially in areas that one is not familiar with) is less stressed and has a better chance to ''enjoy'' the journey.*”

Positive assessments of the navigation service might also be explained by the service being perceived as more beneficial than previously known alternatives. Such mechanisms could for example be found in a typical quote by a participant: *“Less time consuming than looking somewhere up on the Internet”.* The opposite could also be found, connecting low assessment of the service to lack of relative advantage: *“I didn't use the device - would rather use a map”.* One participant also noted that “*I know well all the alternative routes and I very*

rarely need any travel advice", which also could explain the generally low use frequency.

Reported effects
Reported effects of having access to navigation support were (n=450)

- improved possibilities to choose the optimal route according to preferences (64%);
- improved comfort while travelling (49%);
- decrease in the time it takes to reach the destination (41%): and
- decrease in the distance covered to reach destinations (30%)

The effects were in general moderate. Less than four per cent of the respondents reported for example a radical decrease in the "Time it takes to reach the destination", and only just over one per cent reported a radical decrease in "The distance covered to reach the destination". No reported effects were found for the "Number of journeys made by car" or "Number of journeys made by public transport".

That comfort was perceived as an important benefit was supported by comfort being the effect showing the strongest correlation with benefit. These increases in "Comfort" and the "Possibilities to choose the optimal route according to preferences" were however, found to be smaller than the participants had anticipated before the test ($p_{Wilcoxon}<0.0005$; n=447).

Only very weak correlation ($p_{Spearman}<0.05$, $|\rho|\geq 0.2$) was found between reported effects and the degree of reported use. The correlation between perceived benefit and effects were for some effects however, stronger than 0.4 with "Comfort while travelling" having strongest correlation ($\rho=0.449$, $p_{Spearman}<0.0005$, n=446). Degree of trust in the information was also found to correlate with effects ($|\rho|$ up to 0.363).

4.3.4 Conclusions
Generally, the navigation service was used for less than 25% of the trips. Furthermore, use was not found to correlate with the overall number of trips made by car. Use was more frequent for trips where the route/destination was unknown. This indicates that the need for this type of services is intermittent. Driving mainly in areas that you are familiar with might make the navigation service less desirable. The low use frequency and the drop in how the participants judged the benefits of access could also be due to low reliability and poor usability. The findings did however show differences suggesting two categories of users: those who create their own use practice with awareness and acceptance of technical flaws and delimitations of the systems and the efforts associated with learning to interact with a less well designed user interface and those who do not, perhaps because of an exaggerated belief in or expectation of technology.

The degree of trust in the provided information was in general high. Such a high degree of trust could well precede disappointment. The expected benefits

and reactions to the systems were more positively assessed before use than after use. This might indicate that the services failed to meet the high expectations of the users.

Reported effects concerned factors related to comfort to a larger degree than to other factors. This supports the notion of the service being seen as a tool for comfort rather than to change travel behaviour in terms of for example, mode choice. Moreover, reported effects were generally minor and not radical in nature, and more closely correlated to personal benefit than what they were correlated with use frequency; or degree of trust in the information provided by the service. Effects were moreover smaller than what participants expected before testing.

Participants expected to experience, and also reported, comfort from access to the navigation service. An increase in perceived comfort might however, have a negative impact on the overall transport system if it increases car use or delays changes to safer, more energy efficient, and less spatially demanding modes of transport than the private car. No changes in number of trips made by public transport or number of trips made by car were found.

Navigational service should possibly be regarded primarily as a tool for increased comfort, and expectations of radical changes in behaviour from access to navigational services might be misdirected.

4.4 Study D

Study D investigated the effects of access to mature nomadic in-vehicle solutions for traffic information services. The offered services were, in two cases, available in devices similar to those described in Study C. Three out of the four tested traffic information services were mediated by smart phones.

4.4.1 Aim

The aim of this study was similar to the aim of Study C. The studied services differed however and the aim of this study was thus to investigate the effects on car drivers of long-term access to mature nomadic in-vehicle solutions for traffic information. The main objectives of the study were to:

- investigate travellers' long-term use and assessments of the benefits of mature nomadic in-vehicle solutions for traffic information services;
- investigate factors influencing travellers' long-term assessments of mature nomadic in-vehicle solutions for traffic information services; and
- investigate the self-reported effects from long-term access to mature nomadic in-vehicle solutions for traffic information services.

4.4.2 Method

Field operational tests (FOT) were performed with 510 participants from four test sites in three EU countries (see Table 6). The FOTs lasted nine months with a baseline period of three months. Four different mature nomadic in-vehicle solutions for traffic information services were tested (see Table 6).

Table 6 Number of participants per test site and short descriptions of systems and distribution sites

Test site	n	System	Information source	Main distribution point(s)
Finland	110	Logica LATIS sw for Symbian phones	Mediamobile Nordic	Tampere, Finland
Greece	88	Sygic Nav sw for Samsung Omnia II (WinMob 6.1)	Traffic Management Center of Athens	Athens, Greece
Sweden 4	218	Trelocity sw for Android phones	Trelocity: Crowd-sourcing/Stockholm Taxi	Online, Sweden
Sweden 2	94	Garmin Nüvi 205 WT	Swedish Transport Administration	Gothenburg, Sweden

Participants were recruited through advertising in local media. They were instructed to use the services as if they had acquired the system themselves. Paper or online questionnaires, in the participants' native languages, were answered before, during and after the test period. Statements on expectations on the effects of the system that the participants were going to test were collected before actual use, but after the respondents had been introduced to the system.

4.4.3 Results

Usage

In general, the tested systems were used for less than 25% of the total number of car journeys (reported by 54%, n=250). The use frequency of use was not found to change over time. The frequency of use differed however, between test sites. Participants from the test site in the largest populated area (Athens, Greece) used the system to a larger extent than participants from other test sites: 38% of the Greek participants (n=74) had used the system for more than 75% of the journeys, compared to an average of 19% for the total number of participants (n=250).

The way that the service was used also differed and while some respondents reported to always have had the traffic information turned on, another stated that "*My experience is that the most effective way to avoid congestion is to identify the problem before the trip started and already then plan when or how the trip will be implemented. Once in the car, and maybe even in the queue, it is a bit late*". The most common answer to what type of journey that the service had been used for was "No particular type of journey" (44%, n=216), i.e. the service had been used for all kinds of journeys.

Assessments

Assessments of the service were in general positive during the entire test period. Generally, users rated their pre-trial reactions to the system as positive

or very positive (73%, n=495). The assessments of the service were however significantly ($p_{Freidman}$<0.0005, n=211) lower (49%, n=249) in the post-trial questionnaires. This could in some cases be explained by low level of trust. Whereas 32% (n=247) reported post-trial to have trusted the information to a large extent or completely, 30% (n=247) reported to have trusted the provided traffic information to a small degree or not at all. The level of trust in the provided traffic information did not change during the test period. The reasons for not trusting the information was that the participants felt that the information provided was not correct and/or not updated: "*Incorrect, incomplete and irrelevant information. Maybe I did not understand how to make use of the whole capacity but in that case the instructions were really poor*" and "*Many times there was no information provided regarding roads that were closed for infrastructure maintenance purposes."*

Access to the traffic information system was, in the pre-trial questionnaires, anticipated to provide large to very large benefits by a majority (51%, n=494) of the participants. This proportion was significantly ($p_{Freidman}$<0.0005, n=209) lower (30%, n=247) in the post-trial questionnaires. The benefits were primarily associated with convenience (51%, n=218), comfort (53%, n=218) and safety (39%, n=218) but the assessment of benefits differed between the test sites. The Greek and Swedish participants were considerably more positive than the Finnish participants, a difference that can be partly attributed the differences in traffic situation. One of the Finnish participants noted: "*I have […] no personal need. Oulu has no traffic or jams and so the service has no benefits to offer*". The lack of perceived alternatives was also a delimiting factor: "*I have not used the function. Do not have the opportunity to change much of my everyday journeys*" and several participants suggested that adding information about alternative travel options to the service: "*Useful and well communicated information regarding alternative routes on the map would be of value*".

Reported effects

The reported effects that were found were predominantly rated as moderate, and not radical. The statements where the largest portion of respondents (n=240) reported a change were

- increase in the "Possibilities to choose the optimal route according to preferences" (49%);
- decrease in "You getting stuck in traffic jams" (41%);
- increase in "Comfort when travelling" (33%); and
- decrease in "The time it takes to reach destinations" (33%).

The benefit of increased comfort was especially frequent in comments by the participants. Increased comfort was stated as a consequence of experiencing "*Less frustration and less stress*" through the possibility to avoid traffic jams.

Reported effects varied between the test sites. Participants from the Greek test site reported for example, an effect more often than participants from other

test sites in regard to effects deemed central to traffic information, such as "Your delays when travelling" and "Stress associated with traveling".

In general, effects were smaller than the participants had anticipated in the pre-trial questionnaires.

The effects of access to the service were found to correlate ($p_{Spearman}<0.05$, $|\rho|\geq 0.2$) with the level of trust that the participants had in the information, as well as the frequency of use of the service. The correlation between benefit and effects showed however, the strongest correlation. The correlation between assessments of "Possibilities to choose optimal route" and benefit was 0.494 (n=240); and between "Comfort when travelling" and benefit 0.443 (n=240). Spearman correlation between "Trust in information provided" and the assessments of benefit was found to be 0.637 (n=247).

Effects related to behavioural changes were in general reported by a smaller number of respondents than, for instance, changes in assessment of the travel experience (such as comfort). The most common reported behavioural changes were (n=240)

- increase in "Compliance with speed regulations" (19%); and
- increase in "Use of rural roads" (8%).

Changes in the mode of travel were even less commonly reported than changes in travel experience. Equally many respondents reported an increased number of journeys made by public transport as reported a decrease (3%, n=240). A slight increase of 2.5% was similarly reported for the number of journeys made by car, while a decrease was reported at 1% (n=240). A potential reason for the limited signs of modal shift from car to public transport could be illustrated by a quote from a participant *"I would drive less if the public transportation would be improved".*

4.4.4 Conclusions

The traffic information services were, in general, used for less than 25% of the trips. In general, use of the traffic services was not concentrated to a specific type of trip. This differs from the usage of navigation services presented in Study C. Usage for all kinds of trips could indicate a higher frequency of use which could be expected to render larger effects. However, use frequency was found to be more weakly correlated with effects than what benefit with effects. This indicates that an individual perception of a benefit is more important than general use is for achieving effects.

Reported benefits were larger in more densely populated areas. This could be due to the frequency of traffic disruptions (a factor constraining the actual action space) and/or that the number of alternative route options (the perceived action space) is higher in more densely populated areas, offering larger number of occasions to act on provided information. Several respondents expressed a demand for information about alternative travel options.

The traffic information services tested were found to generate changes in assessments of the travel experience. The most common effects were the increase in “Possibilities to choose the optimal route” and an increased feeling of Comfort. This indicates that access to this type of service supports rather than changes established travel behaviour. Increased comfort when using a transport mode could indeed be expected to lead to an increased use of that transport mode. The increase in comfort was, in the case of traffic information however, not accompanied by an increase in the number of trips by car. On the other hand the participants already used their car to a high extent and for almost all trips.

5 Discussion and conclusions

The effects of access to ICTIS will here first be briefly presented and commented. This will be followed by a thorough discussion of the results presented in the previous chapter of this thesis.

Use is a prerequisite for effects and (voluntary) use is dependent on that the user, i.e. the traveller, perceives access to a service offers as beneficial. Perceived benefit can only be assessed by the user. The users' assessments are thus important for understanding the reasons for use, as well as for understanding the effects.

The effects that were found from travellers being given access to ICTIS can be categorised into two main types: Changes in behaviour, and changes in assessments.

5.1 Assessments

In this thesis, the changes in assessments that were found have been categorised as belonging to either (i) changes in assessment of the tested information services, or (ii) changes in assessments of travel experience that were brought about by access to the information services.

Access to the tested services was in general positively assessed. Differences in assessments of benefit *before and after access* were found for several of the tested services. Early access and use were in general found to be accompanied by a drop in assessment of the investigated service (Studies B, C, D). There is no corresponding data available for the services investigated in Study A. That the expected benefit or value was higher before actual access to, and use of, the services could indicate optimism regarding the benefits that new technology may bring to solve transport-related challenges, an optimism that corresponds to that expressed by large societal institutions. The fact that expectations were relatively high could be also be related to the context of exposure. The services in Study B, C, and D were in all cases introduced to the users by university staff as part of a particular test or trial, something that might have raised expectations well beyond state-of-the-art whereas at least for studies C and D the aim was to evaluate mature systems.

A statistically significant change in the assessments of benefit *during access* was only found for one of the investigated services. The change, an increase in reported benefit of access to real-time passenger information in public transport, was found in the study with the longest access period, i.e. Study A. For studies B, C, and D the assessments remained more or less the same over time, i.e. nine months. It is thus possible that changes in assessments of the benefit of the services are slow, or that such changes are arbitrary. The fact that an increase in assessment was found only in the study with the longest access period could thus indicate that the adoption process, through which the users incorporate the services into their lives, takes considerably longer than nine months. Other reasons for the increase in perceived benefit could be that the

services investigated in Study A were improved in terms of accessibility and/or in service quality, for instance information reliability. Study A was accomplished in Gothenburg, Sweden, and for instance the dissemination of real-time information at stops had increased significantly between the time of distribution of the first survey and the second survey, exposing a larger number of travellers to potential benefits. Corresponding improvements were not made to the systems investigated in Study B, C, and D.

Effects from access to ICTIS can also relate to how the individual experiences travelling. Such effects were in all studies found for a sample of the respondents/participants. Several positive changes were for instance found in the participants' assessments of travel experience as a consequence of having access to the tested ICTIS. The changes were all in what could be assumed to be the intended direction(s). Changes relating to comfort were more commonly reported than changes relating for instance to time efficiency. Examples of such comfort-related changes included decreased feeling of stress through reduced uncertainty; increased level of control; shorter (perceived) waiting times at bus/tram stops; and increased feeling of security.

That the travellers perceived access to ICTIS to cause shorter waiting times, less stress, and to make them feel safer is supported by findings in short term studies on public transport (e.g. Sekara et al., 1997; Sane et al., 1999). The results indicated that these effects not only remain, but that they are strengthened over time. That effects relating to comfort, and not travel mode choice, are central to travellers is for example supported by the synthesis by Schweiger (2003) on the benefits from deploying real-time bus arrival systems reported by public transport operators and authorities. The synthesis presented that the most commonly reported effects were improved customer service and satisfaction, but increased ridership was however rarely reported.

5.2 Behaviour

Another type of effect from access to ICTS is the type that is related to travel behaviour. The influence that access to ICTIS has on traveller behaviour can be described as either (i) preserving (reinforcing) behaviour or (ii) changing behaviour.

The role of ICTIS in *preserving* (reinforcing) behaviour could potentially be implemented by decreasing the demand for change through improvements in assessment of the current travel behaviour. Such improvements could be expected as a consequence of factors such as increased comfort, reduced uncertainty, and decreased stress associated with travelling. These kinds of effects were found for all the investigated services, which means that preservation of travel behaviour could be a consequence of having access to the services. Also the multimodal travel planner (Study B), with an explicit intention of facilitating travel mode change was found to increase the participants' use of already chosen modes of transport.

The role of ICTIS in *changing* behaviour could on the other hand potentially be implemented by decreasing travellers' resistance to change and in this way

increasing the probability of altering travel behaviour. Such a decrease in resistance to change could be expected through improvement of factors similar to those that increase the assessment of current travel behaviour: through reduced uncertainty and decreased stress associated with travelling. Real-time information in public transport, investigated in Study A, was for instance found to decrease stress through reduced uncertainty. Increased knowledge about alternative travel modes has been proposed to be of importance in decreasing travellers' resistance to change. It could be argued that these factors were targeted by the travel information services in Study A and the co-modal travel planner in Study B. Only very limited behavioural changes in terms of mode of transport could however be found in the studies.

5.2.1 Documented behavioural changes

Societal objectives for introducing ICTIS have ultimately been related to behavioural change, more specifically in terms of travel behaviour. If one considers society as an activity system including subject, tool, objective, and outcome, expectations on outcomes from using ICTIS can be illustrated as in Figure 5-1.

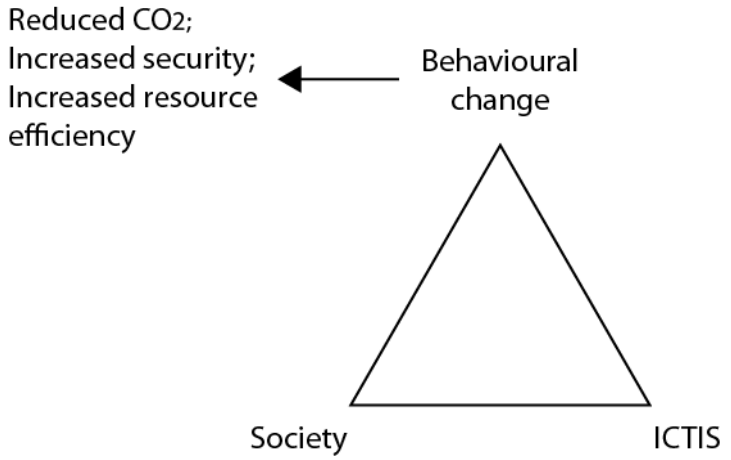

Figure 5-1 Activity system of society with behavioural change as objective for use of ICTIS, and including examples of expected outcomes.

A potential consequence of travellers having access to ICTIS, which would support the idea of ICTIS being part of the solution to transport-related problems, is that of travellers changing their mode of travel to less energy-demanding, safer, and less spatially-demanding modes of transport. Expectations that access to information and ICTIS may cause changes in use of travel modes have been expressed by several institutions (e.g. Commission of the European Communities, 2001; European Parliament, 2010; The Institution of Engineering and Technology, 2011; European Commission, 2011b; Swedish Government, 2013). Support for such expectations has been presented in pre-implementation studies (e.g. Harris & Konheim, 1995; Neuherz et al., 2000) where findings show that travellers believe that they will for instance change travel routes as a consequence of access to information and ICTIS. A change of travel mode expected to have a positive impact on the overall transport system efficiency could for example be a change from car use to use of public transport. Seventeen per cent of the respondents in Study A claimed to travel more by public transport as a consequence of having access to the real-time

information at stops and there was a large (more than 25 per cent units) increase in the share of respondents who often or sometimes travelled by public transport. However, increased use of one mode of travel does however not necessarily entail a decrease in use of other travel modes. Data on decrease in car use as a consequence of access to ICTIS was not possible to be extracted from Study A, and was not found in any of the Studies B, C or D. *Access to ICTIS was thus not found to render changes in choice of travel mode.* The same conclusion was reached in an investigation by Kenyon and Lyons (2003) of the potential of access to a co-modal travel planner, where results suggested that information played a minor role in modal choice. Also a literature review by Dziekan and Kottenhoff (2005) of studies on public transport-related information services concluded that the impact on modal split should not be overestimated. That access to in-vehicle support systems does not affect travel mode choice is supported by for example by Franken (2007). The survey-based study by Franken (ibid.) found that the effects of access were primarily related to route choice and scheduling, and concluded that access to navigation had negligible influence on travel mode choice. Lyons (2006) moreover stated that substantial changes to travellers' mode choice from access to information services would in general be unlikely. The results from the studies presented here have rendered further support for the notion that ICTIS does not (at least in itself) prompt travel mode change which implies that policy expectations might need to be lowered regarding modal shift as a consequence of access to ICTIS, a notion that is supported by for instance Chorus et al. (2006b; 2006c) as well as Farag and Lyons (2010).

The behavioural changes that were found and their consequences did instead primarily affect the specific transport mode targeted by each investigated service (see Table 7).

Table 7 Examples of behavioural changes found as a consequence to access to studied ICTIS

	Effects of behavioural changes
Real-time at stops	Increased public transport use
Online public transport travel information	Increased public transport use
Co-modal travel planner	More travelling*
Navigation service	Increased compliance with speed regulations; Shorter distance covered; Lowered fuel consumption; Increased use of rural roads
Traffic information	Increased compliance with speed regulations; Lowered fuel consumption; Increased use of rural roads

* Respondents reported to travel more often by public transport, car, and bicycle as a consequence of having access to the co-modal travel.

Real-time information for public transport was, for example, reported to increase public transport travellers' use of public transport in Study A, and the co-modal travel planner in Study B was reported to increase the use of several modes of transport. The results regarding increased use of public transport as a consequence of having access to ICTIS are in line with previous studies by sources such as Infopolis (1998).

Neither increase or decrease in the travellers' use of their car, matching to the changes that were found in mode use in Study A and Study B, could however be found in Studies C or D. At the same time, the car was already used for a major part of the participants' travels.

Other types of behavioural changes than mode shift were however found. Participants in both Study C and Study D reported for example an increase in compliance with speed regulations. The decrease in distance covered to reach destination that also was found in both Study C and Study D indicates changes in chosen routes. Such changes are likely to be the origin of other findings in those same studies. Decreased fuel consumption and change of type of road was for instance reported in both Study C and D.

5.2.2 Magnitude of change

Whether or not access to ICTIS will be relevant as a partial solution to transport challenges depends not only on changes in behaviour but also on the magnitude of these behavioural changes. Behavioural changes can be divided into two main categories: (i) changes limited to moderate adjustments of existing travel behaviour; and (ii) changes intended to enable or include withdrawal from, or change of, main transport mode use. Changes limited to moderate adjustment could for example include changes in chosen route, and adjustments in the choice of transport modes to an extent that do not alter the transport mode that would be considered as the main alternative. No changes in what could be considered that traveller's main transport mode were reported. Not even in the study (Study B) that included exposing an intended target group (travellers about to break their travel pattern) to a service intended to facilitate mode change, a co-modal travel planner, was change of main travel mode reported.

The changes that were reported in travel behaviour were most often characterised as "slight" and less often as "radical". For example, only slightly more than one per cent ($n_{C/D}$=450/240) of the respondents in Studies C and D experienced a radical change in the most fundamental effects of having access to navigator service and traffic information services, i.e. the distance covered to reach destination and the time it takes to reach destination respectively. These results are thus in line with other results, indicating the limitation of access to ICTIS as part of the solution of transport-related problems on a system level (c.f. Lyons, 2006).

The investigated ICTIS were not found to have created large enough effects to support the notion that ICTIS will be a factor with potential to fundamentally change the way people travel.

5.3 Understanding the effects

Several factors such as setup, context, and devices differed between the studies, which may make direct comparisons between the results difficult. However, all the studies included travellers and ICTIS and the focus has been on the individual's – the travellers' – assessments of these ICTIS. In Section 5.1 and Section 5.2, users' assessments and reported effects have been approached as

assessments and effects of access to ICTIS in general. This approach highlights similarities in the results between the studies. The differences between the studied services, and the results from the studies are not less important and will be discussed in more detail in this section. The framework (see Section 2) points to factors that potentially explain similarities and differences in the data. The relevance and impact of these factors will be discussed in the following paragraphs.

5.3.1 Positions and possibilities

Individuals can be regarded as decision-makers in the transport hierarchy. This was described in Section 2.2.1 and is illustrated in Figure 5-2.

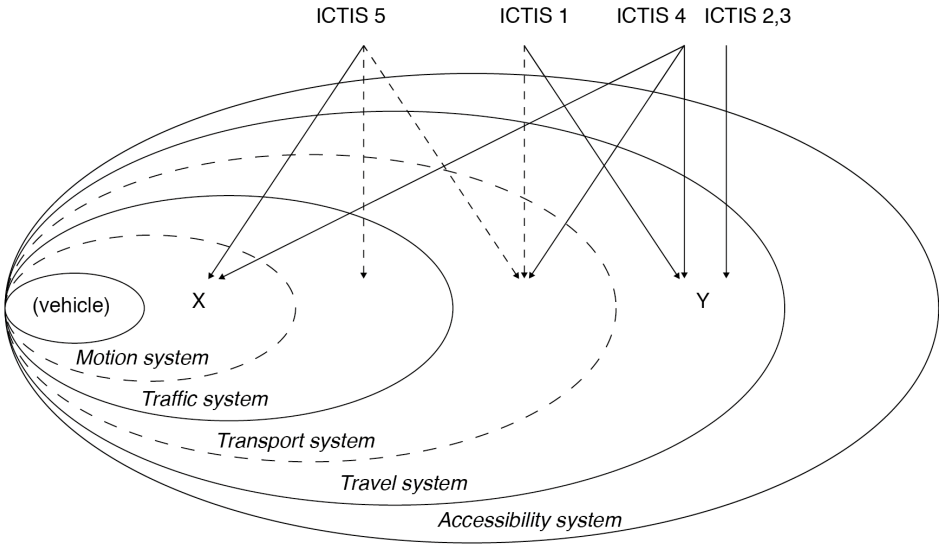

Figure 5-2 Illustration intending to facilitate analysis of perspectives and/or possible actions of individuals X and Y positioned in the transport hierarchy.

Seeing travellers as decision-makers in the transport hierarchy has the potential to highlight

- time perspectives of possible decisions; and
- differences in the set of possible actions that could be performed as a result of a decision for an individual at a specific point of time.

5.3.1.1 Time

Time seemed to be a factor influencing the effects of access to ICTIS.

The respondents (travellers) in the different studies used ICTIS to make decisions on potential actions. However, the possibilities for acting on information depend not only on the design of the transport system and the ICTIS, but also on where in the transport hierarchy the traveller is positioned. The time perspective of the transport hierarchy (Figure 5-3) offers a potential basis for interpreting the influence that information has on the traveller.

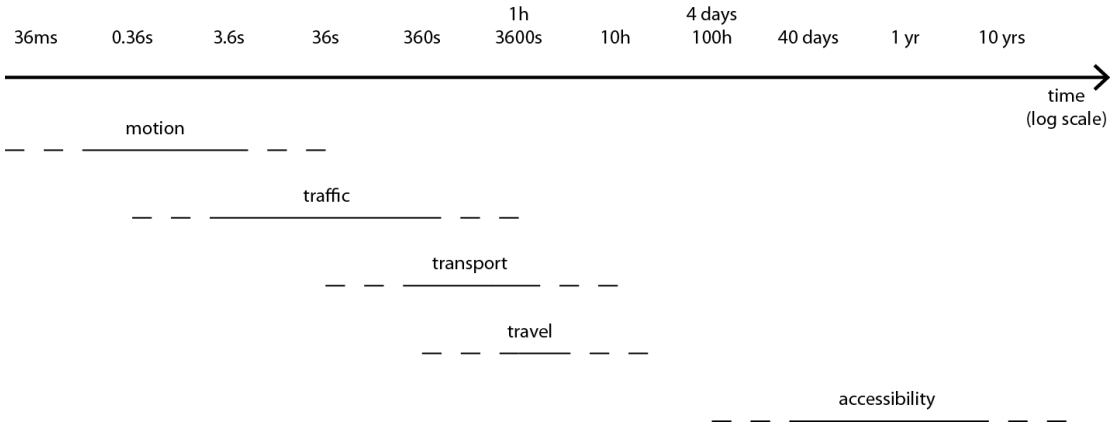

Figure 5-3 Time horizons of the functional levels in the conceptual model (Franzén, 1999)

Access to information that cannot be acted upon in the present situation (i.e. in the traveller's current position in the transport hierarchy) was found to be regarded as less beneficial to the traveller than information that could be acted upon right away. Those ICTIS that offered travel information which was expected to be acted upon in the immediate future, i.e. real-time information at public transport stops in Study A and, to some extent, nomadic in-vehicle device mediated navigation services in Study C, were in general more highly appreciated and seemed to render more behavioural changes than ICTIS offering travel information expected to be acted upon in a longer time perspective, i.e. the co-modal travel planner in Study B (indicated as ICTIS 1 in Figure 5-2). Developing on this issue, the web-based co-modal travel planner (indicated as ICTIS 1 in Figure 5-2) was for example not intended to offer information to be acted upon by a traveller positioned in the motion system (indicated as X in Figure 5-2) and rendered less behavioural changes than did ICTIS 4 and ICTIS 5 intended to offer information to be acted upon by a traveller at a position in the travel system (indicated as Y in Figure 5-2). The type of information needed, the appropriate media, as well as the benefit of the specific ICTIS application, thus differ depending on the position that an individual has in the transport hierarchy.

These differences in time horizons could also partly explain the differences in reported effects of access to ICTIS. Beliefs that ICTIS can radically influence travel behaviour is based on an underlying assumption that ICTIS intended for use in short-term also has the potential to affect travellers' longer-term decisions, i.e. that information tailored to be acted upon when a traveller is in the traffic system also affects that traveller when on the accessibility level enabling more radical decisions than those possible on the lower level. This assumption does not find support in the studies presented here for reasons further developed in the following sections.

Another way to illustrate the differences in time perspectives of the various ICTIS could be by positioning them in a hierarchy of the functional characteristics of control levels. A suggestion of how this might be presented is found in Table 8 below where the intended uses of the ICTIS are placed into the simplified description of the ECOM layers (proposed by Engström and Hollnagel (2007) found in Table 1). High-frequency types of control, as in

Compensatory and Anticipatory control (while driving) are rare with the type of information services that have been studied here.

Table 8 Description of functional characteristics of layers similar to ECOM layers described by Engström and Hollnagel (2007) applied to driver support functions. The columns describing 'Demands of attention' and 'Typical duration' have been removed, as they have been deemed irrelevant for non-safety critical systems. The control level 'Defining' and the columns 'Time in relation to trip' and 'Example of investigated service' have been added.

Control level	Type of control involved	Example of investigated service	Frequency of occurrence	Time in relation to trip
Defining	Deciding on factors related to future transport needs (e.g. choosing geographic position for settlement)*	6	Extremely low (<once/year)	Before trip
Targeting	Goal setting (incl. mode choice)	1,2,3,4,5,6	Low (mostly pre-trip, < 10/day)	Before and during
Monitoring	Condition monitoring	1,2,5	Intermittent (traffic, fuel economy)	During
Regulating	Anticipatory			
Tracking	Compensatory			

* Could be described as goal setting outside of, but relating to, transport system

1. Real-time public transport information on information boards
2. Web-based real-time public transport information on nomadic device
3. Web-based public transport travel planner
4. Nomadic device in-vehicle navigation support
5. Nomadic device in-vehicle traffic information support
6. Web-based co-modal travel planner

Services relating to control levels of monitoring were used during a trip and use occurred intermittently. The co-modal travel planner (Study B) was the only service intended exclusively for use before the trip and use frequency was generally found to be very low. In fact, most respondents had not used it since its introduction. Moreover, the co-modal travel planner was intended to affect travellers even when they were outside the transport system. The level and type of control affected therefore needed to be positioned on an added control level, here named "Defining", placed above the control level Defining (Table 8). The type of control involved on this level could have a longer time frame with decisions taken less than once a year.

The rhetoric surrounding transport telematics solutions often include arguments that ICT-mediated information services, in general, will lead to changes in people's choice of means of transport. Positioning the systems in the transport hierarchy (Figure 5-2) and in the hierarchy of functional layers (Table 8) was done in order to elucidate differences and help develop reasonable expectations for the direct and secondary effects associated with the use of information and communication technologies (ICT) in the transport sector. The use of terms like Intelligent Transport System, or ICT mediated traveller information service, must become more nuanced, and take into these consideration fundamental differences between telematics solutions. There are

services, such as the travel information services in Study A and the multimodal travel planner in Study B, that have been designed with the intention to target (also) a level where decisions are taken on whether to undertake the trip in the first place and if so, by what means of transport. Such information services could possibly lead to important changes. People act, however, in most situations according to their habitual behaviour (e.g. Verplanken et al., 1997). Habitual behaviour is performed without much reasoning or deliberation (ibid.) and according to for instance Kenyon and Lyons (2003) modal choice is rarely the result of reasoned action even when a new and/or unknown journey is to be undertaken. If the traveller does not weigh the pros and cons of different modal choices, the information will not be effective, not even if it points to alternative modes of travel. Such information will in most cases probably not even be consulted. There are also services, such as traffic information (Study D) and navigation support (Study C), that are primarily designed to support drivers in Targeting (e.g. trip planning, route choice) and Monitoring (e.g. turn decisions) components of the overall driving task. These services were predominantly found to offer comfort and assurance (Study C and Study D) but not to influence mode choice. Systems for 'lower' levels, for Regulating and for Tracking, also exist. These systems support the driver's control of the vehicle and have not been included in this thesis but must nevertheless also be considered in terms of time perspectives and possibilities to act.

This is not to say that different ICTIS on different levels cannot contribute in different ways to reaching societal goals of more sustainable transport. As an example of 'lower' level ICTIS, green driving support systems have been found to reduce fuel consumption by around five to eight per cent (van der Voort et al., 2001; Boriboomsomsin et al., 2010). As an example of a 'higher' level system, the navigation support system (Study C) resulted in increased opportunities to choose optimal routes including shortest and quickest which can be described as a more efficient use of existing infrastructure. However, it seems unlikely that access to ICTIS would in itself generate changes large enough to meet the expectations of more radical behavioural change expressed by the US Department of Transport (2010), and the European Commission (2011b), as well as the Swedish Government (2013).

5.3.1.2 Action space

It was argued in Section 2.3.1 that a choice, and consequently a shift, of transport mode is linked to the opportunities available to the traveller. It is the set of actions in the overlap between the perceived action space, which can be influenced with ICTIS, and the actual action space, which cannot be affected with ICTIS, that enables decisions that may lead to desired outcomes (c.f. Figure 5-4).

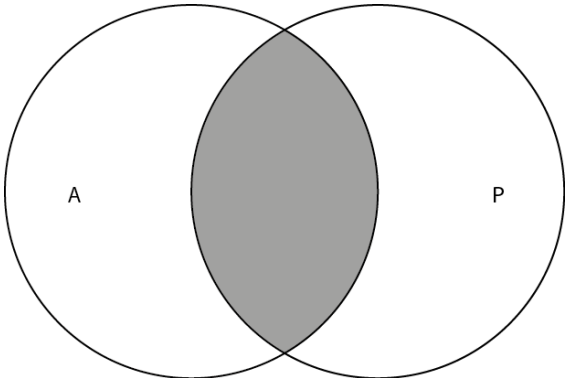

Figure 5-4 Overlap of perceived and actual action space enables decisions that may lead to desired outcomes

ICTIS may change the perceived action space of the individual if it contributes to the traveller gaining more knowledge about the actual space provided that there is a fit between the actual space (e.g. the transport service) and the needs and preferences of the individual. The information provided by the travel information services in Study A, and the navigation support systems in Study C, could be claimed to have contributed to a larger action space in that it allowed the participants to, for instance travel to unfamiliar destinations in a more efficient way. In the case of the travel information services (Study A), the reported result was an increased use of public transport. Also the traffic information services in Study D contributed to a larger action space through offering alternative routes in case of traffic disturbances. The result was that drivers were given opportunities that previously had not existed to them. The shift in perceived action space is, thus, most likely to be limited to the respective spheres or levels (described in Figure 5-2 and in Table 8) that is targeted by the respective information system. It should therefore not be expected that an ICT-mediated traveller information service intended to be used for actions within a certain time frame, or for a specific purpose, will affect actions with other time perspectives, or decisions on other levels in the transport hierarchy.

More knowledge about the actual action space can however also reduce the perceived action space if there is a mismatch between what is characteristics if the space (e.g. the transport service) the needs and preferences of the individual. This is supported by findings in the studies. Several respondents claimed for instance that they would not travel more with public transport as a consequence of having access to the tested ICTIS, as public transport did not offer a sufficient level of service.

The findings thus indicate that ICTIS does not compensate for what is perceived to be an inadequate transport system but rather that ICTIS complements already acceptable transport systems. This is in line with the findings by for instance Lyons et al. (2008) who have claimed that changes to the relative attractiveness of different modes through changes to the transport system per se are more influential than improvements of ICT-mediated traveller information systems.

5.3.2 Perceived benefit and use

Use can be considered a prerequisite for effects of access to ICTIS. According to the studies, and supported by for instance Rogers (2003) and his theory of Diffusion of Innovation, assumed and experienced benefit of an ICTIS is in turn a prerequisite for voluntary use. Further investigations into the potential benefits of access to ICTIS and into the objective for use of ICTIS can therefore increase understanding of the results

Returning to the issue of time (cf. Section 5.3.1.1) the time required for users to incorporate a new technology or service into their everyday lives, depends according to Rogers (2003) on the degree of benefit that the individual perceives the service as providing. The higher the perceived benefit, the more rapid the dissemination. Benefit of access to the ICTIS investigated in Study A was assessed high (and also remained high over time), why it is feasible to assume that the adoption of the services were rapid when they were first introduced. In this case, there is no available data that can confirm or reject the assumption. In Study B the assessment of benefit was lower (and became even lower over time), why a slow(er) adoption rate could be anticipated. In this case, the respondents' stated usage of the multimodal travel planner suggest that this was indeed the case. Even if this holds true, the concept of adoption as well as a straightforward comparison would in these cases be somewhat problematic due to other aspects of time (cf. Section 5.3.1.1). In Study C and Study D, a majority of the participants initially assessed the benefits of access to traffic information and navigation support systems as 'moderate' to 'large', which would indicate a fairly high adoption rate. The systems were however in most cases used for fewer than one in every four trips and the use frequency did not increase over time. Frequency of use might thus be questioned as an indicator of adoption in the case of ICTIS.

Data on frequency of use, degree of behavioural change, and assessment of benefit were collected in the four studies. In several of the studied services, assessment of benefit was found to be more closely correlated to degree of changes in behaviour than what, for example, use frequency was correlated to degree of change in behaviour:

A higher frequency of use affected assessments and the degree of behavioural change in some cases, but not in others. In Study C for example, the correlations between use frequency and the magnitude of behavioural changes were all found to be below 0.2, while correlation between use frequency and reduction in fuel consumption in Study D was 0.4. A high frequency of use should therefore not be regarded as a key prerequisite for effects of access to all types of ICTIS. With reference to the earlier described differences between the systems (Table 8), an ICTIS with a low use frequency could describe an 'adopted' system and be perceived to provide substantial benefits. According to Lyons (2006) only a minority of trips actually generate a demand for information.

Perceived benefit was moreover in general more closely correlated with stated effects than was trust in the provided information. This indicates that benefit

could be attained even though the provided information is not completely trusted. This could for example be possible if an ICTIS offers information that is perceived as complementary to other types of information, as assurance and not something on which the user is dependent. The benefit of access to public transport real-time traveller information at stops was for example top-rated (median value ten out of ten, "maximum benefit") despite not being entirely trusted.

Benefit assessment is affected by several factors. The Diffusion of Innovation Theory, as described by Rogers (2003), declares that an innovation (i.e. an ICTIS) offers benefits if the service is perceived as better than previously known alternatives. Examples of the relativeness of benefit are the respondent stating the navigator service is *"Less time consuming than looking somewhere up on the Internet"*. However, the participants' comments also show that benefit differs between individuals; another respondent for instance indicated the benefit of the same service to be smaller than previously known alternatives: *"I didn't use the device - would rather use a map"*. Use is in this way less likely if travellers assess an ICTIS as offering small benefit. Perceived benefit can in this way be argued to reflect the potential of ICTIS.

The Diffusion of Innovation Theory (Rogers, 2003) further states that perceived complexity is a factor influencing adoption. This is also supported by the Technology Acceptance Model (Davis, 1989; Venkatesh et al., 2003; Veknatesh & Bala, 2008), which emphasises the perceived ease of use of technology as an important determinant of use – even if a number of other, individual factors, have been added to later modifications of the model, such as the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al. 2003). Caulfield and O'Mahony (2007) found that travellers' stated preference of media tended to be those media that demand little effort. However, in Study D, low effort was not found to be a decisive factor for how the benefit of an ICTIS was assessed. For instance, despite being automatically delivered on nomadic devices and thus attainable through limited effort, traffic information (in Figure 5-2 indicated by ICTIS 5) was sometimes perceived as less beneficial due to lack of travel alternatives. Although the amount of effort needed to acquire information might be important to the traveller, the usefulness or the level of benefit from access to the ICTIS seems to be more important.

5.3.3 Goals and mediating tools

From an Activity Theory perspective travellers use ICTIS for a purpose, in order to reach a goal. This defines the mediating role of the ICTIS. In the case of the ICTIS investigated here, the motives for using the systems could be described as to avoid waiting at the bus stop (real-time information), avoid traffic jams (traffic information) or to choose the right, not the wrong route (navigation support) but in most cases probably not to find out about the possibilities for shifting from car to public transport. Even if the ICTIS provides information on alternatives, the effect would be limited as the information does not match the goals of the individual. If the goal for using ICTIS, on the other hand, is that of a shift of mode of transport, the ICTIS must provide

information that allows the user to reach that goal. A navigation support will not support such a shift, whereas a multimodal travel planner might.

The purpose could also be described as that of solving a problem that the traveller perceives to have in relation to the trip to be undertaken, by the mode of transport already chosen. If the ICTIS helps solve the problem, ICTIS would contribute to an increased use of that mode of transport, rather than a reduction. The results (exemplified for example in Table 7) indicated that the outcome of travellers having access to ICTIS was increased use of already chosen travel modes. On the other hand, if the ICTIS provided information that emphasized the problem, for instance congestion and traffic jams, the outcome could be could be (if supported by other information), in the long-term, increased awareness leading to a modal shift but it is perhaps more likely that the ICTIS would not be used as no immediate solutions were provided.

The activity system of the traveller, examples of travellers' objectives, and the outcome of the travellers' use of ICTIS could be illustrated as in Figure 5-5. Considering the mediating role of information, the motive or objective for using ICTIS become a key issue in understanding the role of ICTIS in transportation.

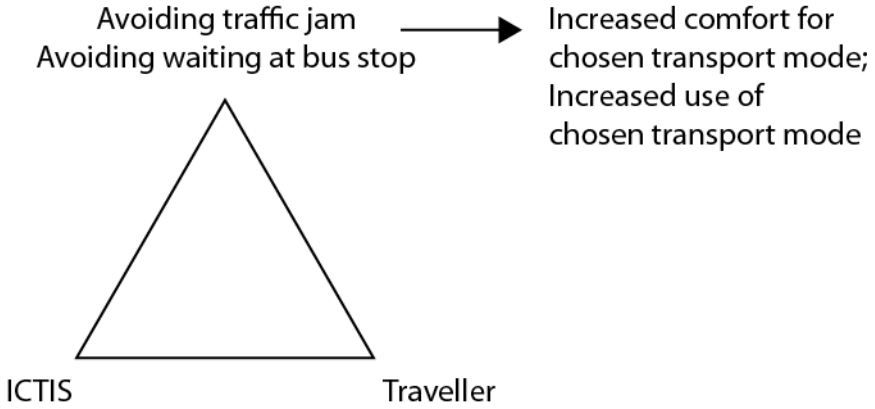

Figure 5-5 Activity system of traveller with Avoiding traffic jam and Avoiding waiting at bus stop as two examples of objectives for use of ICTIS, and increased comfort and use of chosen transport mode as outcome.

Activity theory (see Section 2.2.3) emphasises the connection between the user, i.e. the traveller; the objective of the user; and the tool, i.e. in this case the ICTIS. Benefit can in this way be understood to emerge when the tool, i.e. the ICTIS, supports the individual traveller in reaching his/her objective. Objectives of different actors can be the same, can overlap, but may also differ. The difference in objectives, towards which an ICTIS application is used as a mediating tool, can in overlapping activity systems be illustrated as in Figure 5-6. ICTIS is a tool for society to reach certain objectives with certain outcomes. In order to realise the expectations expressed by institutions (see Section 1.2) the objectives of society and traveller should be the same, or at least overlap to a considerable degree.

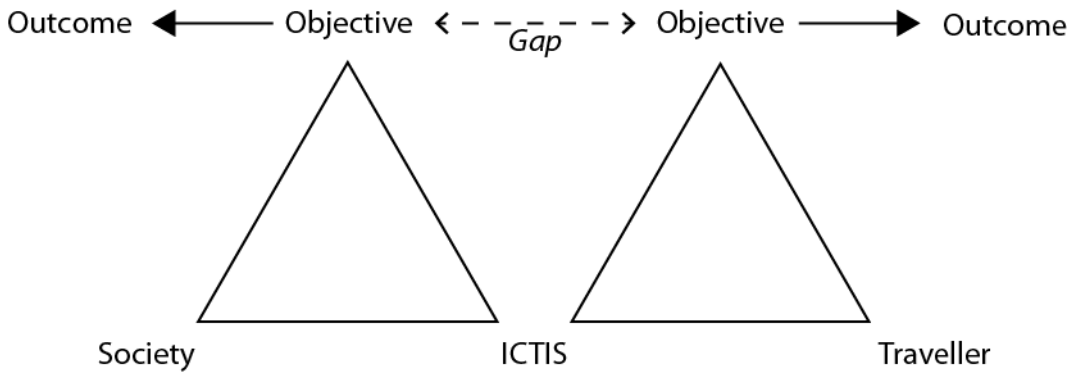

Figure 5-6 ICTIS as a meeting point between the activity system of the traveller and the activity system of society. The gap between the objectives for use of ICTIS is in emphasised by a dotted arrow.

The results from the included studies support the notion that such differences in objectives exist and it seems unlikely that unintended objectives for use will lead to intended outcomes. Predictable and intended outcomes are thus likely to require a more in-depth understanding of the objectives that travellers have for using ICTIS in different situations and context and based on this knowledge possibly create new ICT solutions that can contribute to narrowing the gap.

5.4 Summary of main conclusions

The aim of this thesis was to create a basis for understanding the role of ICTIS in urban transport of people, more specifically the effects that access to ICTIS has on travel behaviour and the travellers' experiences of the travel situation. For years, arguments by policymakers from all over the world have been founded on the assumption that ICTIS is a valuable tool in changing unsustainable travel behaviour. Empirical evidence of long-term effects from access to ICTIS has nonetheless been absent. This work has attempted to fill a part of this knowledge gap by employing a user centred approach focusing on the benefits that travellers noted from having access to ICTIS; and how travellers experienced the effects of having access to ICTIS. This was done through in-depth analyses of results from four different studies engaging more than 1000 respondents over time periods spanning from nine months to twelve years.

Access to ICTIS was in general positively assessed by the travellers. The perceived benefits of access to ICTIS were primarily related to comfort and convenience. Perceived benefit was moreover found to be important in explaining the effects of access. Assessments of overall benefit from access to ICTIS were, for example, more closely correlated to the magnitude of effects such as, for instance, increased comfort, decreased feeling of stress, and increased feeling of assurance, than what assessments of trust correlated to the magnitude of those effects.

Assessments of benefits changed over time, from high ratings of anticipated benefits in a pre-use phase to lower and more moderate ratings of benefits once travellers had had experience of using the ICTIS. These latter assessments were in general not found to change over time. That the perceived benefits are maintained over time indicates that these services met true needs for information. The rhetoric surrounding the development and diffusion of ICTIS

may help in creating positive attitudes and high expectations for ICTIS but if the users do not find that the systems deliver the anticipated benefits, the result could be that the users are disappointed and dismiss the service altogether. Benefit is generated if an offered service is perceived as better than previously known options. Successful introduction of new services must thus not only be trusted but must also be perceived by travellers as better than previously known alternatives.

Access to ICTIS was found to improve the travel experience for public transport use as well as for car use. Results from long-term access (access longer than nine months) indicated that the increased assessments of the travel experience, as well as the assessments of the benefits of the services, did not change over time.

The reported behavioural effects of travellers having access to ICTIS were found to be related to the specific travel mode targeted by each information service. Increased travelling was reported for several investigated services. Modal shift was however in general not found as a consequence of access to the tested ITCIS, not even for ICTIS targeting travellers using several modes. No major or radical changes in travel behaviour were reported from having access to ICTIS. The notion that ICTIS inspire changes in travel behaviour in terms of shifts from less to more energy-efficient modes of transport was not supported. Other factors, rather than access to ICTIS, are more likely to impose needed changes in travel behaviour. ICTIS might however have the potential to play an important role in offering comfort in such a revolution.

The studies offer empirical support to the claim that ICTIS are not consulted to find alternative ways of travelling but rather to confirm or validate preferred or already chosen travel options. Future policies involving introduction of ICTIS should therefore not be based on the expectation that access to ICTIS will change traveller behaviour in itself. Policies should instead combine introductions of ICTIS with other system modifications affecting travellers' actual and perceived action space. Alterations to traffic prioritisations, spatial use, and route choices are examples of such possible modifications.

It is, in order to understand and develop reasonable expectations for the direct and secondary effects associated with the use of information and communication technologies (ICT) in the transport sector, important to consider the time perspectives and the information type of each specific information service. Services address travellers in different roles as decision makers in the transport system, which influences different types of decisions that can be made.

5.5 Reflections on the research

The study of the effects of access to ICTIS in connection with public transport has focused on urban areas. ICTIS have a potentially important role to play in urban areas, but it has not, to the author's knowledge, been shown that ICT-mediated traveller information services are less valuable when used in rural areas. The conclusion that the usefulness of introducing ICTIS without additional system changes is limited in creating mode shifts, for example, might also be valid in a rural setting.

An introduction of ICTIS might not just affect travellers, but also those transport organisations that offer ICTIS. Introducing ICT systems, such as ICTIS, could stimulate changes in operations and in the culture of the transport organisations. Such changes could in a longer time perspective influence the transport service at large, for instance in terms of reorganisation or restructuring of services, and thus also affect the travellers' actual action space. Such potential effects were not investigated in this thesis. Organizational effects of introducing systems for real-time traveller information services in public transport organizations was, for example, studied by Skoglund (2012).

Cross-study comparisons could have benefited from having been further standardised, for instance in terms of formulation of questions, scales, etc. The differences between the questions and survey setups depend on several factors. Differences in the purpose and time perspectives of the studied services are examples of such factors. The setup of Study A was also to some extent defined by a previous survey as it repeated a several years older survey. In this case, it was important to use as identical a phrasing as possible to that used in the first survey. Some new types of questions were added (for example ranking of information sources by use frequency) and some questions were replaced or adjusted to increase relevance (for example questions concerning the availability of monochrome versus colour computer screens). Another factor is the way in which the studies came to be part of the thesis project. For example, the opportunity to include Study C and Study D was not apparent before Study A and Study B were already launched. The focus and setup of Study C and Study D were defined by a larger project description before becoming part of the thesis project, something that to some degree limited the extent to which those studies could be adapted to the previous studies.

A more focused selection of services, for instance either public transport information service, or multimodal information services, could have narrowed the aim of the thesis and thus potentially offer more precise answers. On the other hand, an even wider selection of services could have strengthened claims of results representing ICTIS in general. It is also possible that choosing a different set of services would have caused other results. The theoretical framework, the variety of studied services, and the diversity of systems do however offer some support for the idea that the conclusions in this thesis are generalizable beyond the tested services.

Moreover, the services have only been studied in European countries with advanced transport infrastructure. The conclusions could be expected to be

generalizable also for developed countries with a similar degree of transport system development in other parts of the world. It is also possible that the conclusions of the effects of access to ICTIS are similar in countries with less advanced transport systems. The challenges of transport systems in such countries might however be quite different.

Data was collected primarily by questionnaires. A larger amount of qualitative data from interviews, for example, might have further strengthened the rigour of this thesis and offered greater explanatory power. The group interviews that were carried out did however offer rich data with clear indications of saturation during thematic analysis.

The quantitative analysis was been carried out in a conservative manner (cf. Labovitz, 1967; Knapp, 1990; Jamieson, 2004), using non-parametric methods for significant testing of ordinal data. Non-parametric methods were used although normality could have been assumed for the data in some cases (such as Study A). Robust parametrical methods, with alleged power superiority (cf. Siegel, 1956), might have revealed statistically significant correlations not found with non-parametrical tests. However, it seems unlikely that such findings would have overthrown the overall discussion and conclusions as the findings are coherent and in most cases in line with previous research and theories.

In combination with the qualitative data, a multivariate data analysis might have further strengthened understanding by detecting influences by independent variables. However, the aim of the thesis was not to test a set of strictly focused hypotheses, or create test models with predictive potential, but rather to describe effects as they are perceived by the traveller.

6 Development of Future Research

Different ICTIS were found to generate different types of effects in varying magnitudes. It is thus of limited use to regard ICTIS as a homogeneous entity where effects found for one type of service can be expected for another type of service. Future research on the effects of ICTIS ought therefore be based in an understanding of the specifics and the contexts of use of each service.

Travellers are in general not given access to just one type of ICTIS but several types of ICTIS. The effects of access to a combination of ICTIS may be different than when each ICTIS is considered individually. Moreover, traveller information services and transport services are co-dependent and understanding of the effects might improve by regarding the services as integrated parts of each other. Further knowledge about combining access to ICTIS with other types of offers, such as new transport options, other types of information services, or alternative destinations might also be needed. Decisions regarding investments in transport might also be more successful with less focus on “either information services or transport service” and more focus on “both information services and transport services”.

Future ICTIS will use also other types of media than those investigated here. New combinations of data, collected through other methods than before will also be used. The time perspectives of travel decisions, the restraints limiting the scope for acting on information, and the objectives for travellers are however likely to be similar even in future transport settings. The conclusion that understanding of the action spaces, the objectives, and the time frames of the user, has the potential help to develop a concrete understanding of the effects of ICTIS is thus likely to hold.

The continuous change in character of ICTIS will persist. Having said that, it is likely that the type/size/direction of effects will remain if the design of ICTIS in the future is founded on the notion that availability of information alone will change behaviour. Studying the role of ICTIS as a comforter through imposed change might however be of importance.

7 References

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