THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

Investigating the impacts of ICT-mediated services

The case of public transport traveller information

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Abstract

Transport is of fundamental importance to modern societies but adjustments are needed to improve the sustainability of the transport systems. Transport of people is an important part of the transport system but also regarding transport of people a shift is necessary from less to more sustainable transport patterns. Information and communication technology (ICT) and ICT-mediated travel information are considered important means to achieve the overall aim and influence travel behaviours. However, knowledge is lacking as to the actual effects of introducing ICT-mediated information services.

The overall aim of this thesis has been to investigate the effects of introducing systems for ICT-mediated traveller information services related to public transport.
Altogether three studies have been carried out. Study A was an interview study with representatives for Swedish public transport organisations in order to explore which the objectives for implementing real-time traveller information systems in public transport organizations had been and if these objectives had been fulfilled. Study A also explored how the systems were introduced into the organizations and what consequences, or effects, of the deployment of real-time traveller information systems had been noted. Study B involved a survey to travellers in Gothenburg in order to investigate travellers' assessment of and their use of ICT-mediated information services such as real-time information; the use of different media (computers, mobile phones) for accessing ICT-mediated information services and if any changes in the choice of information channel(s) can be noted over time; and the self-reported effects of travellers' access to ICT-mediated services. Study C, finally, included a survey to a subjective sample of travellers in Stockholm in order to investigate travellers' attitudes towards and assessment of a co-modal travel planner, and if access to the travel planner resulted in any changes in the travellers' travel behaviour in terms of e.g. choice of travel modes.

The results from Study A show that the motives among Swedish public transport authorities for introducing systems for real-time traveller information varied and, furthermore, that the motives were sometimes unclear. Whether the goals for the introduction had been met or not had, in most cases, not been addressed. No organisational changes were reported as a direct consequence of the introduction but might over time have triggered changes.

Study B showed that real-time information (at bus and tram stops and on the web) and travel planner information (on the web) were highly rated, also over time, and several benefits of access to the information were reported (Less stress, More efficient travel, Reduced waiting times, etc.). In addition, between 17% and 19% of the travellers reported to have increased their use of public transport as a consequence of having access to ICT-mediated traveller information. This numbers had risen significantly over time.

Study C showed that the initial assessment of the co-modal travel planner fairly positive but declined over a period of nine months. Nine per cent of the respondents claim to travel more with public transport as a consequence of having had access the co-modal travel planner but no change could be found when analysing actual travel mode choice.

In sum, both travellers and public transport organisations have been affected by introductions of systems for ICT-mediated traveller information. The goals of introduction are in some cases met but the implementation and adoption processes could become more efficient.

Keywords: ITS - Intelligent Transport Systems; ICT-mediated traveller information; Real-time information system; Travel Planner; Co-modal Travel Planner; Public transport; Transit; Behavioural change

Preface and Acknowledgements

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The path to this thesis has not always been as clear to me as it might have appeared to others. I would like to thank my supervisor Professor MariAnne Karlsson for great patience in trying to keep me focused in a multidisciplinary field, for encouragements, and for outstanding support and feedback.

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Finally, I would like to thank my supportive friends and family for the energy and light shared.

Appended publications

Skoglund, Tor; Karlsson, MariAnne; Franzén, Stig E.R. (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)

Skoglund carried out interviews, performed the analysis, and wrote parts of the paper.

Karlsson, MariAnne; Skoglund, Tor (2012)
ICT-mediated information services in public transport: Travellers' use, assessment and long-term effects. Submitted to Journal of Public Transportation.

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.

Additional publication

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

Table of Contents

Instructions for reading

These short descriptions of each chapter are meant to be of guidance to the reader, hopefully clarifying how the parts come together.

Introduction	Includes a description of the background to some challenges in the transport area that need to be addressed. This is followed by a short account of the expected benefits that systems for ICT-mediated traveller information are credited with.
Framework	Explains the framework by which the expectations on ICT-mediated traveller information could be understood.
Research Approach	Describes the methodology and execution of the three studies included in the thesis.
Summary of studies	Describes aims and results of the respective studies carried out. These descriptions include some additional information and conclusions that are not necessarily included in the appended papers. This section also includes a summary of main findings.
Discussion and conclusions	Includes discussions of and comments on the results presented in the section Summary of studies
Future research	Includes suggestions for possible future research

1 Introduction

1.1 Background

Well functioning transport, or rather a well functioning transport system, is an important foundation of societies. Good communications contribute to a high quality of life and can facilitate a development towards a more sustainable society. However, the challenges associated with shaping tomorrow's transport systems are numerous as a demand for increased mobility is accompanied by for instance rising energy prices and spatial limitations.

1.1.1 Challenges

The challenges and limitations to a sustainable transport system are numerous. This section will present some of those challenges.

Economical development and sustainability is today connected to the transport of goods and people (Steininger, 2002). Rising energy prices are be likely to have a negative impact on the transport system and could thus in turn be expected to have a negative impact on the overall economy. The more energy needed for transport, the more will changes in energy prices affect the cost of transport. There has been an overall increase in the amount of energy required to meet transport needs and this increase is likely to continue. The necessary total of energy usage for the world's transport needs will, according to The World Business Council for Sustainable Development, rise from 77 exajoules used in the year 2000 to more than 112 exajoules in 2020 (World Energy Outlook, 2007) The transport sector accounted for 19% of the global final energy use in 2007 and will, according to International Energy Agency, account for 97% of the increase in world primary oil use between 2007 and 2030 (Kojima & Ryan, 2010). Access to primary oil is limited and transport costs might thus become affected to a larger degree than other parts of society by an increase in oil prices.

A significant part of all transport is carried out on roads. Road transport accounted for 26 % of the EU-27's total final energy consumption in 2006 (Huggins 2009). Hence, in trying to increase transport energy efficiency, road transport efficiency has to be attended to. Road transport of people can be performed in several ways and choices regarding path and mode affect the amount of energy needed. The average annual growth rate in transport by passenger cars was in the EU-27 area 1,6% in the years 1995-2006 (ibid.). A shift modes used in the transport of people from cars to more energy efficient modes of transport is sought but the corresponding average annual growth rate in number of passenger transport kilometres by buses and coaches was however only 0,5% between 1995-2006 EU27 (ibid.).

In addition to the possible impact that increased energy prices have on the transport sector, and most likely therefore also the economic development, such an increase in energy use would most probably be hard to attain without negative environmental effects. Land transport already today contributes to more than one fifth of the total anthropogenic carbon emissions in CO_2 equivalents (Uherek et al., 2010). Road transport is moreover the transport subsector with the largest contribution to global warming (Fuglestvedt et al., 2007).

Although difficult to assess (Grant-Muller & Laird, 2006) the cost of congestion has been assessed to costs Europe about 1% of its gross domestic product and would, if projected trends continue, rise by 50% to 200 billion € annually in 2050 (European Commission, 2011). A shift in transport mode use from car use to transport modes that are spatially less demanding per capita might play a part in solving congestion problems.

The last challenge to be mentioned in this section is road accidents. The European Commission estimated the cost of road accidents in the EU to be higher than both the costs caused by congestion or the costs of environmental pollution. It is argued that a modal shift towards public transport would save lives as trips with public transport (i.e. bus/coach or rail bound transport) are shown to be substantially safer than other modes of transport (European Transport Safety Council, 2003).

In short: As mobility demands increase, energy resources are limited, and spatial constraints are definite, solutions that make transport more efficient are needed.

1.1.2 Rationale

Public mass transport is today argued to represent an option less spatially demanding, safer, more energy efficient and less stressful to the environment than, for instance car use. A shift from car use to public mass transport is consequently claimed to be one important element in dealing with challenges mentioned earlier.

A shift from car use to public transport will, if not imposed through legal means, depend on the choices made by travellers. These choices are influenced by a number of factors. Some of the potential factors are practical, like access to information or transport vehicles and the design of the public transport system. Other factors might be found on a psychological level and can refer to knowledge, understanding and attitude.

Information is fundamental in making choices and technology assumed to facilitate information provision has thus been brought into focus. A common argument is that solutions based on information and communication technology (ICT) are important in dealing with transport challenges. This type of rhetoric is found on many levels of society and can be argued to apply especially to traveller information.

The transport industry and members of governing institutions have since long trusted technical development and improved information services in taking on the challenges in the transport systems. There has since some time, according to for example key institutions like the Commission of the European Communities, existed a "… need to make the alternatives to the car more attractive in terms of both infrastructure (metro lines – trams – cycle tracks– priority lanes for public transport) and service (quality of service, information given to users)." (Commission of the European Communities, 2001, p. 89) It was, for example, assumed that the railway system would be favoured by a needed large-scale development of "Telematic applications such as interconnection of seat reservation systems, real-time information systems or even the possibility of on-board telephone communications" (ibid., p. 30)

The belief in ICT-based systems as a problem solver is persistent and the focus on information-based solutions and in particular ICT-mediated traveller information was 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)

The confidence in positive effects of introducing systems for ICT-mediated traveller information is also reflected by influential non-governmental institutions like The Institution of Engineering and Technology in 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." (The Institution of Engineering and Technology, 2011) The same rhetoric regarding information and information services has also been acknowledged on a local public transport level (cf. Groth et al., 2011).

The fact that representatives of such different levels and parts of the society share the same expectations on systems for ICT-mediated traveller information points to a need to know if these expectations are based on real-world facts or if it only reflects a desire for an easy solution.

In sum, although limited by several factors it is assumed that introduction of ICT-based systems for travel information can positively influence travel behaviour.

As a consequence of these assumptions, large sums of money have been invested in systems for ICT-mediated traveller information. Real-time information at bus and tram stops has become available in urban public transport systems in most of the developed world. These systems were often accompanied by web-based services, like advanced route/travel planners, and more recently information applications suited for mobile devices. The dissemination of the systems have been described several studies (e.g. Infopolis2, 1999; Schweiger 2003), some studies have investigated its benefits, assumed or actual, (for an overview, see e.g. Dziekan,& Vermeulen, 2006; Schweiger, 2006), but the understanding of how and why information in general, and ICT-mediated systems for traveller information in particular, affect the users of these systems is still limited, in particular the effects over time.

1.2 Aim and research questions

This thesis aims to elucidate how systems for ICT-mediated traveller information and the information services provided have been received by the different users and what the effects of introducing new ICT-mediated traveller information systems are.

The users of these systems can be categorized into two main groups: travellers/passengers and transport organisers. The first, and the most obvious user of systems for ICT-mediated real-time traveller information, is the traveller. It is ultimately the traveller that decides if, how and when a trip is to be undertaken. The main focus of this thesis has consequently been the potential effects on the traveller of having access to systems for ICT-mediated traveller information. The second type of user of the systems for ICT-mediated traveller information is the transport organizations. The usage by members of this group also influences the effect that ICT-mediated traveller information has on the transport system. Therefore the effect that an introduction of such systems has had on public transport organizations has also been needed to elicit.

It might be appropriate to look into the effects on these two main groups of users separately as members of these groups differ in perspectives and usage. The overall aim has consequently broken down into research questions with two main foci.

The research questions are in relation to traffic organisers:

- Which have been the objectives for implementing real-time traveller/passenger information systems in public transport organizations?
- How have these objectives been evaluated?
- Have the objectives been fulfilled?

The research questions in relation to travellers are:

- Are there any effects of introducing a system for ICT-mediated traveller information on travellers?
    - Can short-term effects be noted?
    - Can long-term effects be noted?
- If effects can be identified, what are these effects?
    - What are the short-term effects?
    - What are the long-term effects?
- What changes, if any, have occurred in travellers' media use related to public transport traveller information?

In addition, the thesis attempts to connect previous knowledge, theories and models on communication and adoption of technology with the empirical results from the studies on the effects of the introduction of systems for ICT-mediated traveller information.

1.3 Delimitations

The focus of this thesis is on the effects of systems for ICT-mediated traveller information in connection to public transport and especially on urban public transport. The studied systems and users have been located in Sweden.

Several types of actors make decisions based on information mediated by these systems. This thesis addresses the usage by travellers and public transport authorities. Other potential users categories such as i.e. politicians or drivers of buses and trams have not been studied.

The public transport travel modes have been limited to scheduled public transport. Long distance public transport travel, as for example air travel, has together with taxis and other demand responsive public transport not been included. For a more detailed explanation to the definition of public transport is used in this thesis, see section 2.1.1.

2 Framework

This chapter describes some key concepts needed to interpret the expectations on ICT-mediated traveller information to change the travel behaviour of potential travellers. The framework is divided into four main parts. In order to give the reader an orientation of the domain this framework also includes an introduction to public transport systems and its actors (section 2.1).

The rhetoric mentioned in the introduction, regarding the potential effects of ICT and systems for ICT-mediated travel information, is shaped by an assumption that information can result in a change in an individual's travel behaviour. How the information is communicated to the potential traveller is central and theories and models describing communication are found in section 2.2.1.

The information is to result in a change of (travel) behaviour. However, changes in behaviour are more complex than what is reflected in simplistic models where information → behaviour. Factors influencing individual change are discussed and analysed based on the Theory of Reasoned Action (TRA) and Theory of Planned Behaviour (TPB) that are described in section 2.2.2.

Given that the information aimed to influence a change in behaviour is communicated through information and communication technology, i.e. through technology and technical devices that are partly new to the individual, the dimension of adopting technology must be considered. The process by which innovations are communicated and adopted is described by the Theory of Diffusion of Innovation, and by the Technology Acceptance Model (TAM) found in section 2.2.3.

2.1 Public transport

In seeking to understand the origin of factors influencing behaviour (and behavioural change) it is important to know the domain to which the behaviour is related. Some models describing general public transport systems will be presented. Short descriptions of the local situation of public transport in Sweden and in the city of Gothenburg specifically will follow as these shapes the context for parts of the research.

2.1.1 Definition

Public transport is by the Oxford English Dictionary described as "transport available for public use; a transport system (of buses, trains, etc.) that runs on fixed routes at set times and may be used by anyone on payment of a fare." (Oxford English dictionary, 2011) The first part of this definition is wide and would include for example taxis. The second part of the definition excludes, much like the limitations of the thesis, for example demand responsive transport and rental bikes. Transport solutions for public use funded in ways that do not require the traveller to pay a fare are also excluded, using this definition. White (2004, p.17) defined public transport as to "include all modes available to the public, irrespective of ownership" including for example taxis and private hire buses. This definition is even wider and would also include rental bikes and could even be argued to include escalators. The Swedish government agency for transport policy analysis, Trafikanalys, uses the definition "pre-arranged, recurrent transport offered to the public or a specific group of people according to defined rules" (2010, p. 9). This definition excludes demand responsive transport and some types of taxi rides but not necessarily air transport.

For the purposes of this thesis, the term public transport will include modes of local and regional mass transport available to the public with fixed routes. Mass transport here refers to transport modes without the possibility to reserve a seat.

The public transport system is part of the larger transport system, a highly complex system with a multitude of influencing factors and actors. It is a socio-technical system that includes dynamic human actors. The human actors are all involved in decision-making or control tasks and information exchange is necessary for the completion those tasks. Franzén (1999) formed an analytical framework for design and evaluation of public transport including a conceptual model of the ideal public transport system, presented in hierarchies of functional levels. These functional levels were the motion, traffic, transport, travel and accessibility systems as depicted in Figure 2-1.

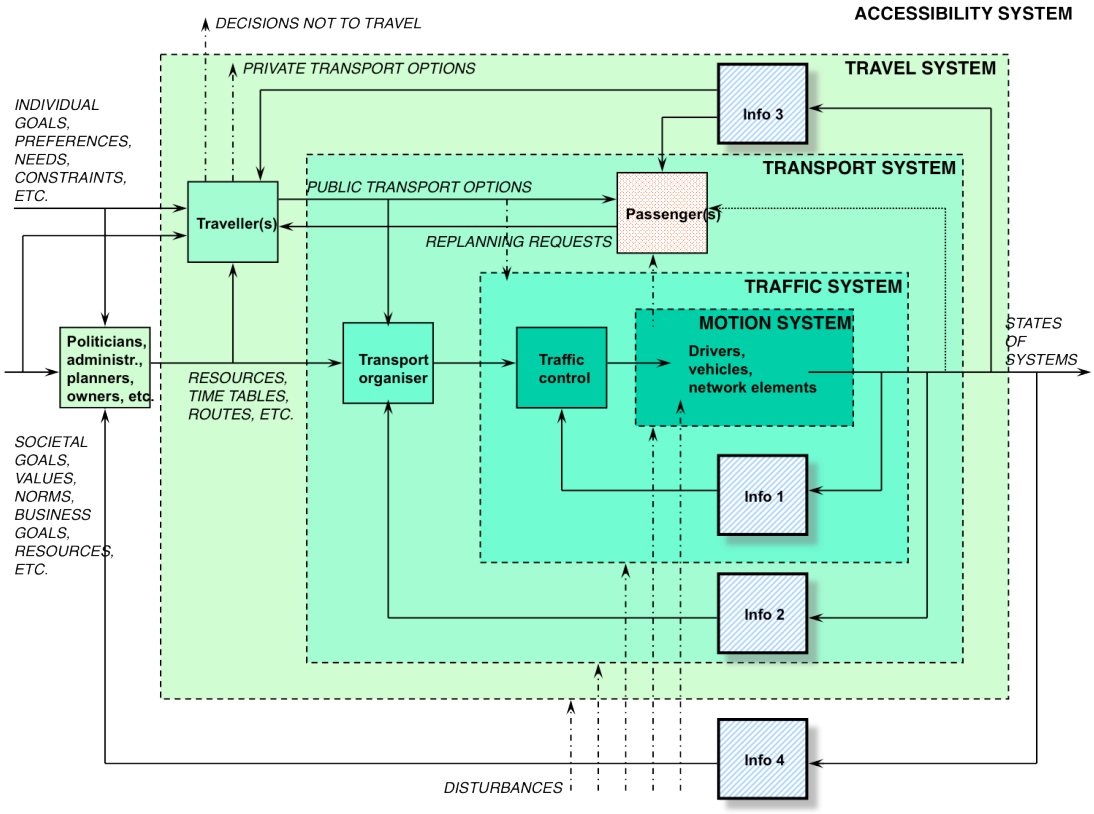

Figure 2-1 The ideal public transport system (Source: Franzén, 1999a)

The different functional levels operate within different time horizons and concern different activities. Each functional level has its specific sets of actors. An individual can take on many different roles and thus be found on several functional levels. It is moreover possible for an individual to appear at two different levels at the same time. This might for example be the case when an individual is planning a trip on the travel level (i.e. being a traveller) and at the same time being transported by bus, thus at the same time also being a passenger on the transport level.

The information flows between the actors on all these levels are important for a transport system to work properly. The focus of this thesis is the communication between actors on the traffic system level and down. The information system supporting the information flows is thus a fundamental part of the transport system. Public transport would be of very limited use if the travellers did not know how or/and when to travel. The information system is equally important to the public transport organization and their employees in order to provide a reliable and relevant service.

In Fig 2-1, Info1 indicates the real-time information gathered by sensors in the motion system and presented to the traffic control and/or information officers. Info2 indicates the real-time information gathered by sensors in the motion system and presented to the transport organizers. Info 3 consists of information flow from sensors in the motion system to travellers and passengers. This is real-time information that has been processed and adapted in order to support decisions on e.g. travel mode choice and/or re-planning a trip. Info4 is the flow of information from sensors in the motion

system presented to actors in the accessibility level, e.g. politicians; city planners; or transport company owners.

Different modes of transport relate to different level of control. The differences in control connected to mode of transport might bring about specific needs in travel information. It is not unlikely that transport organised and operated by someone other than the traveller him/herself, and therefore under a more limited level of control of the traveller, more often causes a higher demand for travel information. The lower the level of perceived control the traveller feels that s/he has over the trip, the more relevant travel information might feel in e.g. a situation of mode choice (cf. Franzén, 1999b; Arai, 2006). It can be assumed that this affects both the type and the amount of travel information.

2.1.2 The public transport information system

The systems for public transport information consist of sensors, data storage, algorithms, information officers, and several forms of information presentation, static as well as dynamic. The most common forms of information presentation are timetables, route maps, ticket machines, information billboards, phone services and web-based services. Waiting shelters, vehicles and drivers could also to be regarded as important parts of the information system (e.g. Karlsson et al. 1994). The travellers could, in addition to the other mentioned human actors (i.e. drivers and information officers), also be argued to be part of the information system. In this way travellers would constitute a front office and information officers and drivers would represent a back office.

The need for travel information has typically been categorised into information pre-trip and information during the trip (when waiting at the stop/corresponding and on board the vehicle) and in some cases also information post-trip (e.g. Karlsson et al., 1994; Caulfield & O'Mahoney, 2007). Two types of systems for ICT-mediated travel information commonly used are travel planners and systems for real-time travel information. While travel planners have been associated with pre-trip information, real-time information is often used during trips.

Travel planners are one example of ICT-mediated traveller information, another is real-time information. In the introduction it was stated that our understanding the long-term effects of ICT-mediated information is limited. Although studies have been carried out in order to investigate different aspects of ICT-mediated traveller information, the studies that have been carried out have all been short-term studies. No studies have, to the author's knowledge, been carried out on the changes that ICT-mediated information has on the behaviour of travellers over a longer period of time.

Studies on the effects of real-time information have most often been limited to the service of presenting minutes left to the next departure while studies on e.g. information on disturbances or route information appear scarce (cf. Karlsson, 2009).

A major part of the studies on real-time information that have been carried out can be characterized as investigations into attitudes towards "the principle" or "the idea" of real-time information and only a few appear to be dedicated to finding out if a traveller actually makes use of the information and the effects that this use may have

on the traveller's planning and execution of journeys in general, and by public transport specifically.

One common approach to the evaluation of real-time information has been to allow the travellers to indicate their level of satisfaction. Overall, most studies have shown that travellers are, in general, positive to and satisfied with having access to real-time information. In a very early evaluation of real-time information systems in Stockholm Metro, for instance Arnström (1986) found that 97% of the travellers were satisfied with the system. Also early evaluations of the London Transport Countdown system (Smith et al., 1994) demonstrated the same positive attitude.

Another approach is to try to reach an understanding of the *benefits* of real-time information, perceived or actual. Even though not all studies tell the same consistent story, most are coherent in their conclusions. In the early evaluation of the Countdown system in London the respondents claimed the benefits to be that their actual waiting time at the bus stop had become shorter, that their perceived waiting time had been reduced, and that they felt safer when travelling (Smith et al., 1994). Complementary observation studies in London also revealed behaviours and body languages that indicated lower levels of stress at stops equipped with real-time information compared with other stops (ibid.). The Infopolis 2 project reached more or less the same conclusions based on studies in e.g. Birmingham, Brussels, Bologna, Glasgow, London, and Paris (Infopolis2, 1999): i.e. perceived effects were shorter waiting times, increased acceptance of waiting, and safer travelling (especially at night), but in addition increased reliability of the public transport system and an overall more positive attitude towards public transport. Also a study in Helsinki (Sane et al., 1999) confirmed these, overall positive effects. Given that travellers knew when the bus arrived to the stop, uncertainty was reduced, and they could make more efficient use of the waiting time.

A third line of thought has focused specifically on one of the benefits mentioned earlier, *perceived waiting time*, the underlying reason that perceived waiting time is considered an important factor in travellers' opinions of the public transport service. For instance Mishalani et al. (2006) interviewed some 80 passengers and found that the difference between actual and perceived waiting time was on average 0.8 minutes. Based on a theoretical model, real-time information was then proposed to have the potential to reduce travellers' perceived waiting time but the authors provide no empirical evidence. Empirical evidence has however been found in two consecutive studies carried out within the Quartet Plus-project (Sekara et al., 1997; Sekara and Karlsson, 1997a). The result of the these studies, where 140 travellers' actual waiting times at different bus/tram stops were noted by an observer and compared with travellers' perceived waiting times collected by means of a short interview, was that travellers without access to real-time information overestimated their waiting time by 25-35% while travellers with access overestimated their waiting time by 10% only. Also another empirical study (Dziekan & Vermeulen, 2006), where a questionnaire was distributed to travellers along a specific tram route before and after the introduction of real-time information found that the perceived waiting time was reduced by 20% (from on average 6.3 minutes to 5.0 minutes).

A more specific indication of the perceived value of real-time information is considered to be travellers' *willingness to pay*. A series of studies have tried to draw

conclusions regarding the effects of real-time information on willingness to pay, primarily by means of stated preferences (SP). According to an overview provided by Dziekan and Kottenhoff (2007), studies by Smith et al. (1994) as well as by Swanson et al. (1997) have shown that access to real-time information at bus and tram stops increases the travellers' willingness to pay. An investigation by Widlert et al. (1989) reached the conclusion that access to real-time information was worth as much as 12-16% lower ticket prices and 6% shorter travel times while a later study by Wardman et al. (2001) found that real-time information was worth corresponding to 1.4 minutes travel time. On basis of the referred studies, Dziekan and Kottenhoff (2007) argued that real-time information at bus/tram stops has a value that compares to between 5% and 20% of the ticket price, a conclusion which the authors however do not want to interpret as though the traveller is willing to pay anything "extra" but rather that the traveller expects that real-time information is to be provided by the public transport organisation.

A desired effect that has been observed, but only in very few investigations, is an increase in the number of trips by public transport. According to a compilation of results by the Infopolis2 project (Infopolis 2, 1999), public transport in Brussels noted an increase by as much as 6%. Similar numbers, a 2-3% increase, have been reported in the USA by Pierce Transit in Lakewood WA, while Montgomery Area Transit System in Alabama reported a 10% increase in ridership (Schweiger, 2006). In Birmingham the reported increase was considerably higher, 30%, but then as a result of several different measures taken of which the introduction of real-time information was one (Infopolis 2, 1999). This was also the case when Tri-County Metropolitan Transportation District of Oregon reported an 18% increase in ridership (Schweiger, 2006).

Studies on the effects of introducing travel planners are considerably more scarce but e.g., a study by Laine et al (2003) indicate positive consequences in that travellers have found faster routes and the information have made the journeys more comfortable. Few investigations indicate, however, an increase in the number of trips by public transport as a result and then in terms of two or three percent of travellers who report an increase in the use of public transport (Laine et al. 2003; Sekara and Karlsson, 1998). There is, however, little evidence to suggest that the provision of information has been effective in promoting modal shift.

2.2 Theories

Information flow and communication between actors are fundamental parts of the transport system in order for mass passenger transport to function. It is therefore relevant to start with some of the most central theories and models of communication.

2.2.1 Communication Theory

Communication theory has been argued to lack a canon of general theory to which all communication theories refer and thus not exist as an identifiable field of study (Craig, 1999). This section will, as a consequence of the diverse traditions of communication theory, include several complementary theories relevant to the understanding the effects of ICT-mediated traveller information.

Parts of the communication between actors in the transport system can be described through using well-known communication models of which some of the most important ones will be described here. The following sections on communication are divided into two main parts. The first part includes so called linear models that describe communication as a sequence of events. Shannon's communication model (described below) is an example of this first category. The second part explains the semiotic communication perspective that focuses on the creation of meaning in a message.

2.2.1.1 Linear communication models

A linear communication model is based on the perception of communication as transport of a message from a sending to a receiving end. The traditional traveller information communication process, where information flows from a Public Transport Authority (PTA) to an end user (of the communication) informing about stops, routes and schedules, bears some resemblance to the linearity found in certain linear communication models. It is then natural to start the description and understanding of this communication process by looking at one of the most predominant linear communication model, Shannon's communication model.

2.2.1.1.1 Shannon's communication model

Shannon's communication model grew out of a need to optimize communication channels and focus on the process of communication as a message sent from A to B. Shannon first presented his mathematical model in 1948 in an attempt to increase the efficiency in message transmission of communication networks, i.e. improve the likelihood of an electrical impulse being reproduced "either exactly or approximately" at another point. Figure 2-2 depicts Shannon's "schematic diagram of a general communication system" (Shannon, 1948).

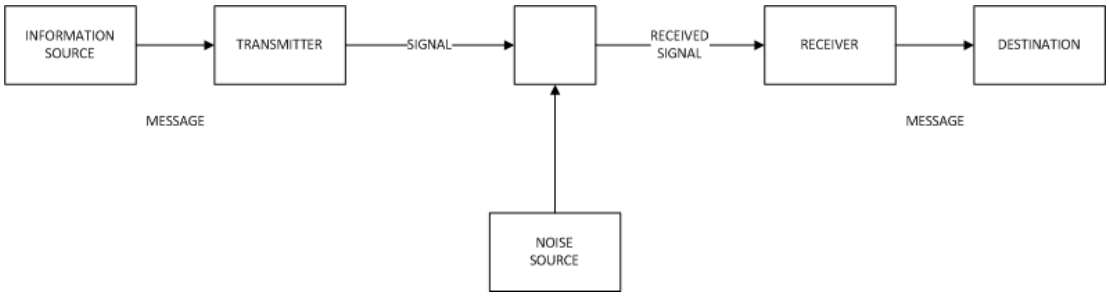

Figure 2-2 Schematic diagram of a general communication system (Source: Shannon, 1948)

The model describes some of the most central parts of communication: **Information source**, **Message, Transmitter**, **Signal**, **Noise**, **Receiver** and **Destination**.

- According to the model, the process of communication starts by the information **source** deciding and producing what **message** that should be sent. This selection of a message from a set of possible messages is an important part of the process. The scope of "possible messages" is not only limited by what the communication system is capable of transferring but also by the capability of the actor choosing the message. The selection phase is therefore interesting both from a technical perspective and from a cognitive/semantic perspective.

- The **transmitter** transforms (codes) the message into a **signal** that is sent over a communication channel to the **receiver**. This part can be exemplified with a telephone as a transmitter, the signal being electrical impulses and a second telephone being the receiver.

- **Noise** can be added to the signal during the transmission process causing distortion. In a strict sense noise includes everything that is added to the signal. An example of added noise could be the background murmur of people in a café interfering with the sounds from a person speaking to you over the phone. This contextual noise, if not preventing the listener from hearing the sound from the caller's mouth, could also add information useful to the listener consequently making the message clearer to the listener.

- The signal is then turned (decoded) into a message by the receiver and sent to the **destination**. The process of turning a signal into a message is similar to that of the message being turned into a signal but in reverse. The transformation from signal to message is dependent on several factors and it is not obvious that a signal, even if identical to the transmitted signal, will be transformed into a message identical to the message that was chosen. The creation of meaning out of that message is yet another matter.

Shannon's communication model is easy to overview and it describes some of the basic factors in communication but there is a need to complement and adapt the model to address challenges associated with describing more complex processes. The static and linear characteristics of Shannon's communication model have for example been pointed out as being misleading when applied to human communication (see e.g. Mortensen 1972; Reddy, 1979). Shannon's model can also be conceived as focusing the sender's perspective. The direction of the arrows in Shannon's model implies that communication depends on terms defined by the sender but this is evidently not always the case.

2.2.1.1.2 Elaborations of Shannon's model

Shannon's communication model has, despite being frequently questioned and problematized, been widely used and misused (Reddy, 1979) and several modifications and/or elaborations of the model have been proposed. The most influential adjustment was that of Weaver in his contribution to the book "The mathematical theory of communication" (Shannon & Weaver, 1949) "to better fit established views regarding human communication" (Blackburn, 1999, p. 58). Shannon's model was by Wiener (1949) connected to the importance of control and communication in machines and animals, "providing a broad context in which Shannon's information theory could be viewed" (Blackburn, 1999, p. 71). Figure 2-3 shows the connection between control systems and Shannon's model adding the effect of a message reaching the destination as feedback[1] to the information source. The concept of feedback became the basis for cybernetics and has had an impact on social sciences.

[1] First significant paper on feedback mechanisms was published by Maxwell (1886)

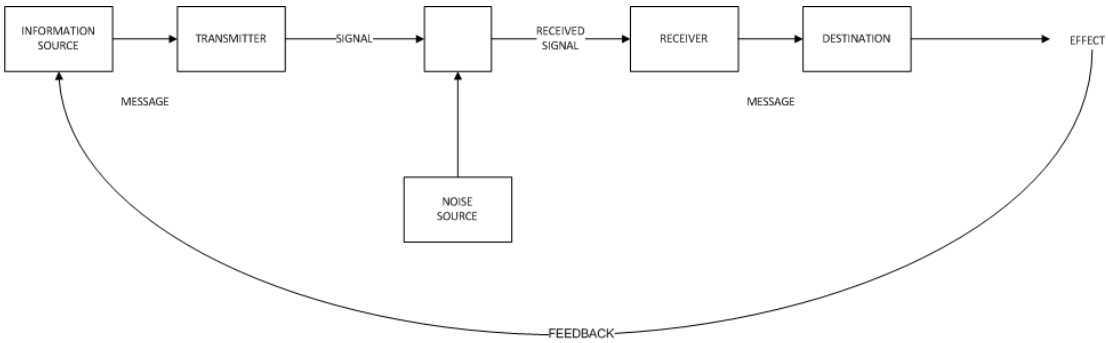

Figure 2-3 Shannon's schematic diagram of a general communication system with feedback added

However, the linearity of Shannon's communication model is not overcome by merely an addition of feedback (Fiske, 1994) since the main purpose of feedback is to help the sender to adapt the message in order to fit the receiver's needs and response, thus preserving the sense of communication as transfer of message from source to receiver. An interactive communication model could nevertheless bring focus to the collaborative tendency of everyday communication similarly to that of feedback being added to Shannon's model. An interactive communication model marks one way to approach important communication related concepts like meaning and understanding and can more visibly address important factors regarding what Weaver (1949) called the semantic problem level. The semantic problems are challenges related to understanding, perception and creation of meaning.

In order to relate the role of information to that of behavioural change one has to accept that 'a successful data transfer' is different from 'impacting behaviour'. In order to have an effect on an individual's behaviour, data has to be meaningful. This can be associated to the claim "information equals data plus meaning" (Checkland & Scholes, 1990). The quote underlines the difference between unstructured data and meaningful information as presented to a person. Although the relevance and precision in this claim has been questioned, it still points to that the concepts of data, information and meaning are connected.

2.2.1.2 The semiotic communication perspective

As stated by Mingers (1996), "To be of relevance to information systems in practice, however, any theory of information must be able to address the semantic and pragmatic aspects of information as it is actually used, unrestrictedly, within systems of human activity" (ibid., p.189). Mingers here uses the expression pragmatic as being the study of the use of signs, and semantics as the study of the meaning of signs. This indicates a slight shift in focus from what is sent, to a perspective including the receiver's understanding and actions as a consequence of communication. This more multifaceted way of relating to communication is shared by Rogers (2003) when he defines communication as "a process in which participants create and share information with one another in order to reach a mutual understanding" (ibid., p 5).

Craig (1999) states that semiotics theorize problems of communication as "misunderstandings or gaps between subjective standpoints". This description of semiotics relates to communication as an act of creating a common understanding. Theorizing a problem in this way could be of use in the context of ICT-mediated traveller information as it is could be argued that there is a gap in understanding between how a traveller understands and uses the transport system and how the usage

of said system would be optimized from a higher abstraction level (i.e. on a society or accessibility level) (cf. Franzén, 1999a).

The approach of understanding communication as creating meaning to a message brings focus to the interpretation part of communication. In relation to ICT-mediated traveller information it also shifts the focus to the receiver of a message, the potential user of the transport system.

Interpretation is, besides the actual symbols used (e.g. letters, numbers, maps etc.), dependent on large numbers of contextual factors. The interpretation is for example affected by contextual factors like the individual's state of mind, pre-understanding, and other cognitive restraints. Interpretation is also affected by timing and the medium used for communicating. It is thus, in order for systems for ICT-mediated traveller information to facilitate behavioural change, highly important for the sender of information to be aware of the vastness of the amount of factors related to understanding that same message.

2.2.2 Theories and models related to behavioural change

A successful usage of systems for traveller information does not only depend on the transfer of information and the creation of meaning in received messages between actors in the system but also of the likelihood of basing actions on the given information. The conception of an instrumental relationship between information transfer and effect, assuming that information transfer will have a direct impact on behaviour, is of very limited use when trying to explain the results of the studies conducted in this thesis. Theories and models explaining relations between influencing factors and behavioural change are required.

There are several theories and models describing factors related to behaviour and possible uptake of technology and innovations. Following is an account of three types of models, each explaining relationships between influencing factors and behavioural change. The first type of models focuses on the psychological process within the individual. Included in this type of model are Theory of Reasoned Action (TRA) and Theory of Planned Behaviour (TPB). These models are then complemented by a type of model that puts a greater emphasis on the relationship between the human and the technology. The Technology Acceptance Model (TAM) could be argued to be the most accepted model in this category. Although all in parts relevant, these two types of models benefit from being supplemented by a type of model explaining the uptake of ideas and technology into a social system. This is done in section 2.2.3.2.

2.2.2.1 Theory of Reasoned Action

The Theory of Reasoned Action (TRA) is commonly used to predict the intended behaviour of individuals. It was first developed in the middle of the 1970s by Fishbein and Ajzen and has since served as basis for a large flora of methods and theories. In sum, TRA describes how behaviour is connected to intentions, as intentions influence behaviour, and how these intentions are in turn affected by attitudes and norms.

A simple outline of the model is depicted in Figure 2-4 and includes a set of connected concepts. According to the model, **Behaviour** is determined by **Behavioural Intention**. The two factors affecting the intention to act in a certain way are **Attitude** and **Subjective norm**.

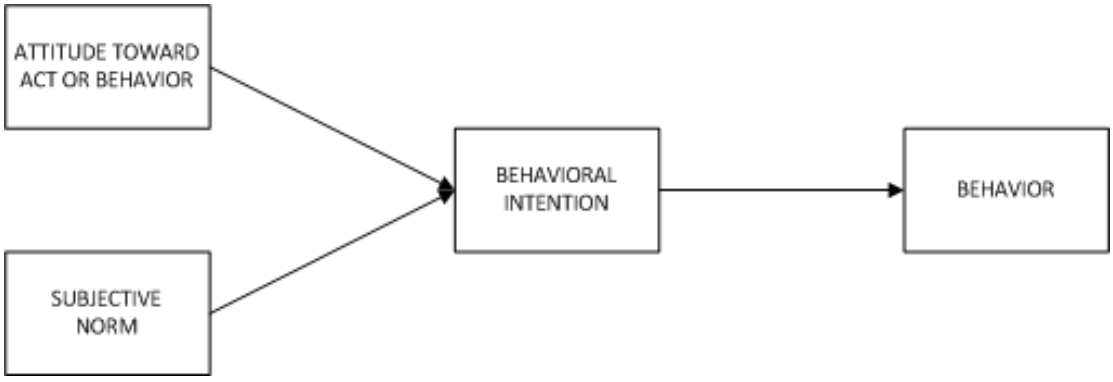

Figure 2-4 A simple outline of the TRA model (Source: Ajzen and Fishbein, 1980; Fishbein and Ajzen, 1975)

- **Behavioural Intention** is by Fishbein and Ajzen (Fishbein & Ajzen, 2010) defined as a person's "readiness to perform a behaviour" (ibid., p. 48) being

the subjective probability of performing a behaviour. Behavioural Intention can, according to Fishbein and Ajzen "indeed be used to predict behaviour with a considerable degree of accuracy" (ibid., p. 48)

- The **Attitude** towards a behaviour can be negative or positive and is according to the theory affected by Behavioural Beliefs. Behavioural Beliefs describe the expected consequences of a particular behaviour. For example: A traveller would be more likely to use traveller information systems if he thinks that it would make his trip more comfortable than if he thought it would confuse him.

- The **Subjective Norm** can be described as the individual's perception of whether the behaviour should be undertaken/performed or not.

- The subjective norm is in turn affected by what Fishbein and Ajzen (1975) calls **Normative Beliefs**. A normative belief is the perceived expectation of what referents or significant others, such as for example family members, think of a specific behaviour. An individual is supposedly more likely to use public transport if s/he believes that his/her spouse thinks that he/she should use public transport.

The definitions and distinctions of concepts included in TRA have been discussed and the degree to which for example Normative Beliefs is a concept distinct from Behavioural Beliefs has been questioned (e.g. Miniard & Cohen, 1981). The validity of this specific distinction is however supported by several sources (Terry & Hogg, 2000)

2.2.2.2 *Theory of Planned Behaviour*

The Theory of Planned Behaviour (TPB) (Ajzen, 1991) has evolved from out of TRA and can today be regarded as the most influential theory on explaining behaviour and behavioural change. The theory was formed as the creators of TRA appreciated the fact that not all decisions are voluntary and under perceived control of the individual. The basic difference between the TRA and TPB models is that another factor, Perceived Behavioural Control, was added (see Figure 2-5).

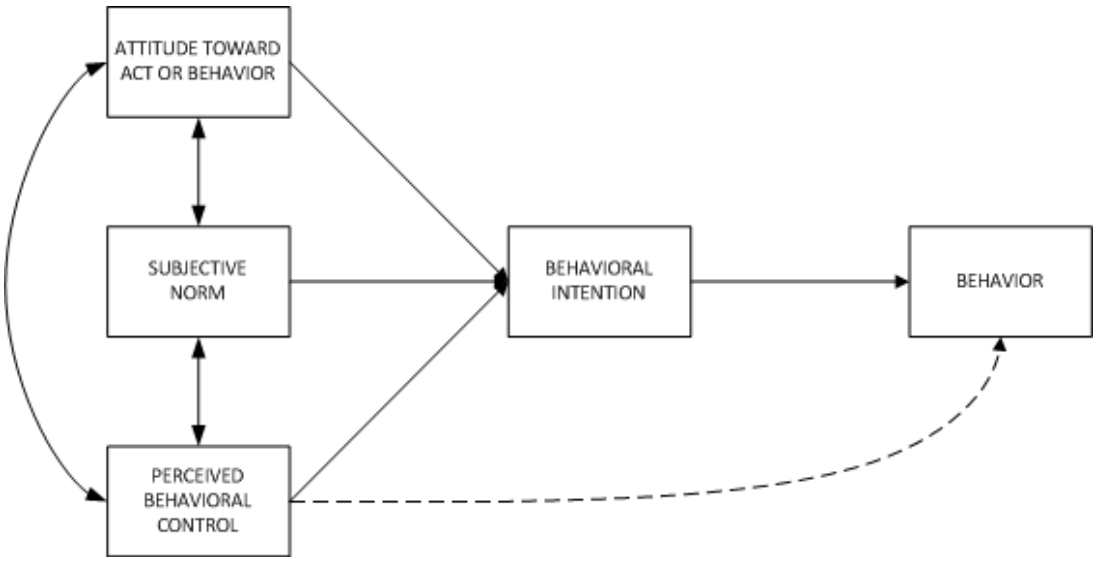

Figure 2-5 Theory of planned behaviour (Source: Ajzen, 1991)

Perceived Behavioral Control is the perceived ability to perform a behaviour. Fishbein and Ajzen define perceived behavioural control as "people's perception of the degree to which they are capable of, or have control over, performing a given behaviour"(Fishbein & Ajzen, 2010, p64). A person's perception of control or capability can be affected by factors that the person believes facilitate the behaviour. A person might, for instance believe that the likelihood of successfully looking up travel information is higher if the information system is interfaced in a way that specific person is comfortable with, than if the interface is very different from what that person is used to.

External factors have in some cases been found to be of greater importance than internal factors like attitude and subjective norm. This brings focus both to the system within which the potential user is an actor and to the innovation in question. Theories and models that that stress the relationship between the human and the innovation is thus needed.

2.2.3 Theories and models on acceptance and adoption of new technology

This thesis aims to describe the effects of introducing systems for ICT-mediated traveller information. Previously mentioned sections describe models related to behavioural change and communication. An equally important factor is the adoption and acceptance of the new systems.

People's acceptance and adoption of technology and influencing factors have been described in models like the Technology Acceptance Model and Unified Theory of Acceptance and Use of Technology.

2.2.3.1 Technology Acceptance Model

One of the most influential extensions of the Theory of Reasoned Action is the Technology Acceptance Model (TAM) (Davis, 1989). TAM was developed as an attempt to create a validated measurement scale for predicting user acceptance of computer systems and has had a big impact on empirical research on user acceptance of information technology (IT) but also other areas.

The model in Figure 2-6 connects IT system design features with the perception of an potential user and points out two other perception factors to be of importance to the attitude towards using a technology and behavioural intention than those found in TRA and TPB. These two factors are **Perceived Usefulness** (PU) and **Perceived Ease of Use** (PEoU). PEoU was defined as "the degree to which a person believes that using a particular system would be free from effort" and PU as "the degree to which a person believes that using a particular system would enhance his or her job performance" (ibid., p. 320)

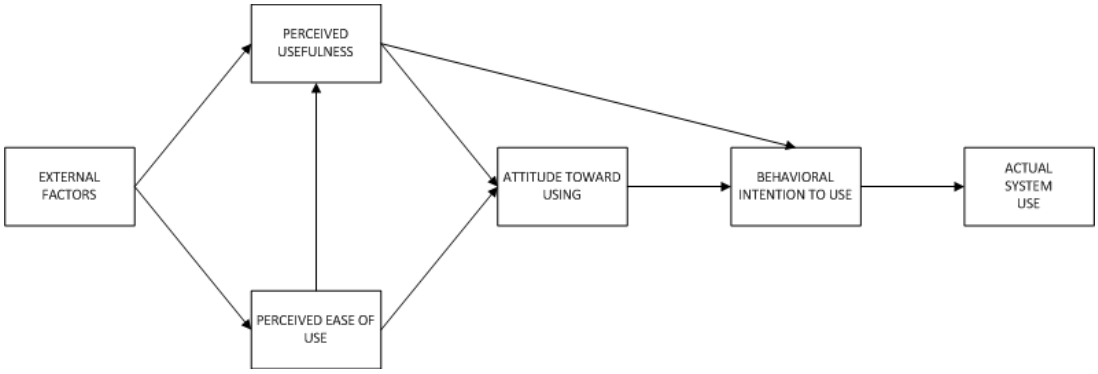

Figure 2-6 First modified version of Technology Acceptance Model (Davies et al., 1989)

Perceived Usefulness and Perceived Ease of Use are in turn affected by several **External Factors** of which some have been pointed out by later adaptations of the TAM model, for example in TAM2, TAM3, and in Unified Theory of Acceptance and Use of Technology (UTAUT)[2] (Venkatesh et al., 2003). The four external factors said to be direct determinants on user acceptance are according to UTAUT: **Performance Expectancy** "The degree to which an individual believes that using the system will help him or her to attain gains in job performance"(ibid., p. 447), **Effort Expectancy "**The degree of ease associated with the use of the system" "(ibid., p. 450), **Social Influence** "The degree to which an individual perceives that important others believe he or she should use the new system" "(ibid., p. 451), and **Facilitating Condition** "The degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system"(ibid., p. 453).

Gender, age, experience, voluntariness of use are called key moderators and mediate the impact of the determinants (ibid.). While TAM has been extensively used it has also been criticized for leaving out important variables. UTAUT has, on the other hand, been criticized for depending on too many independent variables, making it unpractical (e.g. Bagozzi, 2007).

TRA, TPB, TAM and UTAUT all seek to predict intended behaviour and likelihood of behavioural change. Fishbein and Ajzen (2010) state that an intention to act is the best single predictor of behaviour. The focus is on the effect that an individual's beliefs have on behaviour intention. Factors affecting these beliefs are referred to as Background Factors (ibid.). These factors can be compared to the External Factors in TAM and are virtually unlimited in numbers. They include Individual factors such as past behaviour, intelligence and personality; Social factors such as age, gender and education; and Informational factors such as knowledge. These factors are said only to be considered if "we have reason to believe" that specific "behavior-relevant beliefs" (ibid., p. 224) are affected. Which specific background factors that should be considered is not part of Fishbein and Ajzen's framework. In order to find what potentially important determinants should be considered it is necessary to add complimentary theories.

A potential user's perception of a system innovation is affected by the system's design. A theoretical basis with an established focus on the characters of the

[2] UTAUT is an attempt to review and synthesize eight models sprung from a variety of research areas trying to explain information systems usage behaviour.

innovation might therefore be needed. The importance of the perceived character of an innovation[3] is explained as part of Roger's four key parameters affecting potential adoption of innovation mentioned next.

2.2.3.2 Diffusion of Innovation

The previously mentioned Technology Acceptance Model (TAM) focuses on acceptance factors that can be perceived as a user's internally psychological perspective and leaving out much of the characteristics of the innovation. The characteristics of an innovation such as a product or service are potentially very important for the adoption by users. Theories for developing a better understanding the importance of the qualities of an innovation is therefore relevant to consider. One such theory is Rogers' Diffusion of Innovation Theory. Its stronger focus on the characteristics of the innovation compared to the earlier described theories TRA, TAM, and UTAUT makes the Diffusion of Innovation Theory consequently of interest to this thesis.

Diffusion research derives from an idea held by the French social psychologist Tarde (1903). Tarde was the first to identify the s-shaped behaviour of adoption (Figure 2-7) in describing the process of imitation and repetition: "A slow advance in the beginning, followed by rapid and uniformly accelerated progress, followed again by progress that continues to slacken until it finally stops: these, then, are the three ages of those real social beings which I call inventions or discoveries" (ibid., p 127) . The s-shape is based on the conviction that small psychological interactions between individuals are the foundation of changes in behaviour. This points to the importance of social factors as well as the time factor.

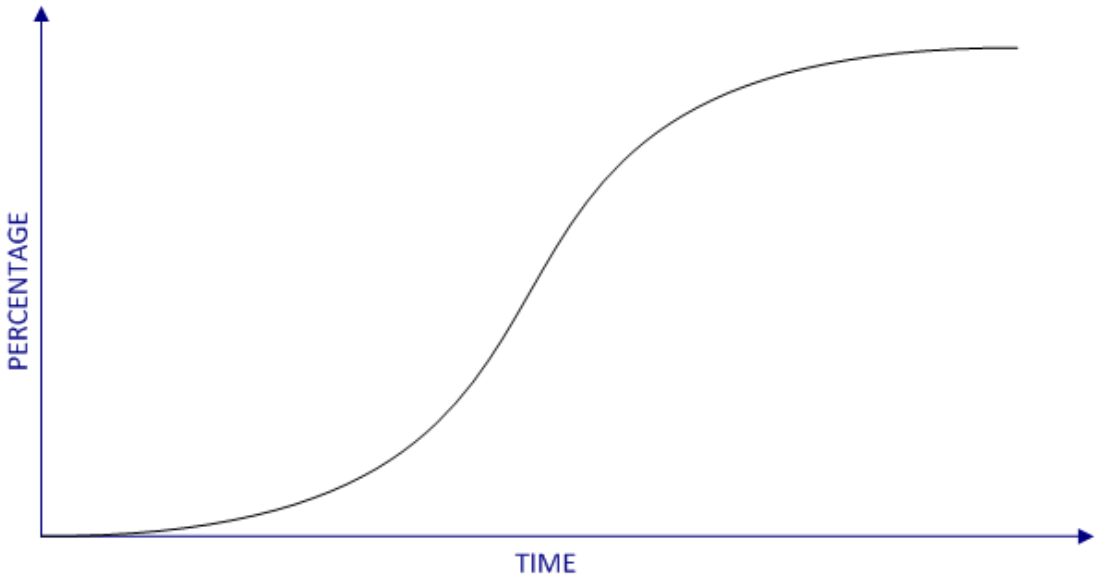

Figure 2-7 A sigmoid function, illustrating the s-shaped behaviour of adoption

Diffusion of innovation has been defined by Rogers (1995) as "The process by which an innovation is communicated through certain channels over time among the members of a social system" (ibid., p. 5). The term **innovation** is here not limited to

[3] Innovation was by Rogers (2003, p. 12) as "an idea practice or object that is perceived as new by an individual or other unit of adoption"

artefacts but also includes behaviours, thoughts and ideas new to that specific social system.

The concept of adoption and the characteristics of different types of adopters will be described, followed by the four parameters highlighted by Rogers.

2.2.3.2.1 Adoption and adopters

The concept of **adoption** is central to diffusion research and has a number of different definitions. One is proposed by Rogers and Shoemaker (1971): "The decision to make full use of an idea", another by Robertson (1971): "The use and continued use of a new item." Rogers (2003) defines adoption as "a decision to make full use of an innovation as the best course of action available" (ibid., p. 21). These definitions all point to adoption as an acceptance and a use extending beyond a first exposure.

Diffusion theory is based on the notion that most adoption processes follow a pattern in which the uptake is slow at start but when it has reached a certain percentage of adopters gains leverage and accelerates only to later slows down again. With this follows a possibility to categorise the **adopters** into groups depending on when in time they decide to adopt an innovation compared to the other members of the same social system. These groups are commonly named (in chronological order of adoption, see Figure 2-8): Innovators, Early adopters, Early Majority, Late majority and Laggards. To be noted is that the groups are ideal types and there are no abrupt discontinuances in the innovativeness between the groups. Additionally, these ideal types are only applicable in a limited system such as a group of people belonging to a society or a cultural sphere, etc. A social system was by Rogers defined as "a set of interrelated units that are engaged in joint problem-solving to accomplish a common goal" (ibid., p.23).

Innovators are the first to adopt an innovation in a social system (Rogers, 1995), by the **Early Adopters**. These have been found to, in relations to later adopters, have a more formal education, greater exposure to mass media and higher social status. The following two groups are called **Early majority** and **Late majority**. They are the two largest groups and make up for about 72% of the adopters. The large number of adopters that could be categorized into these two groups is the reason to why the s-shaped curve takes off. The last members of a social system to adopt an innovation are the **Laggards**. They are said to constitute about 16% of the total number of adopters and do not invest energy into adopting an innovation unless they are convinced that the other adopters have successfully adopted the innovation.

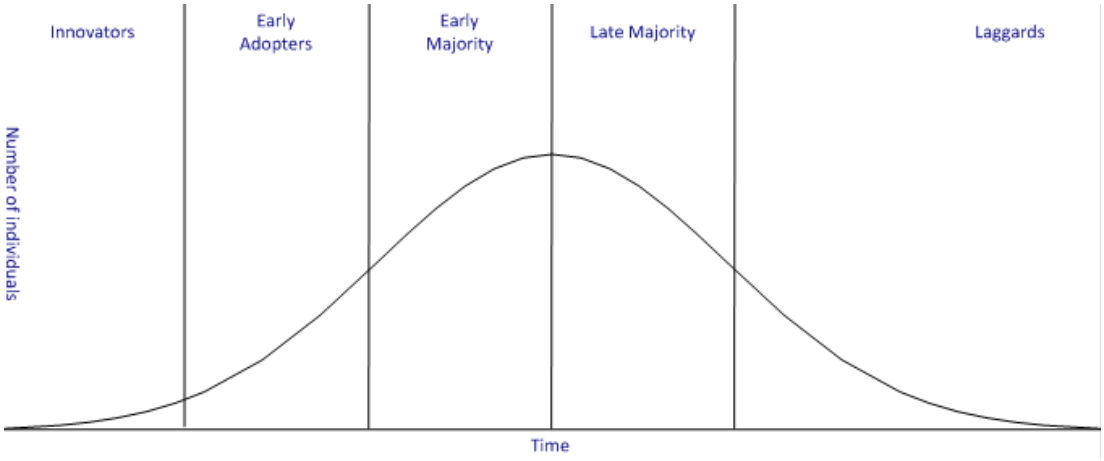

Figure 2-8 Diffusion curve (Source: Rogers, 1995)

2.2.3.2.2 Rogers' four key parameters

Rogers (ibid.) highlights four parameters that affect the potential adoption of an innovation. These are the **Character of the innovation**, the **Communication Channels** used to inform potential users about the innovation, **Time** and the **Social System** in which the innovation will spread. The first two parameters are the most influential to diffusion.

Steps towards adoption are taken at an individual rate. The **time** needed to pass through the innovation-decision period differs between individuals. The adoption process is by Rogers described as consisting of five stages describing a hierarchy where information is communicated through different channels:

- **Knowledge stage** - A prerequisite for the adoption process is an awareness of the innovation. This stage consists of steps such as recalling information about the innovation and understanding the message that is communicated.
- **Persuasion stage** – This stage is where the potential adopter ponders the perceived characteristics of the innovation, the potential usefulness and effect of the innovation.
- **Decision** – The decision could be to adopt or reject the innovation. This decision can be revised at any given moment.
- **Implementation** – When a decision to adopt an innovation is made, the innovation has to be implemented. It is during this phase most re-inventions are made. Rogers (2003) defines re-invention as "the degree to which an innovation is changed or modified by a user in the process of its adoption and implementation" (ibid., p. 17). It is stated that, in general, a higher degree of re-invention leads to a faster rate of adoption and that the innovation will be used over a longer time period.
- **Confirmation** – The potential adopter will after implementing the innovation confirm if its usefulness, ease of use, and relative advantage are what they were thought to be. This can be seen as looping the process from the Knowledge stage to the Decision stage and could lead to either

Discontinuance or Later adoption. Discontinuance can happen for two reasons: either the innovation is replaced by an even better innovation or by disenchantment where the expected effect was not reached.

The way that an innovation is communicated, i.e. the **communication channels** used, also affects the rate of adoption. Different communication channels are efficient in different parts of a diffusion process. Mass media might, for instance, be the most efficient way to get potential adopters to know that the innovation exists but might not be as efficient in stages where trust and detailed understanding are needed. Different communication channels might also be more or less depending on to which kind of adopter the innovation is communicated. For instance Early adopters depend to a lesser degree on word of mouth while Later adopters do so to a larger degree (ibid.).

The **social system**, in which diffusion takes place, is another factor that must be taken into consideration. There are a number of issues in a social system that affects diffusion:

- **Communication structure** - The structure of a social system gives predictability and can be seen as information that decreases uncertainty. The probability of an individual communicating with another specific individual in a system is not evenly distributed. The social structure helps the individual to choose whom to communicate with. This can both impede and facilitate the diffusion of an innovation.

- **Norms** – refer to the behavioural pattern accepted by members of the social system. The norms are guides to expected behaviour of an individual. Norms can inhibit change but can also affect behaviour in a way so that change is encouraged.

- Different individuals take on different **roles** in the system depending on their place in the social structure. An individual can affect the diffusion process both in speeding it up and through slowing it down depending on the individual's actions or inactions. The extent to which this affects the diffusion is said to depend on the role of the individual in the social structure. One type of individual central to interpersonal communication network is a type that Rogers (ibid.) calls Opinion leaders. The opinion leaders tend to reflect the structure of the social system. They also tend to be in the centre of the interpersonal communication structure and influences many other individuals.

- The **system consequences** are "the changes that occur […] as the result of the adoption or rejection of an innovation" (ibid., p. 436). These effects can be categorized into three groups: Desired/Undesired, Direct/Indirect and Anticipated/Unanticipated. The predictability of consequences might depend on more than the design of the innovation. The function of the innovation might, for instance, be harder to understand. This is why consequences of introducing an innovation sometimes can be hard to predict. As an example,

introducing a real-time information system in to a public transport system might not only give the potential travellers real-time information, but might also have consequences on the expectations on predictability of the transport itself.

The rate of diffusion is also affected by how the decision to adopt is taken, that is by the **types of innovation decisions.** The ways in which decisions are made to adopt or reject an innovation are many but can generalized into three main groups:

- Optional innovation-decision: Every potential adopter makes the decision to adopt or reject individually.
- Collective innovation-decision: The decision is made as a consensus decision.
- Authority innovation-decision: The decision is made by a few individuals with power, status and/or technical expertise. The rate of adoption is known to be higher in this authority-driven kind of diffusion.

Innovations differ in character and so does the rate of diffusion. The **perceived character of the innovation itself** might be highly important.[4] Rogers (ibid.) identified five qualities that he states are more important than others.

- **Relative advantage** – The innovation has to be regarded as better than the alternative. Better does not merely refer to efficiency or economic advantages but also factors that affect social status etc.
- **Compatibility** - Refers to the degree to which the innovation is compatible with societal norms and values. The use of public transport might for instance not be perceived as compatible with an individual's status and social class.
- **Complexity** - The perceived level of difficulty of use and the perceived amount of energy needed to learn new skills in order make use of the innovation will affect adoption rates. For instance it can be assumed that less people will start using a traveller information system function if it is perceived as difficult to use.
- **Triability** - A possibility to partially test or in an early phase of planning try the innovation will decrease the level of uncertainty and through this make adoption more likely. An inveterate car user might, for instance be more likely to use public transport if s/he is offered a week of public transport without having to pay for the rides made.

[4] The character of the innovation is mentioned also in TAM and UTAUT but Rogers goes into greater details when describing the qualities affecting the perceived character.

- **Observability** - Refers to the degree to which the results of an adopted innovation can be observed by those that have yet not adopted it. An individual might be more likely to try public transport if s/he notices that the neighbours have sold their cars.

The technology might constitute a barrier for usage of traveller information and the character of the technology is consequently an important factor when studying the effects of introducing traveller information systems.

2.3 Summary and Implications for the work

The presented theories and models describe the transport context and represent some theories and models that can be used in order to understand processes involving and expectations put on systems for ICT-mediated traveller information.

Systems for ICT-mediated traveller information are part of a highly complex transport system. The communication between actors within and around the transport system is as complex as all interpersonal communication and the efficiency therefore always limited.

Models on behavioural change and uptake of innovations are presented as tools in understanding the usage of ICT-mediated traveller information and the sometimes inert process of change in travel behaviour. The models and theories describing behavioural change and adoption of innovations are sometimes noticeably generic in character and need to be combined and developed in order to suit the complex context of transport and technology on the boundaries between public and private investments.

3 Research Approach

The licentiate thesis is based on three studies, here named Study A, Study B, and Study C. The studies had different aims and applied different methods in order to address different research questions.

3.1 The studies

Each of the studies addressed a unique set of research questions (Table 1) and applied different methodologies (Table 2).

Table 1 Research questions per study

Research Questions	Study A	Study B	Study C
Which have been the objectives for implementing real-time traveller/passenger information systems in public transport organizations?	✓		
How have these objectives been evaluated and/or fulfilled?	✓		
What changes, if any, have occurred in travellers' media use related to public transport traveller information?		✓	
Are there any effects of introducing a system for ICT-mediated traveller information on potential travellers?		✓	✓
What effects can be identified?		✓	✓
What are the short-term vs. the long-term effects?		Long term effects	Short term effects

Study A addressed the providers of the traveller information, whereas same Study B and C focused on travellers.

Study A was an explorative study attempting to create a deeper understanding of what effect(s) the introduction of systems for specifically real-time traveller information has had on public transport organizations and employees. Introductions of systems of this kind started already in the mid 1980's but some of the transport organizations in Sweden have still not (2012) implemented the technology. The study was designed as an interview study. Retrospective interviews were carried out with employees who were involved in traffic information at public transport authorities.

Study B aimed to reveal potential long-term effects of access to real-time traveller information and did so through measuring changes in responses from actual and potential travellers. Study B combined the results from a questionnaire study performed in 1997 and responses to a questionnaire sent out in the beginning of 2009. The data collection was therefore to a considerable extent governed by the data collection method chosen for, as well as questions posed in the first study.

Study C explored the possible short-term effects on actual and potential travellers of the introduction of a system for ICT-mediated traveller information, more specifically a co-modal travel planner. The study was designed as a before and after study with

identical questions distributed to a sample of individuals before the introduction and 9 months after the introduction.

Table 2 Data collection method, number of participants; type of participants, and context per study

	Study A	Study B	Study C
Data collection method	Telephone interview	Postal survey	Web survey
Participants, number	N= 12	N=494	N=115
Participants, type	Subjective sample of employees at PT authorities	Randomized sample of individuals in Gothenburg	Subjective sample of individuals in Stockholm
Context	Sweden	Gothenburg	Stockholm
ICT-mediated service investigated	Real-time information	Real-time information at bus/tram stops (minutes left), information on disturbances at bus/tram stops, real-time information on the web, travel planner on the web	Co-modal travel planner

3.2 The systems studied

This thesis has in two of its three included studies, Study B and Study C, taken the traveller's perspective on the systems for ICT-mediated traveller information. The systems are therefore categorized according to the interface and content of the system rather than the underlying technical structure. Four different systems for ICT-mediated travel information have been investigated. Two were placed on the web site of Västtrafik, the public transport authority (PTA) in the region of Västra Götaland (including Gothenburg), Sweden (http://www.vasttrafik.se). The first of these two information services was a web-based public transport travel planner (see Figure 3-1)

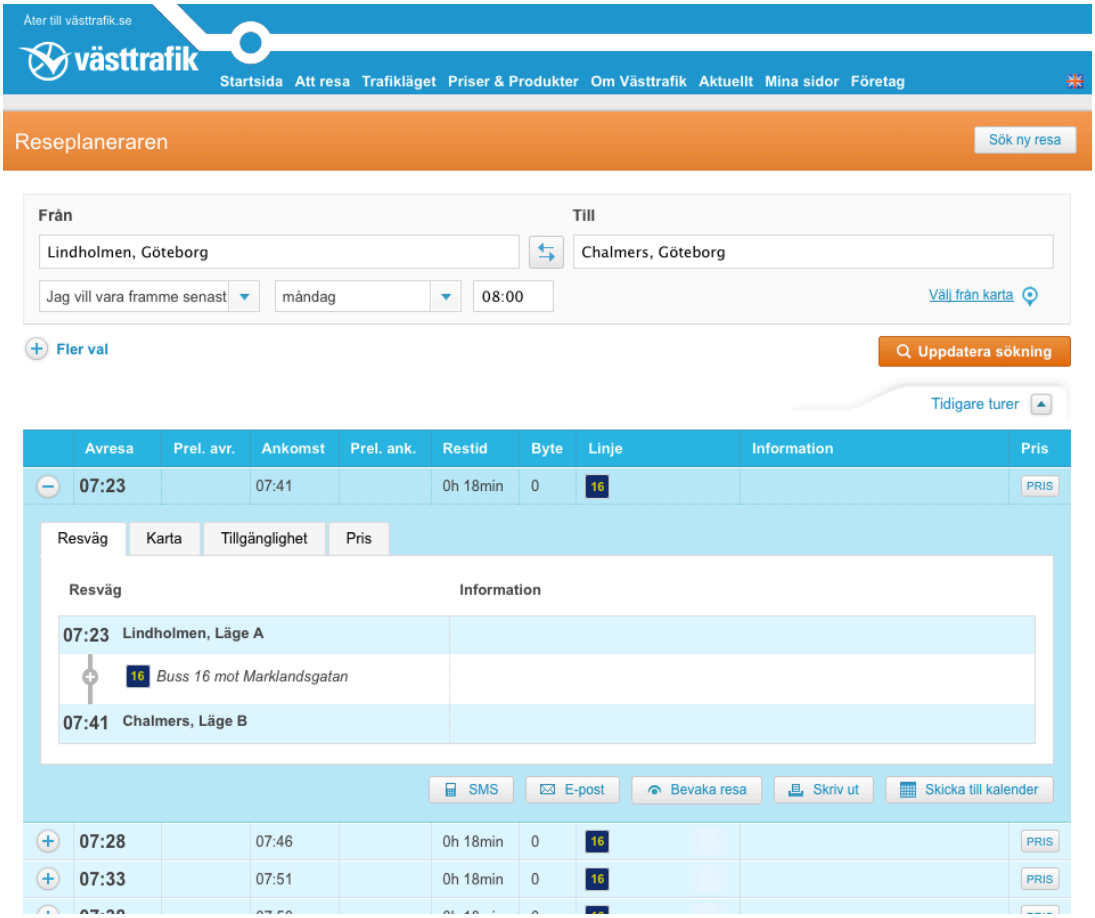

Figure 3-1 The public transport travel planner (Source: http://www.vasttrafik.se)

The second information service was a web-based real-time travel information service for public transport with continuously updated information on estimated departures from a specific stop (see Figure 3-2).

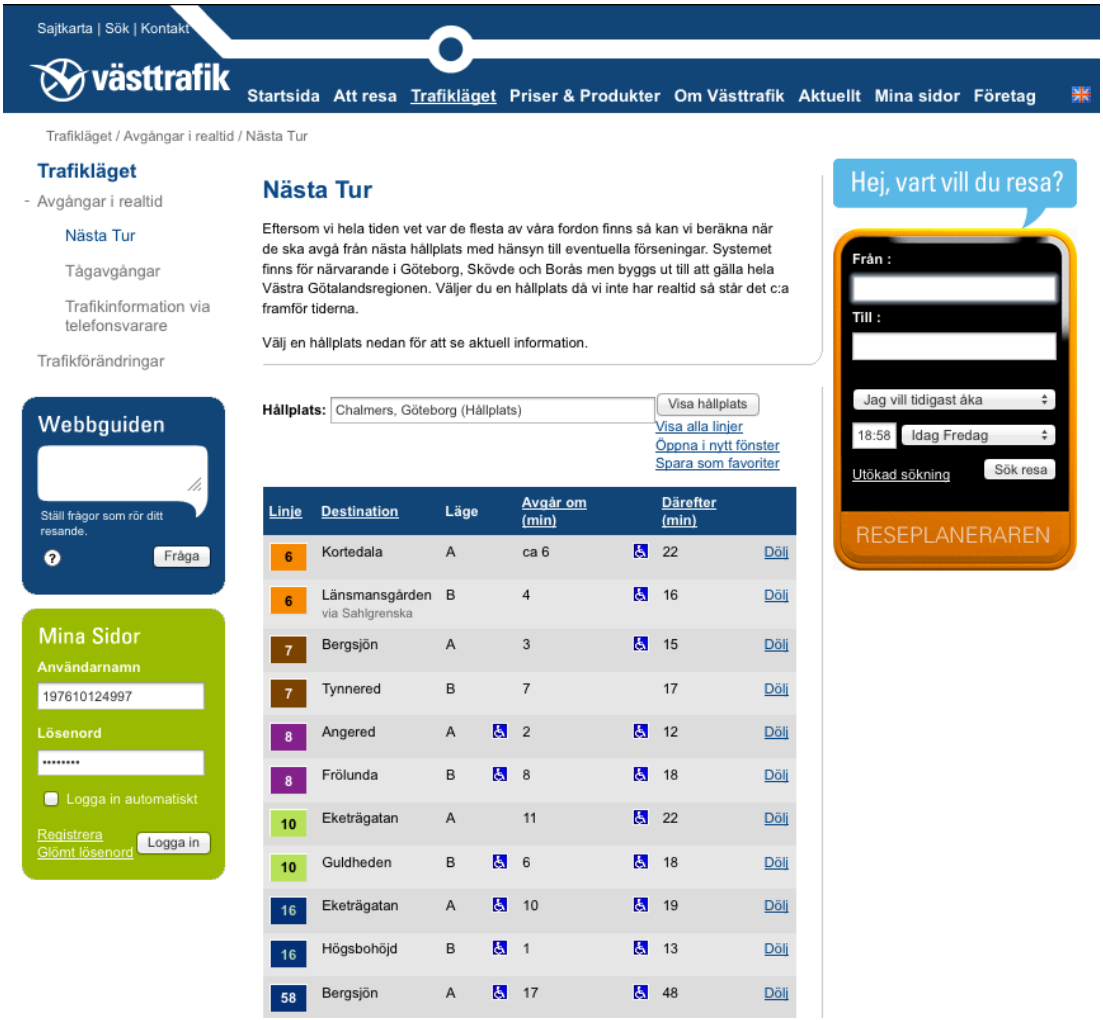

Figure 3-2 The web-based real-time information service(Source: http://www.vasttrafik.se)

The third information service was the same type of real-time information as that depicted in Figure 3-2 but presented on screens at bus/tram stops in the Gothenburg region (see Figure 3-3)

Figure 3-3 Real-time traveller information at bus/tram stop in Gothenburg, Sweden

The potential effects that these three systems have on travellers were researched in Study B.

Study C explored the potential effects that the co-modal travel planner for the Stockholm region (see Figure 3-4) had on travellers. The co-modal travel planner was a web-based travel planner for the Stockholm region that could combine private and public modes of transport in the same trip.

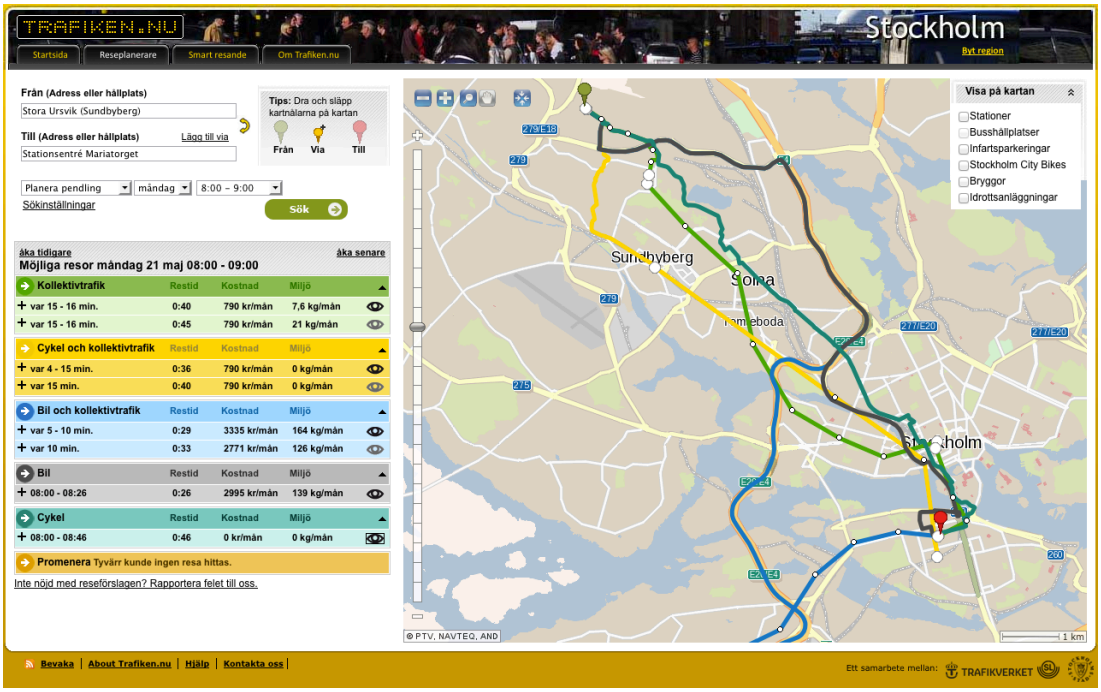

Figure 3-4 The co-modal travel planner of the Stockholm region (Source: http://reseplanerare.trafiken.nu)

Study A focused on the effects that the introduction of systems for real-time travel information had on the PTAs in Sweden. The system was in Study A therefore not defined by the interface of the system but rather by the capability and structure of the sensors and processes that constitute the basis for the production and broadcast of real-time travel information.

3.3 Research perspectives

The potential effects of introducing systems for ICT-mediated travel information have been analysed from two different user perspectives. The use, and the motive for usage, of the automatic vehicle location based real-time information system differ between travellers and transport organisations. The potential effects of introducing these have thus been studied from two different kinds of user perspectives: the travellers' perspective and the perspective of public transport authorities.

Franzén (1999a) connected the time horizons of the transport system with the actors associated with the system as well as the time perspective of the use of travel information. The time perspective is in this way an important factor in clarifying and describing the groups of actors. This facilitates an analysis of both the system from a holistic perspective and the different perspectives and needs of different groups of actors.

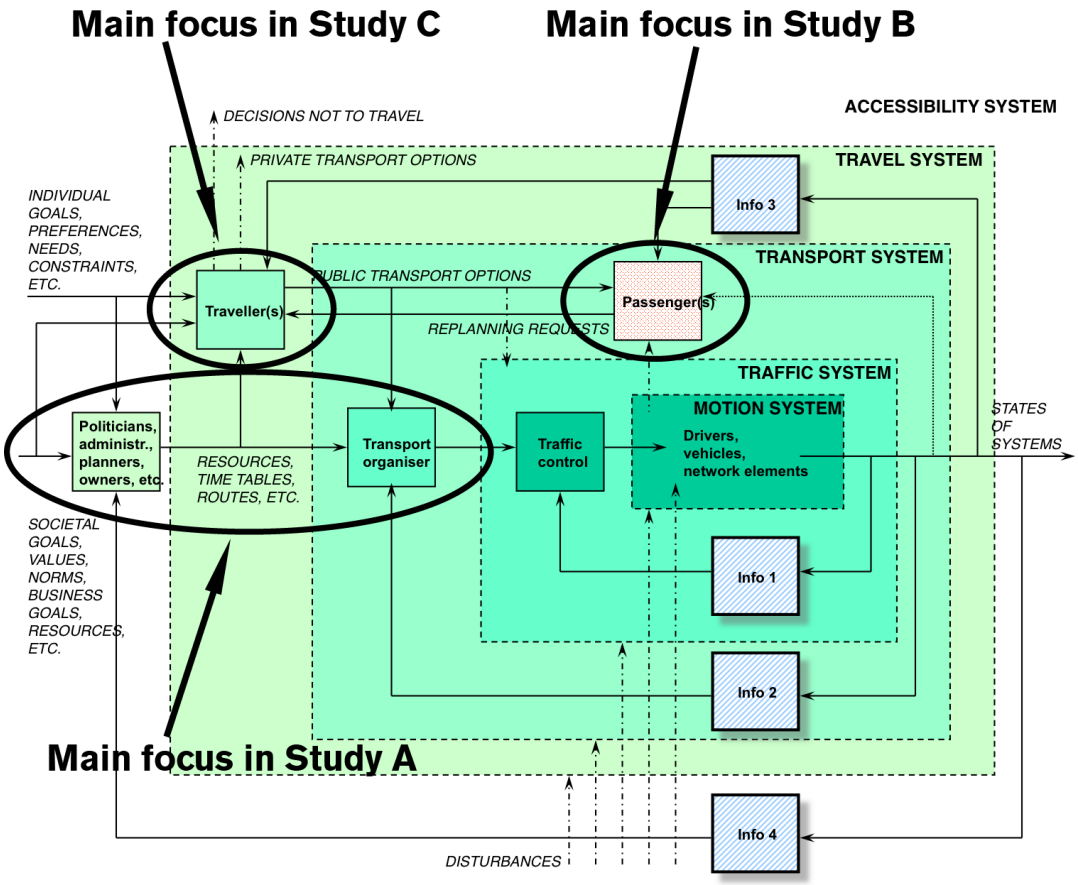

Figure 3-5 The ideal public transport process (Source: Franzén, 1999a). Studied actors indicated with ellipses.

The systems for ICT-mediated traveller information that have been studied here work with information that is also used by other actors than those that have been studied in this thesis. The actors studied in this thesis can in the conceptual model presented by Franzén (1999), (see Figure 2-1), be found on the levels of transport system (transport organisers in Study A, and passengers in Study B), travel system (travellers in Study C), and accessibility system (e.g. travel planners in Study A). The main foci of the studies are indicated with ellipses in Figure 3-5.

Time is, as described in section 2.2.3.2, also an important factor for the diffusion of innovations. This applies both to the large technical information systems that are the bases for ICT-mediated traveller information and to the travellers' uptake of services and technology. Behavioural changes need thus also be understood from a time perspective. It might therefore be relevant to apply both a short- and a long-term perspective on the effects of introducing systems for ICT-mediated traveller information. Studies of both long-term effects of the introduction of real-time traveller information at bus/tram stops, real-time information on the web and a travel planner service on the web as well as the short-term effects of the introduction of a new travel information system, a co-modal traveller planner, have been carried out.

4 Summary of studies

Three separate studies constitute the empirical basis of this thesis. The aim and main results of each study will be described in this section. The aim and main results are complemented with a short discussion on the implications of the results.

4.1 Study A: Real-time traveler information from an organizational perspective: Driving forces, implementation issues, and deployment effects

Study A was an explorative interview study performed in 2008. The first system for real-time traveller information in Swedish public transport was introduced in 1984. These systems are today common in larger cities of Sweden (e.g. Gothenburg, Jönköping, Malmö and Stockholm).

4.1.1 Aim

The main purpose of Study A was to understand the public transport authorities (PTAs) motives for introducing real-time information to travellers. The questions posed were thus:

- Which have been the objectives for implementing real-time traveller/passenger information systems in public transport organizations?
- How have these objectives been evaluated?
- Have the objectives been fulfilled?

A second purpose was to investigate how the systems were introduced and the consequences for the organisations.

How were the systems introduced into the organizations? How did, the organizations e.g. prepare for the introduction?

- What consequences, or effects, of the deployment of real-time traveller/passenger information systems have been noted? For instance, has the organization changed in any way as a consequence? In what ways have the organization benefited from deploying real-time information system?

4.1.2 Method

The study was an interview study performed in 2008. The contacted individuals represented 12 of the 21 public transport authorities (PTAs) in Sweden. These organizations were all members of the Swedish Public Transport Association and were chosen to represent both large and small public PTAs, active in rural as well as urban areas, and with a wide geographic distribution throughout Sweden. The interviews were conducted as semi-structured telephone interviews.

4.1.3 Results

The first systems for real-time traveller information introduced in Sweden were put into place in the mid 1980's and only three out of the twelve organizations did not offer real-time traveller information at the time of the interview. One of these three organizations was planning to introduce such a service in the upcoming year and one organization had offered real-time information earlier but had discontinued this as a

result of technical problems. Those organizations that did not offer real-time travel information to their end customers were those with the smallest number of passenger kilometres per year.

Motives and objectives
Some of the organizations reported well-defined goals associated with the introduction of real-time information systems. Among the motives mentioned to invest were to:

- increase the number of travellers;
- improve the overall quality of the service;
- obtain a more efficient fleet management;
- support traffic planning and political decisions on public transport issues in general;
- increase safety for drivers

There were however those PTAs with more vague motives. The governmental grant covering half of the cost relating to accommodate transport service to travellers with disabilities were said to be an important factor. Another argument was the fact that other PTAs had introduced real-time information systems and a third that one was told to as the local politicians had taken the decision.

Measured effects of introduction
To measure the proximity of goals when motives are vague is understandably difficult. Measurements of potential effects had on the other hand, also in cases, where objectives had been clearly stated, nevertheless been rather imprecise, if at all performed. Effects of increased travelling had for example not been explicitly evaluated in relation to the implementation of systems for real-time traveller information. The effects of introducing systems for real-time traveller information could thus not be found through asking PTAs but must be measured in other ways.

Implementation
The introductions were in many cases problematic and delayed. The top management was reported to not have been aware of the complexity of the system and the matter of implementation seems to a large extent have been allocated to the IT-department and/or traffic planners. This could point to that the introduction of the systems had mainly been regarded as a technical matter, and not a tool for organizational change or a shift in organizational culture or a shift towards a more explicit service perspective.

Based on the interviews, no one from the four main user categories: travellers, drivers, information service staff (or corresponding), and traffic control operators had been involved in neither development, nor implementation of the systems.

Organizational effects
The introduction of the systems for real-time information had in several cases been followed by changes in the organization that were unplanned previous to the introduction. The mentioned changes were e.g. an introduction of a department for customer relations, and a change in the organizational position of travel information service personnel. Some organizations reported, though, to have their information

officers placed outside of the main organization. In specific cases the information officers did not even have access to the real-time traveller information.

4.1.4 Conclusions and Implications

Thus, the objectives for introducing real-time information systems varied significantly. Some objectives were vague and few organizations had followed up on the effects of the introduction. This makes it difficult to judge if the investments in systems for real-time information had rendered anticipated results.

The introduction of systems for real-time information was often accomplished with modest involvement of end-users such as traffic planners, information officers (back-office), or travellers (front-office). The introduction had in some cases been followed by reorganization and placement of divisions working with customer information related services. It is possible that a proactive approach when introducing the systems would have made the results more predictable and more in line with the need of customers/travellers as well as the organisation.

4.2 Study B: ICT-mediated information services in public transport: Travellers' use, assessment and long-term effects

Study B is a quantitative study performed in 2009 as a repetition of a study performed in 1997.

4.2.1 Aim

The study attempted to elucidate what the potential long-term effects are on travellers and travelling of the introduction of a system for ICT-mediated traveller information.

The main purposes were to:

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

4.2.2 Method

Study B consists a survey following a study completed in 1997 (see Sekara et al. 1997; Sekara & Karlsson, 1997b). Study B was therefore deliberately designed to reflect the first study as exact as possible. Postal questionnaires were sent to random sample of households in the city of Gothenburg, Sweden (Table 3) from the same 13 postcode areas of Gothenburg as in the study completed in 1997.

Table 3 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 demographics, technology use, use and assessment of transport modes, use and assessment of sources for information on transport and perceived problems related to transport or traveller information. The questions were mainly of a 'multiple-choice'-type in order to attain as high a reply rate as possible. The questionnaires were collected before software solutions specialized for usage in nomadic devices[5] had been widely accessible.

4.2.3 Results

Travellers' use and assessment of ICT-mediated services

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 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 (e.g. over the phone) was still not established in 2009. The highly rated benefits of real-time information at bus/tram stops lasted from 1997.

Stated effects of access to information services

The perceived benefits of having access to web-based travel planner increased significantly from an already high level in 1997. This was in line with an increase of respondents that reported to experience more efficient travel and shorter waiting times as a consequence of having access to the web travel planner 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.

The benefits of *real-time information* at bus/tram stops were looked into in detail and followed a similar pattern. Between fifteen and forty-eight per cent of the respondents reported in 2009 to experience: less stress, shorter perceived waiting time at stop, more efficient trips, easier to choose route, and/or feeling safer as a consequence of having access to real-time traveller information at stops. These effects are likely to contribute to that 17% of the respondents in 2009 reported to travel more with public transport because of having access to real-time information at stops. This was a significant increase from just under 2% in 1997.

Respondents were also asked about *real-time information* on the web. In 2009 between 8% and 41% of the respondents stated to experience: less stress during trip, shorter perceived waiting time at stop, more efficient trips, and/or feeling safer as a consequence of having access to web-based travel information. Almost every fifth

[5] 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.

respondent reported in 2009 to travel more public transport because of having access to web-based real-time information. This was a significant increase from about 2% in 1997.

Additional effects
The respondents' rating of how well the public transport system (PT) fulfilled their requirements had increased, from a median value of 7 in 1997 to 8 in 2009. The respondents' car ownership had decreased and the usage of public transport had increased between 1997 and 2009. The increase in usage of PT between 1999 and 2009 was twice as high as the increase in population in the same area.

4.2.4 Conclusions and Implications

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 assessment and attitudes towards real-time traveller information and travel planner services remained positive over time. This indicates that its importance to travellers remained, lasting beyond first exposures in which the traveller can be expected to rate such services highly as consequence of a positive change or an unexpected bonus to the basic service of transport. It is likely that a continuous improvement of service quality of the information is required to keep the high ratings in the future.

Another aim was to investigate the effects on travellers of introducing systems for ICT-mediated traveller information. The large increase in the number of respondents stating to travel more as a consequence of having access to the public transport web services and the real-time travel information on stops is likely to be explained by the an increased access and an increase in quality of the services. Other perceived effects, e.g. 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. An increase in the number of trips made by public transport compared to the number of trips made by car might not just demand an increase in the number of people that start using public transport but also by keeping those that already use public transport. The perceived benefits of having access to real-time traveller information and web-based services might contribute to that.

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 the computers have been adopted by a large part of the population but there are still those that do not own or use the technology needed for accessing offered services. As the type of service offered through these media is highly appreciated, this implies that the designers of systems handling information of this type should be aware of the potential in adapting the system to communicate this type information through media already used also by late adopters.

It is likely that the travellers' requirements for accessible and updated information, through different information channels, will increase in the future as a consequence of the corresponding development in other areas. This development is just starting and will rise from a lower level of design maturity: possibility to get information, to a higher as demands increase: good usability and integration into systems closely related to the rest of the life of the traveller.

4.3 Study C: Appreciated – but with a fading grace of novelty! Traveller's assessment of, usage of and behavioural change given access to a co-modal travel planner

Study C was a quantitative study 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 a co-modal travel planner was made in an attempt to influence travellers to, through increased knowledge and understanding, find shorter, more energy efficient, and cheaper ways of travel in the Stockholm area.

4.3.1 Aim

The aims of the study were to investigate

(i) travellers' attitudes towards travel planners in general and the described travel planner in particular;
(ii) if access to the travel planner resulted in any changes in the travellers' travel behaviour in terms of e.g. choice of travel mode.

4.3.2 Method

The study was set up as a web-based questionnaire that was 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 perceived 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 behaviour. Demographic data like gender, age, occupation and distance to workplace/study place was also collected.

4.3.3 Results

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

Usage of service
Less than 40% of the respondents answering the second questionnaire claimed to have re-visited the web site within the nine months period. Half of those that did re-visit the web site reported on the other hand to have visited the site at least once per month over the same period.

Assessment of service
The type of service offered by the travel planner was rated less valuable after nine months (i.e. less useful, less effective, less likeable and less stimulating). Statistically significant negative changes were also found in the respondents' assessment of the value of this specific planner; how well liked the planner was. The level of trust in the

information presented by the planner did, on the other hand, remain high over the nine months period. Few respondents reported not to trust the information.

Anticipated and reported actual effects
Eight per cent of the respondents reported in the first survey to believe that the planner would make them travel more often with public transport and three per cent that they would travel less often by car.

Nine per cent of the respondents reported to have increased their use of public transport but only one (1) individual believed to have travelled less often by car as a consequence of having access to the travel planner. None of the individuals from the group that were subjected to a move of their workplace reported to have changed their travel behaviour. No statistically significant changes in reported travel mode use could however be found despite nine per cent reported to have increased their use of public transport.

Moreover, no correlation could be found between stating to expect a change in one's own travel behaviour and later reporting a change 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 a small number of respondents stating a change of travel mode.

4.3.4 Conclusions and Implications

The travellers' assessment of the planner was initially positive and changed to neutral after nine months despite no changes being made to the planner. Less than 40% of the respondents reported to have returned to the planner during the nine months period between the surveys.

Few travellers reported to have changed travel behaviour as a consequence of having access to the travel planner. Nine per cent reported a perceived increase in the use of public transport but this did not seem to be accompanied by decrease in the use of private car.

The relatively quick negative change in some of the variables in the assessment of the co-modal travel planner might be due to that respondents, in the first survey, might have rated the *idea* of a co-modal travel planner rather than the *actual* travel planner itself.

4.4 Summary of main findings

The generic aim of the studies described in this thesis was to elucidate how systems for ICT-mediated traveller information and the information services provided have been received by the different users and what the effects of introducing new ICT-mediated traveller information systems are. The effects have been studied on a short and a long-term perspective, on travellers as well as on organisations. This summary is divided into two parts. The first set of questions concerns public transport authorities and the second concerns travellers.

The first set of questions focused on the transport organisation:

- Which have been the objectives for implementing real-time traveller/passenger information systems in public transport organizations?
- How have these objectives been evaluated? and
- Have the objectives been fulfilled?

Based on the result of the empirical studies, the following conclusions are proposed:

- Several objectives for introducing systems for real-time traveller information were vague.
- The fulfilment of objectives had rarely been evaluated;
    - The public transport organisations could not report on any effects of introducing systems for real-time traveller information into their organisations. Nevertheless, it is possible that introduction of systems for real-time traveller information facilitated an adjustment towards a more service related approach.

The second set of questions concerned travellers:

- Are there any effects of introducing a system for ICT-mediated traveller information on travellers? Can short-term effects be noted? Can long-term effects be noted?
    - If effects can be identified, what are these effects? What are the short-term effects? What are the long-term effects?
- What changes, if any, have occurred in travellers' media use related to public transport traveller information?

Based on the result of the empirical studies, the following conclusions are proposed:

- Almost every tenth respondents (nine per cent) claimed to travel more with public transport as a consequence of having had access a *co-modal travel planner* despite that few of the respondents (forty per cent) had revisited the planner in nine months.
    - No change could be found when analysing actual travel mode choice.

- Almost every sixth respondent (seventeen per cent) claim to travel more with public transport as a consequence of having access *real-time public transport traveller information at stops*.

    - The share of respondents claiming that access to real-time public transport traveller information at stops make them travel more with public transport has risen significantly from 1997 to 2009.
    - The perceived value of real-time information had remained high over time.
    - The real-time information was frequently used.

- Almost every fifth respondent (nineteen per cent) claimed to travel more with public transport as a consequence of having access to the *web-based public transport travel planner*.
    - The share of respondents claiming that access web-based public transport information service make them travel more with public transport had risen significantly from 1997 to 2009.

- Between 1997 and 2009 travellers' *media use* related to public transport traveller information had changed considerably.
    - Computer-based media had become the most common way to acquire public transport traveller information.
    - The travellers less often turned to the public transport information service centre directly or by using the telephone.

5 Discussion and conclusions

The effects of introducing systems for ICT-mediated traveller information and potential reasons for these effects are discussed in this section.

5.1 The traveller perspective

5.1.1 Travellers' media use

Study B showed a change in the travellers' use of different media for acquiring information. The use of printed timetables was in 1997 the most common type of media for obtaining public transport travel information. In 2009 this had changed and computers had become the most frequently used information channel.

The large increase in the use of web-based information services correlates with the increase of the share of the population that has access to Internet connected computers. The share of the Swedish population aged 17 or older that had access to Internet at home increased from 10% in 1997 to 83% in 2009 (World Internet Institute, 2009). Nevertheless, the change in media used for acquiring travel information was probably also affected by other factors. One important factor may be the discontinuation of distributing printed information (timetables) to households in and around the studied region. Another, that the computer-based media offered additional types of information to the types of information that were available through printed media. For instance, online information is possible to continuously update and will therefore potentially be more relevant to the travellers. Yet another reason for the change is that travellers might appreciate to gather as much information related to public transport as possible through one information channel, in 'one place'. This was possible through web-based media.

The study also showed that the use of handheld devices for acquiring travel information (i.e. mobile phones etc.) was very limited in 2009. It is most likely that the amount of personal information acquisition via handheld devices will increase. Offering good travel information service through this medium will then be increasingly important.

5.1.2 Travellers' assessment of real-time information

A somewhat surprising result from Study B was that travellers' assessment of the real-time travel information presented at stops and on the web after 12 years had increased slightly from an already high level. There are, to the author's knowledge, no other studies that have followed the travellers' assessments of a traveller information system over such a long period time. This also means that it is not possible to compare the reported results with other, similar studies.

The real-time information services also seemed to positively affect the overall customer satisfaction of the public transport system. This is in line with motives mentioned by representatives of public transport organisations.

The focus when attempting to raise customer satisfaction with a product or service has often been to fulfil excitement requirements (cf. Matzler et al. 2004; Deng et al., 2008). An excitement requirement is one of three types of requirements (or needs) that were proposed by Kano (1984): Excitement; Performance; and Basic requirements. The excitement requirements are to be fulfilled by attributes that are not

expected by the customers and would therefore not be missed if not found. The problem with exciters is that they can be considered one-off affairs. That is, if customers get used to an attribute, the attribute can change from being an excitement attribute into a performance attribute, and over time even into a basic attribute. One of the characters of a performance attribute is that it is not assumed to render as high assessment as the exciter. The very high assessments of real-time information services indicate that the services could be exciters but one thing implies that this way of analysing the real-time information services does not render any further understanding. From an already high level there was a slight increase in travellers' assessments over a period of nine years. Had the services been exciters, assessments could be expected to drop after some time as the travellers had become familiar with the services and novelty had faded. This did not take place. Hence, the long-term high assessment of real-time information services does not seem to be explained by a characterization into requirements and attributes of the type proposed by Kano. Instead, other explanations must be found.

The travellers might have considered real-time traveller information as a bonus, an exciter, when it first was introduced but even though they have gotten used to the idea of having access to the real-time information the assessment has remained over time. An interpretation is therefore that real-time travel fulfils an actual need of the traveller. However, the assessment has also increased which cannot be explained by an increased need but rather that the service has matured over the years by improved reliability (in terms of precision) as well as usability. The number of stops where real-time traveller information is presented has also increased resulting in an overall increased accessibility to the information. This could imply that the quality of the service might, from this relatively mature level, have to keep improving in order to keep being highly assessed.

5.1.3 Differences in travellers' assessment and adoption of services

Study B showed that the real-time traveller information presented on the web was highly rated over a period of twelve years. The co-modal travel planner in Study C was on the other hand more moderately rated. This was the case despite that the initial ratings of its benefits were quite positive. Study B also showed the adoption of ICT-mediated traveller information, in the case of the web-based public transport planner, to be well established. Study C found that adoption of the co-modal travel planner had not been established. Few travellers had previous to the study of the co-modal travel planner visited or, during the study, re-visited the co-modal travel planner within a nine months period. Some of the difference in adoption and assessments between the services might be understood by comparing the information services.

There are, indeed, several similarities between the services. They are all services for ICT-mediated travel information available online, offering information about public transport. The services are all designed for a Swedish audience and they are fully or partially funded by Swedish public transport authorities. These similarities could suggest a similar kind of adoption for all services. There are however important differences between the services. One difference relates to the aim and time perspective of the information provided by the services.

The system for real-time information aims to support the traveller in or just prior to a

travel activity. This is a short time frame spanning from seconds to about half an hour. The co-modal planner was, on the other hand, planned to inform the travellers before deciding to travel or even before deciding on where to live or work. This is a longer time frame spanning from minutes and hours to years. This time difference might indicate an order of urgency regarding the need for information amongst the travellers using the services. It could be assumed that such an order would lead to that travellers that are more urgently in need for information would adopt a corresponding service to higher degree than those with a less urgent need. As the adoption of real-time traveller information services was more established than that of the co-modal travel planner, one could argue that this is the case. However, no difference in adoption could be found when, in Study C, the travellers that were assumed to be in more urgent need for the service delivered by the co-modal travel planner (those that were subject to an move of offices) were compared with those that were assumed to be of less immediate need of the service offered. It can therefore not be concluded that the difference in adoption is due to the urgency of the need to know or time perspective of the service.

A second difference between the types of services relates to the kind of questions that the information given by service provides answers to. The travellers using the web-based real-time information service can be assumed to in most cases already have decided to use public transport and to rather seek information about *how* and *when*. The co-modal travel planner was, on the other hand, meant to be used by travellers who need to know *if* they should travel by public transport. These are two different kinds of questions and the difference could be expected to affect the adoption.

If instead the Diffusion of innovation theory is used as a basis for understanding the adoption process, the decision to adopt is in the case of traveller information would be what Rogers (2003) called an optional innovation-decision. A decision to adopt an innovation like traveller information is made by every traveller as an individual. In case of optional decision-making Rogers (ibid.) also states that there are five qualities of the perceived character of the innovation that are more important than others to the adoption process. The differences in adoption of the different types of traveller information, the real-time traveller information and the traveller information given by the co-modal travel planner, could partly be understood by considering these five qualities. The systems could be argued to be equally **Compatible** with societal norms and values as well as having fairly similar **Triability** and also have a fairly similar **Complexity**. It is therefore fair to believe that the difference in adoption depends on other factors. The **Observability** of the real-time systems is higher than that of the co-modal travel planner as the real-time information is shown in a large number of places and travellers are in this way frequently reminded of its existence and possible use. The last of the five qualities that Rogers (ibid.) found most important is the **Relative advantage**. It is possible that the Relative advantage of having access to real-time information online (compared to no such information) is larger than the Relative advantage of having access to a co-modal travel planner (compared to having no such information). In addition, the perceived advantage of receiving an answer to a question regarding how or when to travel in a near future might be greater than the perceived advantage of getting general information on annual costs, emissions and potential trip alternatives in a more distant future (cf. the earlier discussion on time).

5.1.4 Effects of introducing ICT-mediated traveller information

Nineteen per cent of the respondents in Study B stated that having access to web services provided by the public transport authority made them travel more with public transport. Based on the available data, it cannot be confirmed if this increase reflects a change in travel mode used. There are several studies on the effects on travellers' behaviour from introducing systems for real-time travel information for public transport, however only a few that indicate similar numbers as those in Study B (cf. Schweiger, 2003; Chorus et al., 2006) and then as a consequence of far more extensive changes than introduction of real-time information only.

Nine per cent of the respondents in Study C stated that having access to the web-based co-modal travel planner made them travel more with public transport. However, the results indicate that the effect of ICT-mediated traveller information on travel behaviour is limited - if by change of travel behaviour is meant a shift from private car to public transport solutions. Studies on the effects of travel planners are scarce but e.g. Laine et al (2003) show similar results to that of Study C.

Little support for the expectations for ICT-mediated traveller information to influence a change in mode use for transport was thus found. It might therefore be relevant to take a closer look into the reasons for such expectations. One possible explanation to the expectations is that they are based on a similar way of thinking as the linear communication model (such as Shannon's "schematic diagram of a general communication system" shown in Figure 5-1). This linear way of thinking implies that a successful transfer of a message is expected to cause an effect (i.e. a behavioural change) in a way similar to that illustrated in Figure 5-1.

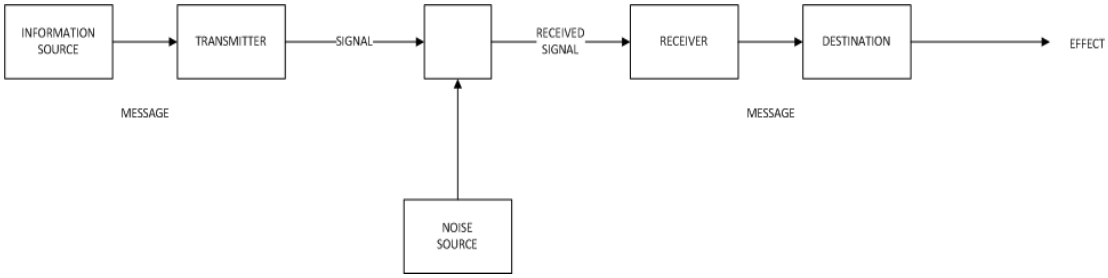

Figure 5-1 Shannon's (1949) schematic diagram of a general communication system with effect added

Considering the theories described in the framework, such expectations must be complemented by a wider understanding of human behaviour. Two factors that are lacking when trying to use a linear models such as the one illustrated in Figure 5-1 in trying to predict effects of introducing a system for ICT-mediated traveller information are those connected to adoption processes and those connected to the process of behavioural change. Theories and models dealing with these two factors were presented in section 2.2 and will be shortly discussed here.

Behaviour, and thus behavioural change, is, according to Ajzen, affected by intentions, which in turn are affected by attitudes, norms and perceived control. The *attitude* towards public transport, and *perceived control* of a mode shift are negative among many car users (Ibrahim, 2003; Beirão & Sarsfield Cabral, 2007)). The *norm* could however be argued to be positive as car driving is often considered as an environmental and spatial problem. Changing attitudes towards public transport use

could be a long process only partly affected by information solutions. It is possible that ICT-mediated travel information has a greater influence on perceived control than on attitudes. The focus on attitude as a dominating factor in behavioural change has moreover been questioned and several sources point to habits being a central factor (cf. Ouellette & Wood, 1998; Verplanken et al., 1997; Eriksson et al. 2008). Several studies show that habitual or repetitive travel patterns are common and often established in a short period of time (cf. Huff & Hansson, 1986; Golledge & Gärling, 2003). Eriksson et al. (2008) found, for instance, car use to be more strongly correlated with car habit strength than with subjective norm while Chen and Chao (2011) found that intention to switch to public transport amongst car users was affected to a larger extent by subjective norm than by habit. Interestingly, Limayem et al. (2007) concluded that the stronger the habit, the less the prognostic power of intention on the behaviour. These findings were supported by Gardener (2009) who found that intention affected behaviour only if habit was negligible. Bamberg et al. (2003) found however that travel habit did not predict future travel behaviour when the traveller experienced a change in decision context (such as move to a new city). This contradicts the results from Study C where those travellers that did experience a change in decision context could not be found to have changed their traveller behaviour to a higher degree than that of the remaining respondents. Thus, even by adding the framework of behavioural change, it is very difficult to predict the effects of introducing systems for ICT-mediated traveller information.

The second type of factors to be lacking is the type connected to the adoption process. Every traveller that is going to adopt an innovation (i.e. change behaviour because of given access to ICT-mediated traveller information) has according to Rogers (2003) to go through five stages of adoption: Knowledge, Persuasion, Decision, Implementation, and Confirmation (cf. Figure 5-2).

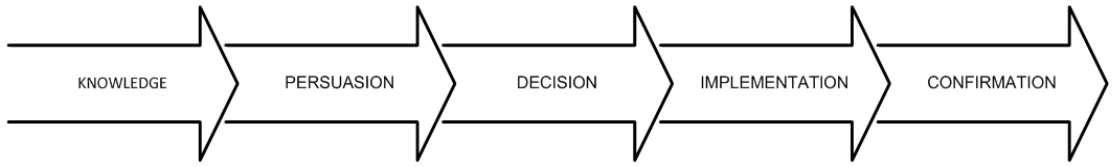

Figure 5-2 Illustration of Rogers five stages of adoption (Rogers, 2003)

The time needed for the process of passing through these stages differs however between individuals. The effects of introducing systems for ICT-mediated traveller information are thus affected by the time used in individual adoption processes. The factors influencing the amount of time needed are several and can be both individual and related to communication. Individual differences that are likely to be of importance in the case of systems for ICT-mediated traveller information could for example be the level of interest in, and experience of, technology (cf. the discussion on innovators vs. laggards). Two types of factors related to communication that might influence the speed of adoption can be found. The first type of communicational factors is a type of factors related to how information *about* the systems are communicated to a traveller and the second is a type related to the kind of information communicated *by* the system. A factor related to the way information about the system is communicated to the traveller could be exemplified by that an individual in the knowledge stage of adoption might be affected to a larger extent by information about the existence of an information service than, for example, an individual in the implementation stage. A factor related to the kind of information communicated by

today's systems for ICT-mediated traveller information is that these systems offers a limited variety of communication types needed. The systems for ICT-mediated traveller information might for example be predominantly designed for one-way broadcasting. This could be one reason that the effects of introducing systems for ICT-mediated traveller information is well distributed time wise. This would in turn then be a possible explanation to a delay in measured effect of such introductions.

5.2 The organisational perspective

Study A focused on the organisational effects of introducing systems for real-time traveller information. A majority of the Swedish public transport authorities have introduced new systems for ICT-mediated traveller information including real-time information services. Several of the motives for introducing real-time information mentioned in the interviews in Study A were similar to what Eason (1988) claims to be the generic benefits often quoted in the employment of ITC systems in general: Cost reductions; higher productivity; improved information to support decision-making; and business enhancement. Such generic claims could indicate a less well-reasoned strategy of introducing said system. Specific motives for introducing new systems for ICT-mediated traveller information were generally described as increasing the number of public transport users and this was also mentioned as a motive for implementing systems for real-time traveller information.

Vague motives and less well-reasoned strategies could be expected to affect the results of an introduction. However, an introduction of a technical tool like a system for ICT-mediated traveller information into a socio-technical system like the public transport system will always result in an impact of some kind. The impact or changes related to an introduction could be difficult to predict but the likelihood of getting the desired impact is supposedly greater if the motives are clear and the introduction is well planned. The impact that an introduction has in an organisation is e.g. affected by the acceptance of organisational change. Senior management support is an extremely important success factor in implementing changes (Pinto & Slevin, 1989; Young & Jordan, 2008). Acceptance of the organisational change processes that accompany an implementation of a large ICT-based system rely a great deal on the seniority of the manager of planning such an introduction (Thompson & James, 2001). Results from Study A indicated however that senior management had limited understanding for the challenges involved. A complex ICT system can also be assumed not to reach its full potential directly upon first operation and to be dependent on adaption by the organisation. However, e.g. Booth and Philip (2005) stated that the importance of IT management is not understood by senior managers, a statement supported by responses given in interviews made in Study A.

In Study B between 17 and 19% of the respondents reported that their number of trips by public transport had increased as a consequence of them having access to ICT-mediated traveller information services. A considerably larger proportion of the respondents reported several other effects. These effects seemed to be related to comfort. For instance, 30% of the respondents in Study B stated to have experienced reduced waiting times, and 53% stated to have experiencing it as being easier to choose between alternative routes. It is not unlikely that the reported benefits for the travellers affect their assessment of the overall public transport service. Had these benefits been more distinctly aimed for, the effects could have been even larger.

5.3 Improving traveller information services

Both the perspective of the sender and the perspective of the receiver have to be taken into account for a communication system to be successful. This section aims to bring these two perspectives together in order to find indications on how to improve the potential of systems for ICT-mediated traveller information.

The use of systems for ICT-mediated traveller information in achieving a change in travel behaviour can be explained in terms of travellers' adoption processes. These adoption processes can be described as three parts or levels, each with its own adoption process:

- Adoption of information technology – physical tool mediating the service;
- Adoption of information service – intellectual tool affecting behaviour;
- Adoption of new travel behaviour – practical change affecting life

These three parts could in turn be associated with specific obstacles, impeding the effects from introducing systems for ICT-mediated traveller information. Individuals can be found in different levels of this change process. Those individuals that are the furthest away from changing their travel behaviour as a consequence of the introduction of systems for ICT-mediated traveller information would be those that have not been through an adoption process on any of the three levels. Those individuals would then have to overcome obstacles on all three levels and could lack the needed technology (e.g. an advanced handheld device), technology knowledge/experience, experience of similar type of information services, and little experience of changing travel behaviour. Those individuals that have reached the third and last level have, on the other hand, already adopted the mediating technology, adopted the information service, and have adopted a change in travel behaviour. The effects that systems for ICT-mediated travel information have on these latter individuals are therefore of a different kind but could still be highly relevant to e.g. the confirmation stage (cf. 2.2.3.2.2).

As mentioned, the three levels of the adoption of a new travel behaviour as a consequence of introducing systems for ICT-mediated travel information each includes challenges. A type of challenge more specifically connected to the adoption of information technology could for example be economical. A type of challenge more specifically connected to the adoption of a specific service could be poor usability of the service or a lack of awareness of the existence of the service. Finally, challenges more specifically connected to the adoption of a change of behaviour could be social or physical.

The number of levels of adoption might also depend on the information service and technology. Some of the services that were studied, e.g. the real-time information service at bus/tram stops, are partly presented through technology with a lower threshold regarding adoption: The real-time information presented on screens at stops does not require an economical investment from the traveller. The same real-time information presented through a connected mobile device might, on the other hand, require both an economical investment in technology as well as a greater interest and knowledge in technology in order to prepare for use of the service.

The separation of the adoption processes of technology-mediated services into three parts (Adoption of information technology; Adoption of information service; Adoption of new travel behaviour) relates to how Rexfelt (2008) explained technology-mediated services (shown in Figure 5-3). The user interacts with a tool (in the case of ICT-mediated traveller information e.g. a desktop computer or a mobile phone) with a purpose of fulfilling a need. The user can in the case of ICT-mediated traveller information not interact directly with the service. The interaction is through technology that is a part of the service content. The total outcome from interaction with the technology as part of the service content is according to Rexfelt what the user judges.

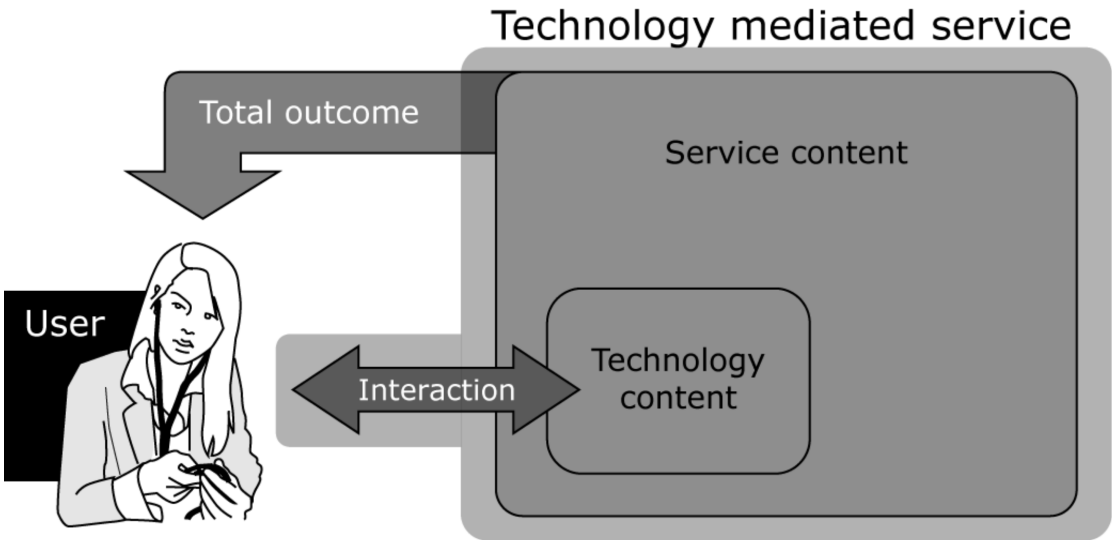

Figure 5-3 A technology-mediated service (Source: Rexfelt, 2008)

The ICT-mediated traveller information service (of which technology content is a part) is, in a similar way to that technology is part of the total service content, a part of an even larger service: the transport service. This leads to that the traveller might judge the total service (i.e. the public transport service) on how the technology and the service content perform (the service content here including both transport service and the travel information service). This forces a successful traveller information system designer to consider the characteristics of the transport service and the user's interaction with the system for ICT-mediated traveller information concurrently.

For information services based on one-way broadcasting, as public transport travel information services tend to be, high quality may be especially important. The importance of ensuring high quality in one-way broadcasting might be due to a lack of feedback from users (travellers) that renders difficulties in useful adjustments of the communication. The quality of the communication is affected by many factors. One of these factors is the channel used for the communication. The choice, design and usage of the communication channel all affect the outcome of the communicative attempt. The capability of a communication system limits, as briefly mentioned in section 2.2.1.1.1, the number of possible messages that can be chosen to be transmitted. The transmitter, receiver and the channel used for the transfer of the signal are all limiting factors and therefore the design of the communication system is an essential part of the process of communication. Designing the communication channel is in this way a technical instrument for defining and restricting the messages

that will be sent via that same channel. The design of a communication system is based on assumptions about the system's future usage. Obviously, if a system/channel has less narrow limitations to what message that can be transferred the selection of possible messages to choose from would be greater than if the limitations were more narrow. The designer's assumption about who will communicate what, to whom, and when, is therefore a limiting factor that will shape the communication.

Another factor vital to the success of communication is the understanding that a sender has of the receiver's mental models. The type and the amount of the information and the time perspectives allowed by the communication system will affect the meaning being created from a message. It is thus possible to consider the system designer as a sender.
It can be argued that no two individuals have the exact same understanding of the world and it is the overlap between the respective fields of experience and hence the overlap in horizons of understanding that enables communication (cf. Gadamer's reasoning about horizons "The horizon is the range of vision that includes everything that can be seen from a particular vantage point" (1998, p.301)). No creation of meaning will be successful without common pre-understanding.

The communication channel used for sending information is typically not created by the receiver (the traveller), nor the sender (in the shape of an information officer) but by a third party, a system designer. The system designer should not be assumed to be an isolated individual but the design is often a result from multiple processes and individuals. An overlap in horizon of understanding between a sender, e.g. an information officer, an information system designer and a traveller could be illustrated as in Figure 5-4.

Figure 5-4 Venn diagram of three overlapping horizons of understanding

The most inner zone where all horizons of understanding overlap constitutes a limitation of potential capability of the communication system. The size of this zone

changes as experience changes, for example if communication between the actors includes feedback. The size of the overlap would also change if the roles of the included individuals were shifted or combined. This leads to two ways of widening the potential of a communication system of this kind:.

- The (re-)design of a communication system like traveller information systems for public transport could be assumed to facilitate improved communication quality if created with/by travellers;
- The (re-)design of a communication system like the traveller information system could be assumed to facilitate improved communication quality if created for feedback from travellers

6 Future research

A similar kind of argumentation that have been the basis for knowing more about the effects of ICT-mediated traveller information for public transport can also be heard regarding other transport areas. It has for example been argued that systems for ICT-mediated travel information for car drivers could have an impact on route choice and driving style and therefore be part in lowering the energy need in relation to car use. To study if such claims are correct could thus be relevant.

A potentially relevant study would be to follow the effects of the adoption process of mobile device mediated information services. One might for example expect that the effect of using these systems differ from that of desk/laptop mediated use as the place and time of usage of these services differ.

An extensive use of mobile devices also opens up for new type use communication and feedback from travellers to the transport organisers. This could affect the public transport system and could be relevant to follow from a systems perspective.

Some software solutions specifically designed or mobile devices are created by travellers with an aim to fulfil an information need of those designers' own needs. A development towards a reduced gap in understanding could also be interesting to follow.

It might also be relevant to study the potential effects of different techniques of bringing the system designers a more clear understanding of the users' perspective. If the type of system designers changes, so might the efficient settings for successful development.

Real-time traveller information makes perceived waiting time shorter and better. The ultimate goal could be not just to make the waiting time as short with minimized negative sides but to turn the waiting time a positive experience. In reality, making waiting time a positive thing is somewhat of a utopia, but having that as a goal might help public transport organisers to shift from a transport to a traveller's perspective. Finding such techniques might be a relevant and interesting task.

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