# Role of ICT in Sustainable Transportation

— Focus on reducing traffic congestion

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<th>Master’s (one year) thesis in Informatics (15 credits)</th>
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Abstract

Our cities have been continually growing at an uncontrolled rate leading to the problem of traffic congestion, which has discernable effects on all the aspects of sustainability, be it social, environmental or economical. This continual shift of increasing size of centre and decreasing size of periphery poses huge sustainability challenge of meeting the consumption demands. We presently face the most unprecedented times in terms of the pace at which our natural resources are getting consumed. It is clear that replenishing some of these resources is totally out of question. On the other side of the coin, the advances of human technology have provided its greatest gift of information & communication technology (ICT). Today we have access to data from any point of the world to anywhere. There is a growing need to use this data and information with a holistic view to build more Intelligent Transport Systems. In our paper we discuss how the advent of ICT can have an impact on bringing a sustainable transportation system. The work is divided in two folds, by first understanding the direct role of ICT in transport sustainability and then observing the direct correlation between usage of ICT and travel demand. The problems of traffic congestion and its solutions like congestion pricing have existed in practice since ages; the perspective which we add to it is the role of ICT in making it better. The greater perspective that is being researched here is at an absolute fundamental level and takes us to the question if and how ICT can work on root level challenges, like finding methods to have a better traceability without compromising on privacy, changing driver behaviour patterns and stopping the expansion of centre & contraction of periphery.

Keywords: Sustainability, Traffic Congestion, Driver Behaviour, Centre & periphery, Congestion Pricing, Real Time Information Sharing, Extensibility
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We would also like to thank all the respondents who responded to the questionnaires. Finally we would like to thank our friends for putting up with us during the thesis writing. The thesis is dedicated to our parents without whom this endeavour would not have been possible. This thesis is mainly dedicated to God Vinayagar.

Borås, March 2011
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<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>ALPR</td>
<td>Automatic license plate recognition</td>
</tr>
<tr>
<td>ALS</td>
<td>Area licensing scheme</td>
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<tr>
<td>ATM</td>
<td>Automatic teller machine</td>
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<tr>
<td>ATIS</td>
<td>Advance Traveller Information System</td>
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<tr>
<td>CCTV</td>
<td>Closed circuit television</td>
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<tr>
<td>CEN</td>
<td>European commission of transportation</td>
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<tr>
<td>CCS</td>
<td>Control Centre System</td>
</tr>
<tr>
<td>DSRC</td>
<td>Dedicated short range communications</td>
</tr>
<tr>
<td>EPC</td>
<td>Event-driven Process Chains</td>
</tr>
<tr>
<td>ERP</td>
<td>Electronic road pricing</td>
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<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>FCD</td>
<td>Floating Car Data</td>
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<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
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<tr>
<td>GHZ</td>
<td>Gigahertz</td>
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<tr>
<td>GLONASS</td>
<td>Global Navigation satellite system</td>
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<tr>
<td>GPS</td>
<td>Global positioning system</td>
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<tr>
<td>GPRS</td>
<td>General packet radio service</td>
</tr>
<tr>
<td>HOV</td>
<td>High Occupancy Vehicle</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and communication technology</td>
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<tr>
<td>ITS</td>
<td>Intelligent transport system</td>
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<tr>
<td>IVR</td>
<td>Interactive voice response</td>
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<td>IVU</td>
<td>In-vehicle unit</td>
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<tr>
<td>LED</td>
<td>Light Emitting Diode</td>
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<tr>
<td>MMS</td>
<td>Multimedia Messaging Service</td>
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<td>OBU</td>
<td>On-Board Unit</td>
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<tr>
<td>PDA</td>
<td>Personal Digital Assistant</td>
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<tr>
<td>RF</td>
<td>Radio Frequency</td>
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<tr>
<td>RFID</td>
<td>Radio Frequency Identification</td>
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<tr>
<td>SMS</td>
<td>Short Message Service</td>
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<tr>
<td>TDM</td>
<td>Travel Demand Management</td>
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<tr>
<td>TMC</td>
<td>Traffic Message Channel</td>
</tr>
<tr>
<td>UN</td>
<td>United Nations</td>
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<tr>
<td>VPS</td>
<td>Vehicle Positioning system</td>
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<tr>
<td>WAP</td>
<td>Wireless application protocol</td>
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<tr>
<td>WIFI</td>
<td>Wireless Fidelity</td>
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<tr>
<td>WIMAX</td>
<td>Wireless Interoperability for Micro Wave Access</td>
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<td>WIM</td>
<td>Weigh-In-Motion</td>
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Chapter 1 – Introduction

1.1 Background

The progress and inspiration of the private automobile is without parallel. The number of motorized vehicles grew from 75 million to 675 million in the last half of the previous century, with more than four-fifths of these vehicles being used for personal transportation (Organisation for Economic Cooperation and Development, 1996). Towards the end of the previous century 15 members of the European Union experienced substantial growth of car travel as a 40% increase in passenger kilometres (Marshall, Bannister, & McLellan, 1997). The road transport traffic forecast for Europe expect an increase in road traffic of up to 150% by the year 2025 (Bielli, Carotenuto, & Delle, 1998).

There should be a proactive aggressive approach in advance planning and implementation of large-scale land transportation measures. A sustainable transport approach is needed throughout the world to bring together traffic congestion problems and social concerns to an end. Transport in advanced capitalist economies is entering a new era of technological development. Advances in IT, based on linking the power of mobile devices and ICT, are creating fresh opportunities for modernizing traffic infrastructure. For the world’s leading cities, where traffic congestion is wreaking havoc with the economy and the society, these IT-Based transport innovations will play a major role in plans for ‘sustainable development’ (Loukopoulos, 2005). The fact now is that though many ICT applications have been developed and put into practice, they have not been fully up to the mark because of their non-customer centric approach. Therefore it is of utmost importance, when the applications and technology are developed for road transport congestion control, then their design should be in synchronization with that of the customer perquisites and ought to be more user friendly and ubiquitous (Weisers, 2008), keeping in view that the customers in this context can belong to all age groups, with varied technological ‘know how’ skills.

We in this thesis have based the term ‘sustainability’ as the one that is directly proportional to the decrease in traffic congestion. The most primitive and old method (A Primer: Federal Highway Administration, 2008) being used for controlling congestion across the world has been the usage of congestion pricing where in travellers are charged to use the roads during peak hours (Bielli, Carotenuto, & Delle, 1998). With ICT coming into the picture the method of congestion pricing has grown by leaps and bounds, and has been used to promote not only the reduction in traffic & reduced emissions at one place, but also to promote greener vehicles with use of exemptions (A Primer: Federal Highway Administration, 2006), improved public transportation and other benefits. We study the role of ICT in reducing the road congestion and help an individual and an urban area, to achieve a sustainable lifestyle and a sustainable economy respectively. Now this explicitly moves with the choice of technologies in co-ordination with the research to attain solutions for the perspective of traffic congestion. The connection between ICT and sustainability is addressed by choosing two levels, i.e., the social and economic sustainability from all three levels of economic, environmental and social sustainability (Elkington, 2004).

With the growth of real time information solutions, our study has taken a further step ahead of doing what is considered the most difficult step in controlling traffic, i.e., to change driver behaviour, by giving them options to choose from alternative route, travelling mode and travelling time (Stockholm Traffic Administration, 2009). The underlying concept and
motivation for this part of the study is the so called universal principle of information equals power, which implies that if the commuters can have the information then they can take real time decisions to reach their destination faster. In simple terms, the summation of energy consumed in providing information and actual energy consumed on the road should be less than the future energy consumption without real time information.

Now many extensible applications like last minute ticket booking, e-commerce websites etc. that can have a direct correlation with traffic congestion are being used in day-to-day life, without keeping the goal of reducing or increasing travel demand. These have been studied only to understand how they increase or reduce travel demand and how intelligence can be embedded into such applications (Black & Geenhuizen, 2006), (Kenney & Curry, 2001).

The gaps in various studies has taken us to a new approach being studied here which is, how we can bring together the usage of congestion pricing with improved real time information sharing systems and extensible applications to change the driver behaviour, improve public transportation infrastructure, and at root level stop the expansion of cities to change the existing dimensions of centre and periphery.

1.2 Problem statement

Traffic congestion has discernable, but seldom researched effects on community life, social interaction and liveability, all which are important components of psychological and physical wellbeing, and quality of urban life (Elkington, 2004). There are numerals of detailed situations which cause or exaggerate congestion, most of them lessen the volume of a road at a given point or over a certain length, or surge the number of vehicles required for a given volume of people or goods. The most important consequence of traffic congestion is the increase in travel time, especially at peak hours, and this has reached beyond the level of acceptance in some cities that have an upper hand on the liveability standards. Besides this, the slow pace of circulation is a source of exasperation and triggers aggressive behaviour in drivers. The poor accessibility can also have a greater influence on the economy of the city, as a lot of time usually is wasted in congestion. According to a December 2006 report by Bruce Schaller of Schaller Consulting, the total value of time wasted by NYC traffic congestion comes to about $8 billion annually (Nzbcsd, 2003).

To control the traffic congestion, and increase the volume of the roads there have been a wide range of policies been proposed with the aim to alleviate the increasing negative consequences of the automobile use, and ultimately guiding the society towards a sustainable future. Some social Travel Demand Management (TDM) measures like ideas on either restricting sales and ownership has been the case in Singapore (Foo, 1998), or by demarcating the car as a status symbol & convenient accessory of modern life (Wright & Egan, 2000). However such policies can’t possibly reduce the travel demand to a great extent as it demands dramatically radical changes in social behaviour of human beings, and thus there is an increasing need of intelligent systems for it. This is where the role of Information and communication technologies (ICT) and the emergence of the mobile devices have stronger influence towards congestion free transport. The most important point will be, put simply, how ICT has played its role in giving hand to the above presented problem in a variable duration, e.g. Congestion pricing has its footprint for quite a long period starting with manual ways, like the drivers pay with cash & get access to the road, which increased the waiting time and further caused congestion in the payment area. However the advancement of ICT at the present has paved way for a fully automated pricing scheme that levies the charge without the distraction of the driver, and has proven to be a perfect example of ubiquitous computing.
### 1.3 Purpose of Study

**Motivation:** Globalization, for good or bad, is a prevailing aspect of our contemporary time. With the increasing urbanization of the population the barriers among countries and cities are getting removed. As barriers between continents, countries and cities have reduced, the economic growth has become directly proportional to ease of access, be it the ease of access to global markets, logistics or IT services. However on the other side, the ever-increasing density of people living in cities does slows down the movement of people as well as goods, caused by traffic congestion, and thus end up doing exactly the reverse of what a sustainable system is expected to do i.e., faster delivery and ease of access. (Frost & Sullivan, 2009). It is not necessarily a good idea to make only bigger and bigger transportation system if the gap between the demand and supply is not handled by the existing set of infrastructure.

**Focus of Knowledge Creation (The Loop of ICT solutions):** The idea thus really is to optimize the existing system and reach a state of equilibrium. In our study we keep our focus on the road network of intra cities to study the factors that cause traffic congestion, and the valuable IT solutions within the urban areas, which with the technological advancements have already been implemented, & have a documented record of success. The purpose of the study thus delves into two categorical aspects, namely technological and success. In the former we study the various existing technologies built across global cities and with later, the purpose is to study the success of the technological implementation to evaluate the catch of our topic “The Role of ICT in reducing traffic congestion to bring sustainable transportation”. Let’s begin with an example, we commute on busy, overcrowded public transport or sit in congested traffic on the road to make it to the office on time. After the end of a long day, we repeat the process in reverse before arriving home tired, and then have to start all over again the next day. Now investigating the reasons of the growing nature of traffic we observe that ICT can give us the power of flexibility to control the traffic by providing us the options for substituting physical travel that reduces, travel demand, or by giving the power of flexibility to Public agencies to implement travel demand management policies. However the same ICT that increase flexibility for public agencies or substituting business also gives the flexibility power to individual and business to create absolute new travel demand leading to a cyclical cause and effect loop (Samuelson & Zeckhausen, 1998). This is where we focus our thesis on to understand the cause and effect cycle, and to answer how ICT systems (the answer and the creator of problem) can help in traffic reduction.

![Figure 1: The potential of ICT to decrease and increase the accessibility (Bayliss, 2000)](image_url)
1.3 Research Questions

The use of new technology is considered as a key ingredient of innovation in urban transport management. New technology in the transport system has many faces. Research through the ICT delivers openings to encourage innovations in addressing problems regarding safety, congestion, environment, and community impacts. Bearing these in mind, we have designed a group of research questions in this thesis to address the problems mentioned above, and to fulfil the purpose of study.

**Main Question**

1. What are the potential ICT solutions that can contribute to minimize the traffic congestion, to attain a social and economic sustainability?

**Sub Questions:** To answer the main question, following are the sub questions that we focus on.

a. What can be the ICT solution that best fit for congestion pricing that can help in reducing the traffic congestion?
b. In what ways does the real time information sharing solutions helps in reducing the traffic congestion?
c. What is the role of extensible ICT applications (VPN networks or e-business) in reducing traffic congestion?

The first sub question takes a look at the oldest and most successful method of traffic congestion control; congestion pricing, being considered as most effective in changing driver behaviour. (Ed Pike, 2010). It defines the criteria to judge the effectiveness of such a system (A Primer: Federal Highway Administration, 2008), and further recommending how with the potential solutions of ICT it can be made more effective, user friendly and ubiquitous. The second sub question then goes on to answer the potential that real time information sharing solutions can have on changing driver behaviour, which in itself has an ultimate influence on traffic congestion reduction (Shekar, 1996) The third question not only takes a look at the extensible applications, and their role in reducing traffic demand (Black & Geenhuizen, 2006), but it also works to increase the existing understanding of extensible applications and instils a more holistic view on its potential role in distributing and channelizing the traffic flow. The three questions being collaborated illuminate on the main question of how potential ICT solutions of the future can bring these three factors together while addressing the problem of traffic congestion control to create a socially and economically sustainable system.

1.4 Focus Areas and Target group

There are an enormous numbers of problems that can affect the transport sustainability, but to limit the scope of our discussion, focus areas have been identified. Traffic congestion being one main problem that acts as a gateway for many other social, economic and environmental problems is identified as a key area, which can contribute a lot for the sustainable mobility (Elkington, 2004). This thesis focuses on the ways to control traffic, which ascends to the effort of attaining sustainability using ICT. Though there can be a lot of attempts to bound the traffic congestion, to limit the scope of this document, we have taken a special focus on the present day fully automated congestion pricing scheme, that is adopted in many developed countries to overcome traffic congestion. The discussion also throws light on the improvements in ICT,
present day real time information sharing, and it does also share ideas for the extensible applications that can reduce the travel demand itself. The unsustainable impacts of traffic congestion are many-sided, and can be characterized into different dimensions (Behrends, 2009). The impacts could be grouped under social, economic and environmental pillars of sustainability. There are two main key concepts under which sustainable development principles are derived, which can further pave way to the sustainable urban transport, and this is explained from the below diagram (Behrends, 2009).

![Figure 2: Our Focus area on the principles of a sustainable urban transport (Behrends, 2009)](image)

From the above conceptual diagram we would like to point out our area of focus for sustainability. We would like to focus more in meeting the needs of the present generation by abiding to some principles of sustainable transport under the social and economic growth. The main focus areas within the domain of sustainability have been marked in green colour inside the boxes in the conceptual form. To achieve these areas of sustainability, we follow some TDM measures with the clear support of ICT.
Target groups

a.) In Academia: Researchers within informatics who intend to study the role of ICT solutions in reducing traffic congestion with a social and economic perspective.

b.) In Practice: Leading organizations that are involved in developing (e.g. IBM) or implementing such solutions (e.g., city municipalities, administration organizations like Trafikverket), and are looking for a base to understand the role of ICT in the same, and what challenges exists in terms of standardization of the solutions.

1.5 Delimitations and Time Frame

This thesis will not study much about the environmental sustainability, even if the area will be touched for some reference. The thesis will not study the deep theoretical relationship between ICT and sustainable development. The study of technical design of the used ICT is out of scope of this thesis. There may be a lot of applications that can be considered under the subject areas that have been mentioned, but we have focused on the applications that are widely in use and meet our potential aspects, e.g.: Real time information is a vast topic and has wide range of applications to prove its sustainable potential, but we in order to limit the scope of the discussion have discussed a very few applications for the data collection and data dissemination.

The ideas of applications recommended in this report have been grounded on existing technology, and the ones to be implemented in the near future. Also there are instances where in the technology is not essentially in place where we need it to be, but with incentives or by reducing dependencies it can be placed there, e.g. Implementation of congestion pricing with the help of ‘Vehicle Positioning Systems’, has a huge potential but still has not been put in practice in many countries because of its dependencies on a specialized satellite system (Federal Highway Administration, 2008). The time and space perspective can be viewed from different angles, and thus for some reasons, some could be implemented in a country right away, while others often need more time.

1.6 Expected Outcomes

This thesis pays a special attention to contribute to the research that explores the sustainable development from the social and economic perspective of reducing the traffic congestion. The thesis delivers knowledge on the functionality of various technologies in a concrete manner, and it corroborates that ICT acts as a skeleton for the modern era TDM measures. The thesis attempts to give ideas on developing an understanding of how ICT and related services can contribute to the expansion of sustainable travel in the transport system. It further attempts to combine the role of congestion pricing with real time information systems and extensible applications, to attain the desired goal of traffic congestion reduction.
1.7 Provisional Thesis Structure (Bottom up model)

C1 Introduction
- Background
- Problem statement
- Research question

C2 Research Method
- Research perspective
- Research Strategy
- Data collection

C3, 4, 5, 6, 7, 8 Theoretical Study
- Subject Areas
- Theoretical findings

C9 Empirical study
- Interviews
- Questionnaire
- Empirical findings

C10: Analysis & Result

C11: Conclusion & Discussion
Chapter 2 - Research Method

2.1 Research Perspective

It is important that the researcher makes it clear about the knowledge, he or she creates before conducting a research (Gilje & Grimen, 1992). It is also significant that a researcher is certain about the distinction, whether the nature of the knowledge to be contributed is a theory, or more of practical. The main aim of our thesis is to create a theoretical knowledge, which deals with some of the potential ICT solutions, and their roles in reducing traffic congestion. Therefore we will place more focus on what the solutions can be, and how they do their role. To do this it is vital, to have a clear perspective on what we do and how we view. In general terms there has to be a perspective on the kind of research that is to be conducted. Research can often be grounded based on two main perspectives (Rudestam & Newton, 2001) 1> positivism and 2> hermeneutics.

**Positivist perspective:** This perspective deals with a set of epistemological perspectives where the knowledge created is testable, and the research can be proved only by means of empirical analysis and not solely by argumentations. Positivist subscribe to a reality through verification by formation of deductive and inductive hypothesis to put forward the findings by independent observers (O'Brien, 1998). This perspective has objectivist ontology, and depends on the numerical methods that are easy to prove.

**Hermeneutic Perspective:** It is an interpretation theory, which puts emphasis on a holistic way of presenting the whole picture, rather than presenting in broken segments. It has constructivist ontology, and cannot be addressed by the use of pre-determined criteria because it has interpretive nature (Klein, 1999). The hermeneutic perspective involves investigating people’s experience and perceptions (Anderson, 2005). Using this perspective, it is easier to interpret and explain meaningful concepts with the help of some collective experiences like the text, language and design. The general prototype is that it does not have any specific results immediately, and it permits the researcher to learn and produce results only through experience.

2.1.1 Motivation for choosing Hermeneutics

We in our research have decided to go with the hermeneutic perspective for the reason that with this perspective, it becomes easier to interpret and explain meaningful concepts of sustainability. Texts, language and artefacts can be seen as collective experiences according to the hermeneutic perspective, which we consider is the most important factor in identifying the travel demand management measures. Hermeneutic perspective also corresponds to the ontological position, that human being constructs his or her own world, and consciousness plays a major role in shaping up the world. Anthony Giddens (1982) argues that some social sciences like sociology are engaged with ‘double hermeneutic’, that not only studies what people do, but they also study how people understand their world, and how that understanding shapes their practice. Because people make choices, think and use abstract knowledge to revise their understandings (and hence their practice), they can use the knowledge and insights of social science to change their practice. Wherein in our thesis we have taken ideas constructed by different people, with the whole consciousness, and we have constructed our own ideas, which may or may not exist and have taken steps to use the ideas to change their practice. In our research a holistic perspective of the role of ICT either in an applied TDM measure or as extensible applications is needed to conclude on the effects on the traffic congestion reduction. To do this we understood the
perspectives of different researchers on the applied TDM measure, and took steps to find their understanding that has shaped the effect in reducing congestion.

2.1.2 Arguments for qualitative method

Research can be classified in two methods, quantitative and qualitative (Yin, 2003). As we have chosen to conduct a research based on the double hermeneutic perspective, the qualitative research seems to best fit the situation. The idea of choosing qualitative or quantitative depends on the result, which we decide to produce. Both the methods have their strengths and weaknesses, and neither one of the methods can be called the best compared to the other one.

Quantitative Research: Quantitative research is usually associated with the natural science mode of research; data is quantitative and obtained from samples & observations, seeking for relationship and patterns that can be expressed in numbers rather than words (Tull & Hawkins, 1990).

Qualitative Research: Qualitative research is the search for knowledge that is supposed to investigate, interpret and understand the phenomena by means of an inside perspective (Tull & Hawkins, 1990).

The main thing that contrasts qualitative from quantitative methods is that it aims not principally at precise measurement of pre-determined hypotheses, rather aims on multifaceted realities, so that even the questions and hypotheses emerge cumulatively along with the investigation progresses (Anderson, 2005). The issue of traffic congestion is considered to be a subject area with a great deal of research. However, many traffic congestion research has traditionally been quantitative in nature and dominated by applied research. In that context the economic cost of traffic congestion has been documented very well in a quantitative manner, and there has been a very little work on qualitative documentation on traffic congestion reduction. However, the purpose of our research is to identify the technologies that can have influence over the TDM measures, and in general by changing the driver behaviour. Therefore, our research involves the understanding, interpretation and investigation on what the technology has contributed to the applied TDM measure in attaining the goal of congestion reduction. Identification and interpretation of ICT in reducing traffic congestion being a broad and open ended question subject to reality, qualitative method proves to be the best and more compatible.

2.2 Research Strategy

The strategy is a tool used to generate solutions for problems and to derive new knowledge (Lekwall & Wahlbin, 2001). The first step that we considered was the research question. The research question can be identified with three purposes namely descriptive, explanatory and exploratory (Marshall & Rossman, 1989). According to Marshall, Rossman and Yin the ‘what’ question leads to exploratory studies, wherein the ‘how’ and ‘why’ question leads to the explanatory studies. As our main research question is framed to find out ‘what are the potential ICT solutions that help in controlling traffic congestion to attain social sustainability?’ is a kind which needs some sort of an exploratory study on the relevant subject areas to produce the desired result.

In this thesis the character of the knowledge, we used is exploratory, and we did it with the help of semi-structured interviews with experts in the concerned field of traffic congestion reduction.
We also distributed a questionnaire to a wide range of respondents, to gather more information to explore the changes they expect in the present ICT that can provide more flexibility, in meeting the present generation needs. The interviews were conducted more in a way that was investigative, so as to create a knowledge on the advancement in the technology, and ways to form a sustainable city with respect to the social and economic aspects.

It is important to identify the role of theoretical and empirical study. It can be done by handling the research either in a deductive or in an inductive way. A deductive research is used when the researcher wants to find suitable empirical evidence relating to the theory. An inductive research starts with the collection of empirical observations from which theoretical deductions for the study can be made. When there is collaboration between the deductive and inductive research, it is called as abductive. An abductive research tries to gather knowledge from the theory and at the same time the theoretical aspirations can also be gathered from the empirical data (Edstrom, 2001).

\[
\begin{array}{|c|c|c|}
\hline
 & \text{Deductive} & \text{Inductive} & \text{Abductive} \\
\hline
\text{Theory} & & & \\
\hline
\text{Empirical} & & & \\
\hline
\end{array}
\]

Figure 3: Types of research (Edstrom, 2001).

We in our thesis have performed a deductive research by mining empirical data that supports the theoretical findings. The interviews and the questionnaire usage in the empirical study will induce partiality, and has remarkable some effects on the results (Edstrom, 2001). This problem could be overcome by analysing the classified responses and interviews empirically with an open mind. The data generated yields clear information after processing, and therefore the research cannot be classified into one particular component, rather can be considered as mixture of both deductive and inductive.

The empirical part is used to validate the results found during the theoretical study. In the case of questionnaire, it provides the data that is needed for the analysis of extensible applications. The use of both primary and secondary data collection means that there will be possibilities to compare and understand the empirical part with the help of the theory. To create a better understanding of the research questions, the results are synthesized using the theoretical and the empirical study results.

2.3 Data Collection Methods

Data collection means, gathering information to address the critical evaluation part that will be identified later for the research questions. There are many methods available to gather information from a wide variety of information sources. The most important issue related to data collection is selecting the most appropriate information, or evidence, that can answer the research questions and act as an evidence for the empirical study. Before planning data collection, necessary steps were taken to think about the questions to be answered and the information sources available. There were multiple ways to collect information to answer our research questions. The choice of a method for collecting evidence must balance several disquiets including: resources available, credibility, analysis and reporting resources, and the skill of the inspector (Creswell, 2007). We also kept in mind, that the information gathered could be organized, analysed, interpreted, and then can be reported to various audiences. Both
ICT and Sustainable transportation being huge concepts, the perfect option was to collect data from more than one source and / or to collect more than one type of information.

Data collection for research can be of two types, primary data and the secondary data (Creswell, 2007). Primary data is collected for a particular research in response to a specific problem, and this is conducted using some means of questioning usually via a survey or interview, or the information can be gathered through observation. It is typically more time-consuming and expensive compared to that of the secondary data. Secondary data can be obtained from various sources, e.g. research reports, annual reports, books, and articles (Weidersheim-Paul & Eriksson, 1999, DCM). We dealt with a set of practical concerns before selecting the data collection methods

- What information is already available?
- How much money do we have to spend on data collection?
- What procedures are feasible?
- Do we have the staff and time to implement the data collection?

After being certain about the above concerns, we found secondary research to be a valuable way to start our research, as it identifies any relevant data that is necessary to form a strong theoretical base. Then to support, compare & validate the theoretical findings, and to bring solutions for specific problems, we intended to go with the primary data collection with the help of interviews and questionnaires.

2.3.1 Theoretical study (Text Analysis): Computer Databases

Computer databases can be categorized in to two sections, internet databases and the offline databases. We plunged our research for the theoretical study as text analysis with the help of the web resources. Research on the internet begins like any other research; possible research areas related to transportation and sustainability was explored until we arrived to the final stage. Web resources helped us throughout our research with different search objectives. The Internet has a searchable online database of hundreds of journals and table of contents related to our research area. A range of secondary sources helped us with our research which includes library catalogues, electronic texts including literature, newspapers, and peer reviewed articles, journals, and academic web directories like Intute guided us to the best online resources for our research. Though the online resources were much helpful in collecting data, we discovered that there could be some risks in collecting data from the Internet.

According to (Hewson, Yule, Laurent, & Vogel, 2003) it is not a good idea to collect data through internet without establishing the guidelines for judging the reliability of the web pages. We followed some of his guidelines to judge reliability of the websites and the published documents inside them

- The first step in establishing the reliability of a web page was to search the web for the author’s name. The goal of this step is to establish the author’s stipulation; in other words- to check if the author really an authentic person in the subject field.
- The second step in testing reliability was that we checked, whether the site embodies other sources impartially; the resources were checked to see if the information is adequate and the information is material to the hearing of our research.
- Next we checked the accuracy of the data in a specific source by succeeding the links to the cited sources.
• For the reason that ICT changes day to day, and knowledge towards this area needs regular updates, we put some emphasis in checking

1. What is the date of the published material?
2. When the material was last updated?
3. When the web page was last updated?

• We developed the ability to recognize bogus sites quickly, which helped us to spend time efficiently on our research.
• We also kept in mind that all data are not knowledge, and gathered the data according to the character of the knowledge that was predetermined.

To gather data for our research, we travelled through a lot of publications from the Internet and checked them with the guidelines mentioned above, and found materials from some online journal databases like European Journal of Information Systems (EJIS), Information Systems Journal (ISJ), Information Systems Research (ISR), Journal of MIS (JMIS), and MIS Quarterly (MISQ). For the reason we used a lot of academic publications and journals, we made sure that we followed all the conventional citation processes so that it would be much helpful for the future researchers.

2.3.2 Empirical study: Interview and Questionnaire

**Sampling**

It is essential to sample the empirical studies, which in our case were interviews and questionnaires. The sampling should be typical for the group of people that the issue is related to. There are two types of sampling we should address before selecting the interviews. One is probability sampling and the other one is non-probability sampling, (Alliger & Alliger, 1993). Probability sampling is the one which is based on the unstructured and random processes whereas non-probability sampling has a structure before proceeding with any action. Professionals who have knowledge and experience in the concerned field of research are sampled for the interview section. We have structured a format for interview and performed the non-probability method. Regarding the questionnaire a heterogeneous sample of respondents were selected. We targeted respondents from different social, economic and educational background.

**Interview**

Interview is the most efficient tool that can be used to gather information on various subjects. An interview for a qualitative research demands explanations of meaning for a central theme in the world of subjects (Sekaran, 1992). The interview questions can be further classified in to two main types, one is open type and the other one is closed (Kvale, 1996). An open type question can pave way for creativity from the respondent and will help to get the answers in a detailed manner, whereas the closed type would give an option with a ‘yes’ or ‘no’ type questions (McNamara, 1999). Before conducting the interview, we have structured a list of questions in an interview format. Open-ended interviews were conducted to entertain innovation. We browsed some articles about how to conduct and perform an interview and structured the questions in order to build the interview.
**Questionnaires**

Questionnaires can either be open ended or close ended. We considered the fact that most of the respondents would not have wide knowledge in the subject areas that we focused. We also knew that it is very difficult to get the response for an open ended questionnaire, for the reason it requires more innovation from the respondents side. Therefore we decided to design some simple close ended questions by giving the respondents an easy and clear picture of the questions asked. We analysed the collected data and found out what are the expectations of the commuters, and in what ways the developing ICT can help.

**2.4 Data Analysis**

Analysis of data gives meaning to first impression as well as final compilations (Stake, 1995). Usually there are multiple levels of data analysis in a case study that is qualitative. Initial step is the organization of the data in a chronological or in some kind of an order related to topics. This would help in displaying the data in a descriptive manner. Secondly it is possible to categorize data into some sort of themes or types, and the last method can involve analysis by creating models, developing theories or deducing inferences (Merriam, 1988).

**Primary data:** The responses to the questionnaires sent through mail are summarized to understand the key points. As Stake (1995) points out that getting the exact words of the respondent is not important but being able to reproduce the meaning is the chief priority. There will be a taping of the conversations during the course of the interview, as face to face interviews are not conducted. The data analysis method that is planned is comparative in nature. The theoretical findings will be reiterated using the questionnaires and the interview. In case of the traffic congestion reduction in our thesis, the data captured is more of explanatory in nature and would be logically summarized to understand the phenomenon.

**Secondary Data:** The analysis of secondary data and the theory was carried out in two stages. The first stage consisted of an initial selection of papers based on reading the abstract, and the second stage was reading in details the full papers considered relevant from the filtered list. There were a large number of papers (around 50) that were taken to be relevant but skimming through the content of the paper eliminated quite a lot of them leaving only around 20 papers in the final analysis.

**2.5 Evaluation: Rigor, Reliability, Relevance and Validity**

Many a commentators have argued over judging the quality of the qualitative research in various fields. It is often argued over the parameters to judge a research work. The quantitative research can be usually evaluated by the criteria of validity and reliability, as they involve the usage of data which can be statistically verified. However, when it comes down to qualitative research like ours it becomes imperative to have other evaluating parameters to really understand the work. This is where we discover the role of relevance. IS research has often been accused of being irrelevant to practitioners. The reasons for the same have been argued to be many, like the knowledge gained through past experiences is deficient, because of the pace at which information systems are developing surpass the pace of research being carried out (Fernandez & Lehmann, 2002). This is where our defined approach of doing case analysis and treating them as a whole falls into the evaluation methods of grounded theory (Glaser & Strauss, 1967), to arrive at the results with the flow of data to codes to categories to concepts. This is unlike the traditional evaluation method of building a theoretical framework and judging the results in its
backdrop. The reasons for choosing grounded theory for carrying out the research work and using it for evaluation are many, of which the following three needs a noticeable mention (Benbaset & Goldstein, 1987)

a.) As researchers, we can study the system in their natural state of art setting to develop theories from practice.

b.) We can treat the parts as a whole, and try to capture answers for the questions that can take us to a greater understanding of the more complex processes going around in different contexts.

c.) The limited time period at hand doesn’t allows us to try evaluation techniques like triangulation or respondent validation or using an external moderator.

Coming to the main criteria of evaluation, we base our work and its evaluation on the following three criteria.

**Rigour & Relevance:** The rigour position states that the role of academics is to produce several commodities and basic research finding that expand the body of knowledge, while relevance section suggests that researchers should focus on producing findings that are directly applicable and implementable in the practitioners field (Simon, 2004). Thus rigour and relevance might themselves be considered as phrases of debate in the world of researchers vs. practitioners. We intend to keep the methods for judging the two in the same light with a more focus on the research, as the field of traffic congestion control using ICT is still in its nascent stage of research & development with very few implemented solutions.

![Figure 4: Rigor and Relevance in Information System](image)

**Reliability:** The need to include reliability comes even more from the fact that we have used reliable internet links as a main source of data collection to form a strong theoretical base.

**Validity:** We judge the validity based on the criteria developed by Larsson (1993). Through his argumentation, he has put forth that there are three main concerns of quality in the work as a whole, which are perspective consciousness, internal logic and ethical value, with three qualities in the results namely richness of meaning, structure & theory development. Finally there are five validity criteria: discourse-criteria, heuristic value, empirical anchoring, consistency and pragmatic criteria. We in our work address the perspective consciousness and structure at the level of quality being created and we use all the five criteria mentioned here in to evaluate these.
2.6 Result presentation and referencing technique

The presentation of the result is more in a text form, and it would be accompanied with some conceptual designs and distinguishing tables. To make it vibrant for the readers, we have also added few flow diagrams to make the reader understand the result presentation concept in a better way. The results of this research are presented after following a sequence of work related to the research. Since we have gathered most of the information from the academic publications, referring the citations was also done with much care in the needed area. The reference technique that we used in our paper is the Harvard system. In this system, we include the author name and the year of publication, in a closed bracket when we refer to the source in the text. The reference is placed before a sentence period if that sentence period is alone to be cited, and if it is placed at the end of the sentence period it means that the whole of the session is been referred.
Chapter 3 - Theoretical Framework

3.1 Key Concepts

Traffic congestion

For our work, we refer to the definition by Thomson and Bull (2001), “Up to a certain level of traffic, vehicles can circulate at a relatively free determined speed. At higher levels of traffic, however every additional vehicle interferes with the circulation of others. In other words Congestion is a situation where the introduction or addition of a vehicle into traffic flow that might have the power to increase the journey time of others”

Information and communication technology

ICT refers to technologies that provide access to information through telecommunications. It is the extension of Information Technology (IT) which focuses primarily on the usage of communication technologies for the transmission of information. This includes the Internet, wireless networks, cell phones, and other communication mediums.

Transport Sustainability

Sustainable systems are the ones that allow the basic access and development needs of individuals, companies and society to be met safely and in a manner consistent with human and ecosystem health, and promote equity within and between successive generations. (ECMT, 2004). It is generally accepted that sustainable development, and more specifically, sustainable transportation, implies finding a proper balance between (current and future) environmental, social and economic qualities (L.Steg & R.Gifford, 2005).

Road Pricing

Road pricing is a generic term for the variety of different measures and practices which involves levying charges for the use of the road. This idea being one of the oldest approaches became more popular for the reason that it had great influence on the traffic congestion reduction.

Real Time Information

Real time information denotes information that is delivered immediately after collection. There is no delay in the timelines of the information provided. Real-time data is often used for navigation or tracking. Some uses of this term confuse it with the term dynamic data.

Extensibility

As the very word suggests, it is the capability of an existing application to extend its usefulness to other independent applications by expanding or adding to its existing capabilities. It can be a very rooted approach at the very code level design principles, or at the stage of writing a program, protocol etc., or it could be at a structural level, like in the case of traffic congestion control to develop applications that can help in substitution of physical travel with e-options to reduce the very travel demand itself.
Driving behaviour

Driving behaviour can be linked close to a person’s choice of drive and it results mostly from what he/she thinks and feels; it has very less to do with what he/she knows or can do. Most of the times, a driver makes decision on an unconscious level, based upon an inner set of values as to what actions are acceptable or unacceptable. By adopting to some preventive behaviour habits, a driver will automatically process information and execute decisions that result in low risk and high gain.

3.2 Subject Areas Relevant To the Research

This section deals with an introduction to the subject areas that are explained in the study. In addition, it describes our view on the relevance between subject areas and their relationships to the research questions. We have considered the following subject areas for our study

a> ICT and sustainable transportation
b> Congestion pricing
c> Real time information sharing
d> Extensible ICT application

The below diagram gives a clear picture on the subject area and their relation to the research questions:

![Diagram](image)

Figure 5: Subject areas and their relationship with the research question

In the above diagram the relationship between the subject areas are explained. The subject areas congestion pricing, Real time information sharing and extensible ICT answers the three research sub questions respectively. The subject area extensible ICT helps the people to overcome the economic challenges created by congestion pricing and in this context both are related. The subject areas congestion pricing is related to the real time information sharing with the context...
of providing revenue to the real time infrastructure, and thereby the real time infrastructure’s provide good accessibility and thus the quality of urban life is increased.

### 3.3 Previous Research

The issue of traffic congestion has been given a great importance in the recent years and there have been an enormous number of researches in the past and in the present related to traffic congestion. The congestion research in the past took an effort to produce more of quantified results with the help of applied research and engineering based approaches. In relation to this context the economic costs of congestion, have been well documented and strategies for congestion mitigation have received considerable attention (Senft, 2009). Comparatively very little work has been done on social and behavioural implications of congestion. Our focus is to identify the role of ICT in attaining the social and economic aspects of equity, by breaking the barriers of traffic congestion, and thereby attaining the principles of transport sustainability.

At present, there are lot of researches under transport sustainability, that mainly focus on to attain the ability of meeting the future generation’s need by finding solutions to solve the environmental problems caused by vehicle mobility, wherein our focus is the goal of meeting the needs of the present generation, and we realized that it would be a good idea to identify related researches and some of them are listed below:

Melville(2010) in his work “Information Systems Innovation for Environmental Sustainability” has provided a perspective from the environmental aspect of sustainability, and the role IS can & does plays in building sustainable practices. However he hasn’t addressed the economic and social aspects of sustainability, and has kept a complete focus on the environmental aspect. However, there were major key deliverables which helped in building our study as it brings out the sustainability with a perspective of ‘IS enabled process & practices’. This helped in building the view that sustainability can actually be viewed with such a standpoint of IS enabled processes unlike the more contemporary views of operational research.

Williams (2008) has precisely the same focus of study as ours, though it is centred only on the Singapore ERP systems, and the factors that determine the implementation of same in Singapore. It also leads us to major point of discoveries, with a strong reasoning of whether the developed system will work or not work in other countries, clearly citing out the pros and the pitfalls. In an exact co-relation with our study this paper also points out the key need of the systems to interoperate and communicate. The other major point of the study that helped us was the important role of standardization in ITS, if they have to be implemented globally.

The work on congestion pricing to define its nine functionalities criteria for judging its quality have been discussed by many authors amongst which of our interest are the work ‘A Primer: Federal Highway Administration. (2006). The role of ICT in congestion pricing is already in practice and our list of references varied from its state of art technological usage varying from DSRC (LINDSEY & PALMA, 2009),to ALPR (Ezell, 2010), to usage of combined technologies, through to the recommended usage of VPS (IBM, 2007), (Xu & Von, 2005).

The work on extensible applications got majorly inspired by the work of Black & Geenhuizen ‘ICT innovation and sustainability of the transportation sector (2006)’ which lend the idea for forming base definition of ‘extensibility’ and ‘traceability’. It further talked about the varied existing applications that can cause or reduce travel demand. For the understanding of existing models of centre and periphery we considered the ideas of Yanagita’s Toko Shoin. The building of thoughts about how intelligence can play a major role in building an extensible application...
was influenced by work ‘Beyond Transactions Costs: E-Commerce and the Power of the Internet’ (Kenney & Curry, 2001). This inspired us to mould the thought towards traffic reduction, and how domain of extensible applications could be extended further with a more hermeneutic approach beyond the obvious information websites, distance education and the e-commerce applications.

### 3.4 Relevant literature sources

<table>
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<tr>
<th>Subject Areas</th>
<th>Relevant Literature sources</th>
<th>Data collection</th>
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| **ICT & Sustainable Transport**   | 1. Multimedia applications for sustainable urban lifestyle *(Palmgren & Zamico, 2005)* - This literature speaks about the overall usage of ICT and its potential in forming sustainability in a selected domain, and gives a clear explanations on the ICT that acts as a skeleton for the so called sustainability.  
2. Changing definition of sustainable transport *(Beela & Brezet, 2007)* - This paper helps in giving a general description of the changing definitions of sustainability and its relationship with the transportation sector.  
3. Information systems innovation for Environmental sustainability *(Melville, 2010)* - This paper helped us in creating strong knowledge in understanding the roles information systems can play in shaping the beliefs about the environment and transforming sustainable processes and practices in organizations and in improving the performance.  
4. Ubiquitous Computing: Past, Present and Future *(Abowd & Mynatt, 1999)* - This paper gave us a clear idea on ubiquitous computing and it also helped us in preparing the list of systems that comes under the ubiquitous computing. | Computer Database (Whitepapers) |
| **Congestion pricing**            | 1. Transportation in the Information city *(Mark Hepman & Ken Ducatel, 1992)* - This book helped us to attain a wide knowledge on the concept of pricing and the technological factors that promote or inhibit its implementation.  
2. Technologies that enable congestion pricing *(US Department of Transportation, 2008)* - This paper gives an explanation about the brief list of the technical components that act as a heart for the active functionality of the fully automated congestion pricing. | Library Reference (Book)  
Computer Database (Report) |
### Real Time Information Sharing

1. **Road Traffic data: Collection methods and applications (Leduc, 2007)** - This paper speaks in detail about the data collection from various sources about the traffic congestion and the ways that can be more effective.

2. **Intelligent Transport systems (Ezell, 2010)** - In this document there is a clear and detailed picture on the systems that help in real time traffic information sharing and related applications.

3. **Road Travel Demand-Meeting the challenge (OECD, 2002)** - This working paper has a brief explanation of the concept of cooperative driving and the formation of it with the help of Real time data sharing.

### Extensible Applications

1. **ICT innovation and sustainability of the transportation sector (Black & Geenhuizen, 2006)** - This talks about how extensible applications can reduce or increase travel demand and the importance of building intelligence in extensible applications.

2. **Go with the flow: Transportation information management solutions from IBM (IBM, 2010)** - This document speaks about the upcoming applications based on resource optimization, video analytics and traffic prediction with a focus being to reduce the operational cost of the TDM measures.

**Table 1: Relevant Literature sources**
Chapter 4-Sustainability and ICT

4.1 Sustainability-A short history

The inception of the term sustainability is not so long. The first and foremost step for the emergence of sustainability was seen in the UN Conference on the Human Environment held at Stockholm in 1972. The term came into general use in 1987 when a report was published on common future by GroBrundtland. This report had in together economic and social development with environmental protection under the new style of sustainable development, and gave one of the most cited definitions, “to meet the needs of the present without compromising the ability of future generations to meet their needs”. Sustainability has turned to be a rising political work with the United Nations Conference on Environment and Development in Rio in 1992, and its global action plan for sustainable development (Agenda 21), that brought the term into the political agenda. The concepts of sustainability and sustainable development originally focused on certain long-term environmental concerns, such as natural resource depletion and ecological degradation (including climate change), and have expanded to include other issues as well. Most current definitions recognize three main categories of sustainable development issues: economic, social and environmental (or ecological), and some incorporate other issues such as governance and fiscal sustainability (Litman, 2008). We in this report to limit the scope of the discussion, have planned to discuss transportation sustainability in terms of society and economy with the aim of reducing the traffic congestion, and identifying the ways this idea can be implemented with the help of ICT.

4.2 Transport sustainability

Several definitions of sustainable transportation have been proposed (CST, 2003). Of them, we recommend the definition selected by the European Council of Ministers of Transport (European Commission, 2004), because it has a broad scope and recognizes specific transportation issues. According to this definition, a sustainable transport system:

- Allows the basic access and development needs of individuals, companies and society to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations.
- Is affordable, operates fairly and efficiently, offers a choice of transport mode and supports a competitive economy, as well as balanced regional development.
- Limits emissions and waste within the planet’s ability to absorb them, uses renewable resources at or below their rates of generation, and uses non-renewable resources at or below the rates of development of renewable substitutes, while minimizing the impact on the use of land and the generation of noise.

In general transport sustainability is the one that should have the following (Bayliss, 2000):

1. Maximum number of citizens should be able to flexibly meet most of their local needs by foot, cycle and public transport.
2. Public transportation should be sufficient to meet the needs of the present generation’s mobility.
3. Long distance journeys should be made convenient with the help of IT enabled public transportation.
4. There should not be any environmental or economic exceptions for people travelling by private vehicles.
5. The capacity and management of the road system is in balance with the demand for highway capacity with full social cost pricing.
Transport sustainability can be determined based on the standards, allowing natural capital to be replaced by human capital or a strong standard, which rejects such substitutions (Litman, 2008). Strong sustainability helps in transport favouring the development of ecological rate over industrial rate. A weak sustainability entertains the deployment of the environmental resources, or if negative impacts can be offset by other sectors, such as pollution reductions by heavy industries. Therefore sustainability concerning transport should be well determined and analyzed whether the plan of sustainability is strong or weak.

4.3 Traffic congestion and its unsustainable impacts

The word congestion is frequently used in the road traffic context by both the technicians and by the public at large. The fundamental cause for congestion is the friction or mutual interference between vehicles in a traffic flow (Bull, 2004). To a certain limit of traffic, vehicles can circulate in a relatively high speed. At higher levels of traffic every additional vehicle has a mutual interference with the circulation of the other. A possible objective definition of traffic congestion could be “congestion is a situation where the introduction of an additional vehicle in to the traffic flow increases the journey times of the others” (Bull, 2004).

The unsustainable impacts of traffic are enormous and multifaceted and it can be categorized according to different dimensions. This can be grouped under social, economic and environmental pillars of sustainability (Nykvist & Whitmarsh, 2008). In addition the impacts differ in time as well as in geographical scale. There are few impacts that can be limited to a scale and are palpable only at the locality where the traffic takes place (e.g. noise). Congestion arises when the travellers compete among themselves for a small transport system space (Behrends, 2009). This leads to several economic costs of which the travel time gets rapidly increased. There are some other concerns due to unreliability of travel times, and additional fuel costs due to higher fuel costs consumptions under stop and go conditions. More congestion and traffic is accompanied with the noise in urban areas which is getting worse year by year (European commision, 2007), and imposes undesirable social disturbances which finally ends up with discomfort and inconvenience.

Most traffic has the capability of increasing the risk of accidents which may further lead to pain, grief and suffering of people, which stays as an underlined burden for the society. Accidents also cause material loss or damage, administrative costs, medical costs and construction costs which all stays as an underlined burden for the economy. Even though the road safety has improved a lot with around 41,600 deaths and more than 1.7 million injured in 2005, road still remains the least safe mode of transport because of traffic congestion and delay in times (European Commision , 2006).

4.4 ICT and sustainable transportation

Information and communication technology plays a vital role in the sector of transportation. The ICT market continually launches new applications that support traffic congestion control, transport logistics and transport infrastructure management. In addition to all these ICT has also invaded the new era of transporting information rather than people. The ICT applications have the potential to increase the efficiency of transport networks and decrease the negative externalities, e.g. decrease the congestion and increase the quality of transport networks. However their actual impacts on transport sector and the sustainable development are still unknown. In the transport sector, the deployment of ICT in the developed cities like Stockholm has been the era of developing sensing capabilities both of vehicles and traffic monitoring
4.5 Need for solutions supporting sustainable traffic

Throughout this thesis we have based the sustainability assessment mainly in the potential of reducing the traffic congestion. Transport systems are no way an exception to these impacts and quite often we witness the restructuring of the automotive sector, and after sometime we get forced to change our travel behaviour and planning as well. In the European Union, some years ago the price tag of traffic congestion was around 0.5% of the community GDP, and by 2011 this figure is expected to 1% of the EU GDP (Weisers, 2008). High technology in transport sector has mainly remained intended for more operative and safer motor vehicles, satisfying the need of a segmented population of consumers. With the exception of vehicle manufacturing technology, traffic sector has remained a low-tech area. Therefore the daily travel, choice of travel and traffic operation is still a practical concern. There is a need for certain traffic management systems to improve the safety and efficiency of the road network by harmonizing traffic flow and focusing on the driver behaviour. The use of traffic management systems has the capability of enhancing the capacity of the road by 10-40% (Weisers, 2008). Information and communication technology has given us the wonderful opportunity of video conferencing around the world. During the worst of last winter’s blizzards, more than three million people connected to their office systems from home. At emergency timings, there’s an argument we should use the advancement of technology harder for a more sustainable future. The chase has been to progress applications for Real time information systems for the road authorities, for the maintenance and traffic management operations. If traffic congestion is decreased in a remarkable manner and the commuters are provided with proper accessibility, the act stands inside the transport sector without bringing any troubles to the natural resources or any other third party, which in turn stands out to be the ultimate goal of a strong sustainability.

4.6 Information and communication technologies

To attain a more sustainable context in traffic we have proposed a set of ICT that has more influence in the road and in the people’s life. The main platform’s we intended to use are mobile devices, congestion pricing and the real time information sharing. The technologies discussed in this document are both established and emerging and are presented below.

Mobile Phones

Mobile technology had an immense growth around the world, and the mobile phone has touched all diverse social groups in a short time. The mobile phone penetration has today surpassed 50% worldwide (Palmgren & Zapico, 2008). It has come a long way from the prototype equipment days of 1950 developed by Ericsson and Televerket to the first generations mobile phone system through to the second generation’s mobile phone technology GSM (Global System for Mobile Communication) with services like SMS, WAP, GPRS and MMS, empowering contact with internet, being able to send pictures and other more data and multimedia emphasized services (Palmgren & Zapico, 2008). However the data services in these were quite partial in capacity and therefore did not had vast penetration in to the consumers. However in 2002, the first system
of third generation’s mobile phone technology, UMTS (Universal Mobile Telecommunications System) was hurled. With the new technology, more emphasis was placed on more advanced multimedia and data services, and with increased capacity and usability the new technology has radically changed the way in which a mobile phone can be used in the areas of transport by the commuters in accordance to the pre-trip planning and other ways of receiving information about the traffic flow, making it more of a computer/multimedia/communications device. The limit is more of an open kind of allotment, for new applications to be brought in relation to trip planning and finding routes (Weisers, 2008). Having a whelming view, the mobile phone gives commuters the primary access to the communication technology and also plays a major role in other value added services like internet. The mobile phones provide the commuters to make an easy and hassle free trip to the determined destination in many ways with its supported applications.

Urban computing

The urban environment of today can be categorized into three main layers; the natural layer, the constructed layer and the virtual layer. The natural layer is the one which is in the already existing state and has its own inception, or in other words it can be said that they are not manmade. The next layer is the formation of things with the help of man’s intelligence in the city environment like the roads, bridges, cars etc. The virtual layer is the newest and most abstract concept, and alludes to all the technology throughout the city, both visible and embedded. Now virtual layer can be the presence of personal computers in homes, mobile phones and most appositely extra invisible technology that is placed throughout the city to assist different activities. The thought of combining the urbanity and ubiquitous computing, is like quite possible to say that computers are getting into the fabric of the city. It is possible to find these kinds of technologies not only at homes, but also in public places and outdoors in our communities, whether we realize it or not. One basic example can be the road intersections, which are controlled by different traffic control algorithms to better manage traffic.

Ubiquitous technologies

Ubiquitous computing is the next generation of computing that moves us away from the personal computer desktop model, and instead integrates information processing into everyday objects and activities (Weisers, 2008). Instead of a single user consciously engaging in a single device for a specialized purpose, as with the desktop paradigm, someone using ubiquitous computing engages with many computational devices and systems simultaneously, within the course of ordinary activities, and may not even necessarily be aware that they are doing so (Weisers, 2008). The catch with the ubiquitous technologies is to hide the technology completely from the user so that he is not aware about the technology, but purely benefits out of it. The man who coined the phrase ‘ubiquitous computing’, Mark Weiser, says that “Ubiquitous computing is the method of enhancing computer use by making many computers available throughout the physical environment, but making them effectively invisible to the user” (Palmgren & Zapico, 2008).

Within the ubiquitous computing community, there has been little research regarding road pricing and the real time information. To have a complete picture of the ubiquitous computing and its application we had a clear literature review of the literature “Ubiquitous computing: Experience, Design and science (Abowd & Mynatt, 1999). Our thesis works on gathering knowledge related to congestion pricing and the real-time information has largely benefitted from context awareness computing research. The context aware systems devices leverage a simple piece of context, user location, and provide valuable services (automatic call forwarding
for a phone system, automatically updated maps of user locations in an office or anywhere in the traffic). Location is a common piece of context used in application development. The most widespread applications have been GPS-based car navigation systems and handheld “tour guide” systems that vary the content displayed (video or audio) by a hand-held unit given the user’s physical location in an exhibit area (Abowd et al. 1997). Another important piece of context is recognizing individual objects. Earlier systems focused on recognizing some sort of barcode or identifying tag. While recent work of Weisers (2008), includes the use of vision-based recognition.

We understood that there is a clear need to identify these concept of ubiquitous computing in parts that is related to our research, for the reason that we in our thesis deal with most of the systems that are ubiquitous in nature, like the naive congestion pricing system that would employ a ubiquitous network of monitoring devices, (e.g. cameras) or requires license plates with unique RFID tags to track the path of a specific vehicle in order to assess charges. To understand the concepts of ubiquitous computing in relation to the congestion pricing we dealt with the work of Blumberg (2004), “congestion pricing that respects driver privacy”. To gain a stronger understanding on the ubiquitous form of real time information sharing we dealt with some literature sources that shares some concrete knowledge about these systems and we referred to works like “The smart Tachograph- Ubiquitous form of systems” (Coroama, 2005).
Chapter 5 - Congestion Pricing

The subject area of congestion pricing mainly deals with the technologies that can help in charging the commuter more efficiently and the analysis of this section is carried out with the help of the research that is carried out by the Federal Highway Administration on the technologies that enable congestion pricing. The analysis in this subject area is mainly carried out to answer the first research sub question “What can be the ICT solution that best fit for congestion pricing that can help in reducing the traffic congestion?”

For theoretical findings, we first analysed the concept of congestion pricing and how automation of congestion pricing can further prove its sustainability potential. Then we choose to analyse the primary functionalities which are necessary for the proper functioning of the automated pricing system. Then we try to evaluate the best ICT solution which can undergo the majority of the functionalities along with the secondary functionalities mentioned below.

5.1 Concept

Road pricing is a generic term for the variety of different measures and practices which involve levying charges for the use of the road. In the simplest context, the vehicle exercise duty is a fixed yearly charge for the use of roads, which is levied by governments firstly to reduce congestion and secondly to pay for the costs of constructing and maintaining the national road network, the priority differing from region to region. Fuel tax levied on petrol and diesel is also arguably a charge related to the use and distance travelled on the road network. However, both types of charges do no distinguish between the type of road, the type of journey, the prevailing level of traffic congestion, and the time of travel- all factors (Hepworth & Ducatel, 1992), which influence the motorist travel behaviour & pattern, and provide scope for more effective traffic demand management on specific points or zones in the road network.

Congestion pricing is one potential way of harnessing the power of the market to reduce the waste associated with traffic congestion. It works by fluctuating purely optional rush hour highway travel to other transportation modes or to off-peak periods, taking advantage of the fact that the majority of rush hour drivers on a typical urban road are not commuters that compulsorily need to travel at a fixed time. With idea of removing a portion of the vehicles from a congested road, this pricing model enables the system to flow much more efficiently, allowing more cars to move through the same physical space (A Primer: Federal Highway Administration, 2006). There is a consensus among economists that congestion pricing represents the single most viable and sustainable approach to reducing traffic congestion (IBM, 2007).

The application of congestion pricing to solve the traffic congestion and sustainability problems provide a strong opportunity to solve other transport problems or infrastructure maintenance without the funding of the government. The plan of congestion pricing is a conceptual first step, but at this instance it cannot be a complete plan of action. There should be a prolonged coordination with other policy measures and environmental measures to reach the heights of all round sustainability. Through this thesis report we intend to examine the use of ubiquitous technology that acts as a backbone for a fully automated congestion pricing. We have put more focus in studying how the current congestion pricing technology works and, what more could be added to make it better in the future, so that we can identify the ‘Role of ICT in sustainable transport’.
5.2 Primary Functionalities

The most basic function of any congestion pricing scheme and its supporting technologies, that exist around the world is to collect the payment from the users for the usage of a particular road or an area. This can differ significantly with regards to the local conditions, policy framework and the nature of outcomes the system is intended to achieve (Ezell, 2010). The options of the technologies available, in our research, have proven to play a major role in shaping the functional design. The options and the abilities of the technologies have improved the compatibility of charging and can be most likely used to improve the key objectives. On the other side of the coin, some technology limitations have restricted (and still restrict) some looked-for options. The rapidly developing capabilities and option of new technologies can also offer choices that may previously have not been considered. No matter what the technology has been adopted, put simply the collection of payment from the road users within the outline of any congestion charging must include the consideration of the following nine functional requirements (A Primer:Federal Highway Administration, 2008).

- **Informing**: Providing the needed information to the users and the one who make their frequent trips.
- **Detection**: Detecting and making note of each instance that happens in a road with a measurable account of the usage.
- **Identification**: Identifying the user, vehicle or the license plate of the vehicle entering the area and finally matching it with the identified owner in the database.
- **Classification**: Measuring the vehicle to confirm its class, aligned with the classification framework for the scheme.
- **Verification**: To double check the process and the subordinate means of detection to support in confirming the transactions, dropping the processing cost, and providing a backup for enforcement.
- **Payment**: The options of pre and post payment for the users, by providing a cash card for the users interested in prepayment, and sending an invoice or giving an option of paying through online for the users interested in post payment.
- **Enforcement**: Identifying the leans to penalize the users for violating the rules and escaping the payment of charges or fines.
- **Exemptions**: On condition that the facility with the means to accomplish a range of exemptions and discounts within the context of the scheme.
- **System reliability and accuracy**: Providing the above eight functional requirements through a cost effective technology, that can meet the criteria of reliability and accuracy and minimize the revenue leakage and fraud.

The above mentioned basic functional requirements have been used under this subject area of congestion pricing to consider, and compare the functional capabilities of the systems with the help and support of the modern technological advancements described below.

The forthcoming sections describe the use of primary technologies in the congestion pricing system. In this document, we have given more focus on the advanced technologies that have been used in the system and in addition to that we have also thrown light on the basic methods that were used earlier, like the paper based systems and manual facilities. This idea is for the reason of completeness and at the same time, we believe that describing the basic functions for a simple system can help improving the understanding of the reader while travelling through more complex systems.
Paper Based Systems

This is more of a traditional way of collecting the charges for the usage of roads. This was previously adopted in many countries around the world, and it can also be said that this marked the beginning of an era for the idea of charging to control congestion. Even now in some parts of the world this method is adopted to control congestion. Paper based systems is a structure for the user who intend to drive within a defined area during a defined time period (Peak time) and this requires the user to purchase and portray the license in the vehicles windshield or the dashboard. The implementation of this system involves two main options (A Primer: Federal Highway Administration, 2008)

- **Entry permit schemes:** A valid license sticker is displayed in the vehicles before entering and leaving the restricted zones.
- **True Area Licensing schemes:** A valid license sticker to travel or park the vehicle within the restricted zone.

The delivery of the permits or licenses is managed through a combination of existing retail outlets and with a very little coordination of ICT systems like operator channels, such as vending machines, the Internet, and phone-based mail order. The drivers have a liberty of travelling in and around the priced area many a number of times without ending up paying for each time they pass through area. The enforcement was carried out by the checking authorities at certain barrier points, by inspecting the vehicle for the display of license sticker. The equipment that is generally used for the distribution of the license or the permit to travel around the congested area is street based.

Manual Pricing Facilities

Manual pricing for the usage of roads was widely used around the world and it is still used in many parts of the world, and some under developed countries with a very huge population are continually planning and implementing this kind of a system to control congestion. This system comprises payment points, where a driver pays the charge using charge cards, vouchers, credit cards, or even with cash. The manual pricing has changed in some ways, where a terminal or a cash register is used to collect the charge, using the support of the traffic lights or an automatic boom gate which holds the car until a payment is made. This method is not considered to be a successful implementation for controlling traffic by many economically developed countries because:

1. The space required for setup of the conventional toll booths is considered to be an inappropriate system for dense urban networks.
2. The main goal of attaining the congestion control is affected at the points where, the vehicle stops to pay the charge.

DSRC Charging Using Transponders and Gantries

DSRC is an advanced form of pricing technology that is being used nowadays to control congestion, and it is found to be standard on most free flow toll facilities. In this kind of technology there is a special unit called the On-Board Unit (OBU) (A Primer: Federal Highway Administration, 2006), which is sometimes referred as the tags or the transponders. This unit does the job of connecting to the equipment that is mounted on the gantries at the check points. The tags or the transponders inside the cars are detected by the equipment each time, when the
car enters or leaves the defined area, and depending on the designed system either charges the account or it makes note of the access. The enforcement in this kind of ICT is carried out by either using the road side enforcement cameras, or with the combination of ALPR technology.

The DSRC systems differ in a wide range in use and under development. The very beginning stage for this technology was supported by the infrared communications, but this was not appropriate for high speed applications, put it simply it is not considered to be an open standard. The recent deployment of ICT has gifted this technology with the support of microwave communications. The system that is in use nowadays relies on the 5.8-GHz frequency which uses the European CEN-278 standard (A Primer:Federal Highway Administration, 2008). This standard has its roots strong, and it delivers robust & secure OBU devices that have an average battery life of 5 years. With the deployment of additional tolls or check points, this system can be expanded easily on to other routes. Moreover expanding these systems can be less cost effective in order to cover wider areas, and the number of toll points to provide coverage in an effective way can be done significantly. The DSRC system that is street based requires essential components like the pole or gantry that is mounted with the transceivers, illumination devices, vehicle classification devices, independent verification devices, ALPR cameras and road side cabinet controls. The transceiver unit is generally mounted separately from the cameras; the reason for this setup is to allow the cameras to detect vehicles in the pricing zone, through technologies that are accessible to combine all functions at one location (LINDSEY & PALMA, 2009). An auxiliary variation in addition to all these is the use of front and rear cameras that requires an additional camera support structure. The same as mentioned in the above section of ALPR, the deployment of system controller that has a potential power supply, and other data communication setup through a purpose designed base unit should be installed in each gantry location.

In the case of multi-lane roads a sequence arrangement of transceivers and classifiers will be required; those are mounted on the gantries and are built for this purpose of managing the traffic congestion. At the same time when the multi-lane facilities are installed in opposite directions then there should be a clear definition of mounting the devices on the gantry (e.g. the space between the equipment’s should be given a proper consideration)

**Automatic license plate recognition (ALPR) Technology**

ALPR technology is used in most of the electronic congestion pricing systems; this system has been so much in favour of controlling the congestion in a documented way. This technology of ICT is very often used as a backup for either the DSRC systems or the VPS for enforcement (Ezell, 2010). The ALPR system is based on taking the images of the number plates of the...
vehicle crossing the area, and then processing the image with the character recognition software to identify the vehicle and its owner. In most of the case in the recent days, the electronic pricing system has a front and a rear camera to take pictures of both sides of the car, so that the identification rate can be improved.

The components that the ALPR system merely requires are the pole or gantry mounted cameras, and an illumination device, provided the entire setup is road side or street based. Depending on the system design there might be a need for the two cameras (Front and the Rear), and classification devices.

Figure 7: A simplified form of ALPR system (Bayliss, 2000)

In addition to these basic components of ALPR, there should also be some necessary form of system controller that requires a constant power supply and communication connections through a purpose designed control unit for each camera locations. The communication connection should have a promising network set up with a dedicated fibre-optic connection, and the power supply should be uninterruptable. This system is not only used for enforcement backup, but some cities like Stockholm are using only the ALPR systems for charging. When there is a complete absence of the in vehicle unit with the tags or transponders, it simply takes the picture of the number plate and the picture is matched with a highly reliable character recognition software to identify the owner of the vehicle, and a monthly invoice is sent (Stockholm Traffic Administration, 2009). The picture below gives a clear idea, on how the matching is done to identify the owner.

Figure 8: Matching the license plate in case of enforcements and charging (Bayliss, 2000)
The main problem with the ALPR technology is proving the reliability of the images. A very good system is capable of read rates of around 98% in fair environment (A Primer: Federal Highway Administration, 2008). This can be affected in the case of light reflection on the image or in case of the damaged or dirty license plates. There are some other problems that are faced by these systems implemented in the European Union, as the system fails in judging the license plates of the foreign vehicles, as a result of this a wrong owner is charged. This problem obviously leads for the manual checking of those plates and adds to the additional operating costs.

**VPS Technology**

This technology of ICT (e.g. Galileo Global Navigation Satellite System [GLONASS], GPS) with an aim to collect charge for the goal of reducing traffic congestion is still in research, and the road authorities have been exploring the possibilities for quite a few years (IBM, 2007). This gathers the attention for the reason that it does not requires any roadside technological infrastructure to position the vehicle. VPS technologies use satellite location system, generally the GPS, to regulate the position of the vehicle and charge the vehicle accordingly to access traffic control. These systems provide a flexible option for the authorities, to vary charges with regards to the time of travel or the defined entry area can influence more aspects of travel behaviour and transportation choice. The plan of launching the Galileo satellite system in 2012 by the European Union will assure greater accuracy of position and location (A Primer: Federal Highway Administration, 2006).

The method of VPS based congestion pricing method is the best method to balance the requirements from different perspectives. The VPS based pricing system functions with the In-Vehicle unit and the control centre system. The blocks of the in-vehicle unit and the control system centre are shown below in fig 9 and fig 10 respectively.

The In-vehicle unit provided with a continuous vehicular position is analysed by the GPS system, and is integrated in the vehicle, and the IVU also transmits the vehicle ID to the control centre system. Data fusion is mainly to fuse the entire sensors’ data to get more accurate and robust positioning information. Display function spectacles functions related to the driver, such as guidance, charging information and map interface. Transceiver provides two-way data link via wireless network and IP based packet data transmission. The gathered data is then broadcasted into the internet so that any approved user can make full use of the services. The card interface is for charging via pre-paid smart card (Xu & Von, 2005).

![Figure 9: Block Diagram for In-Vehicle Unit (Xu & Von, 2005)](image)

Control centre system is the one that carries on its functionality by providing the guidance, charging, tracking and maintenance. Charging is based on matching of the road links that the
vehicle travelled with the map database. Once the vehicle position is received, the CCS matches vehicle trace with the road links through map matching and computes the vehicle cost. Payment can either be made through smart card in IVU immediately, or later on a cyclical (e.g., monthly) basis. The simple block diagram is portrayed below (Xu & Von, 2005).

![Figure 10: Block Diagram for Control centre system (Xu & Von, 2005)](image)

The VPS offers an effective means of vehicle tracking, the information gathered should be sent to the control centre very frequently for the processing of charges and for the enforcement procedures. In that case the VPS systems can be combined with other technologies such as wide area communication, Google maps and short range GPRS. The combination of the recent DSRC systems such as the 5.9-GHz technology along with Wireless Fidelity (Wi-Fi), Worldwide Interoperability for Microwave Access (WiMAX), and other 3G communication capabilities that are being implemented in Baltimore, and in other cities across the United States will make vehicle positioning system more popular for congestion pricing (Ezell, 2010). Till date these systems have not been implemented for a more contained congestion pricing scheme for reducing the congestion. It has a couple of problems to be stated, the primary problem being the problem of receiving the signals from the satellite in the urban regions. The secondary problem is the higher cost of in vehicle unit that may prove to be excessive for small areas and less congested regions. If this system is implemented by overcoming the problems stated above, then this would be more efficient and would give a hassle free process of charging, and would be a major mile stone for the role of ICT in sustainable transport.

**Combination of Technologies**

The majority of the congestion pricing schemes that are currently in use, are combinations of the above mentioned technologies. One combination that is very often used is the DSRC with the OBU for charging and identification technology, and in combo with this is the ALPR technology used for the enforcement backup. This combination of technologies allows operators to benefit from the higher accuracy, reliability and lower operating costs of DSRC, at the same time practice of ALPR helps to overcome DSRC limitations of casual-user management and enforcement (A Primer:Federal Highway Administration, 2008). This package also helps in bounding the usage of the less precise and more operations cost ALPR technology to a reduced number of transactions. Another less commonly used combination is the vehicle positioning system, for German and Swiss Truck toll pricing systems, wherein the VPS system is employed to address the location and to charge the vehicle using distance based elements.

We have used a process modelling idea to clearly explain the functionality of the technological working of a fully automated congestion pricing system that uses a combination of systems by using ‘Event-driven process chains (EPC)’, which is a modelling language that can be easily
understood by a non-professional. The main elements of an event driven process chains are event, function, organizational unit, information system, logical connector, organization unit assignment, process path and control flow. The EPC diagram that is modelled is for the fully automated, congestion pricing system that uses the prepayment method, and this particular method has proven its success in Singapore.

Figure 11: EPC diagram for the congestion pricing -OBU and prepayment method
5.3 Sub System Functionalities

As mentioned in the above section of functional processes, congestion pricing is the combination of sub-processes which requires a close integration to the primary technology. There are a wide variety of sub systems, for which a range of technological support exists. These sub processes play an important role in increasing the efficiency, reliability, and accuracy of the above mentioned functional processes. If the quality of these systems is improved then the support laid by these systems to the primary systems will be more efficient (A Primer: Federal Highway Administration, 2006). There are a lot of sub systems that are in research to improve the supporting quality for the primary systems, some of technologies which are in existence, are mentioned below.

- Vehicle occupancy detection methods
- Vehicle classification and identification systems (Laser, Infrared Technology, Video, Digital loop, etc.)
- Telecommunication: Roadside and centralized computer control centre,
- ITS integration

Vehicle Occupancy Detection Technologies

The most promising ICT advancement that could help the congestion pricing system attain its goal of minimizing traffic congestion would be the, development of Vehicle Occupancy Detection Technologies. This system helps the congestion charging system to charge accordingly, depending on the occupancy of the vehicle. In some countries like U.S., this system is followed for categorizing the travel through the HOV lanes (Ride sharers are given access to these lanes) and minimizing the congestion charge if the vehicle does not come under the drive alone category (Diamond, 2008). The advantages with this system is that the rideshare commuters and car-poolers may benefit with this, so most of the people opt for the transit options, thus in all the goal of congestion reduction is achieved. At present there are few systems in work that could read the Closed-Captioned Television Images and disclose the number of travellers in a vehicle; this is accompanied with the infrared sensors that can detect the human heat signatures. Though the collaboration of some potential algorithms and discernable advancement, of the technology has improved the capability of the software in detecting the human occupants, still there are a lot of inherent limitations that act as a barrier for the implementation of the automated vehicle occupancy detection (e.g. a sensor can go wrong in sensing the arrangement of the seats, or it can miss to count if the occupant is a small child). For automated enforcement the sensor should perform properly, which has not been possible to attain till date.

The solution for the above problem can be the focus of vehicle occupancy, from inside the vehicle. Most of the vehicles in present days have the option of sensors fitted to the seat belt and the air bags, through mechanical seat belt closure sensors and the weight sensors installed within seats. In the near future, we can expect the vehicles to have the sensors to be installed in the rear seats allowing the vehicles to have the complete analysis of the number of occupants in the vehicle. Additional advanced sensors include the light emitting diode (LED) and infrared imaging. The in-vehicle communicates with the sensors fixed in the infrastructures through the GPS, cellular networks and some other reliable way of communication to notify the occupancy details of the vehicle for the appropriate charges to be applied.
**Vehicle Identification and Classification Systems**

The vehicle classification technology varies with the type of the primary technology used. For semi-automated pricing lanes, the classification is done by measuring either the size of the vehicle or the weight of the vehicle. In cases like these, Weigh-In-Motion (WIM) detectors or lasers can be used with relative accuracy. Once the free flow roads are introduced and the vehicles at their full speed, the classification is very difficult with the technology available. The WIM detectors and axles are not to their best in classifying the vehicles, in the case of the free flow environment and do not provide sufficient accuracy, therefore there is a need for size based classification system (IBM, 2007).

At the moment there are two reliable methods available to classify vehicles by size in a free flow multi-lane environment a> scanning laser technology and b> stereoscopic video technology. Digital loops also provide classification but losses its control in the case of the lane change and do not provide best solution like the laser and the video technology. The technology for the classification of vehicles is an area, in which standardization is required across all ICT supported congestion pricing schemes that are implemented around the world. Current classification system creates uncertainty and confusion among the drivers; therefore there should be a common reference system to assist the drivers in knowing the charges that is to be levied.

**Road Side and Centralized Control Systems**

No matter what the congestion pricing technology combo is, all the systems require the continuous processing of outsized transactions. Depending on the charging scheme and primary charging technology, the complexity of the transaction and the volume of data, can be handled to reach a suitable balance between the system reliability and the operational costs. One major area that has to be considered is the road infrastructure and the computer control system, and the communication architecture to support these processes. Decisions can be based on the following factors a> the volume of data that has to be moved around the system for processing, b> the availability, reliability, accuracy and the cost of communications and finally c> the number and the accessibility of the road-side installation, and the security that has to be provided for these installations.

Congestion charging system depends on the large volume of data that is flowing from the road side facilities to the control centre systems (A Primer:Federal Highway Administration, 2008). With regards to the type and the structure, the data size can be determined; whether it is a low volume character based files or much larger digital image files (ALPR). The requirements of this control centre system will have a definite influence on the architecture of the system in particular the communication networks.

For example, directing ALPR processing at the roadside may meaningfully reduce communications and storage costs if the system provides for this type of operation. However, this feature requires a very higher level of functionality, that may prove too costly to provide at a large number of locations (Lindsey & Palma, 2009). If there is an improvement in the architecture design, the ALPR system will have more to gain because this system has the highest potential data requirements.

**ITS Integration**

The level and the kind of ITS integration depends on the pricing system, the area of traffic congestion, congestion limits, the definition of the problem in the congested area, and also the
technology in use, but there are several opportunities to integrate ITS in various levels of the pricing scheme. Another major application of ITS would be the collection of the charging information to provide real time travel information and congestion information through various websites. One of the famous systems is the ‘Italian Telepass’ system that has been in operation for many years in the road network. In this system the large number of OBU’s mobbing around the area are tracked and the information is provided to the real time information systems or to the traveller information system.

5.4 Sustainability Potential

Congestion pricing has its definite role in attaining the sustainability from all three sides i.e. social, economic and environmental. But to limit the scope of our discussion we have shared ideas only about the ways congestion pricing helps in attaining social and economic sustainability.

![Diagram](image_url)

Figure 12: Role of Congestion pricing in increasing social and economic equity (Bielli, Carotenuto, & Delle, 1998)

**Economic sustainability**

Congestion pricing helps in improving the economic sustainability of a city because it gives access to those road users who value their time utmost highly to avoid congestion delays. Many criticisms have been levelled against congestion pricing, the most common being that some environmental profits that the program can offer including the quality of the air and reduced congestion rate, would not make up for the fee that consumers will be forced to bear. But critics fail to realize that congestion pricing, at its fundamental, is an economic issue. The time that drivers expend while stuck in traffic is the time that could be used to make money. According to Bruce Schallar(2006) of Schaller Consulting, the total value of time spent by the New York traffic congestion is worth about $8 billion annually. This figure reflects a larger area than that can be equalled by the proposed congestion pricing plan, and the message is proposed clearly and precisely (Cohen, 2007). For example, in a fully congested city a courier delivery van has the capability to accomplish more deliveries during business hours than it could, without road pricing, enabling the use of a smaller courier vehicle fleet.

**Social Sustainability**

The congestion pricing effect on social sustainability also needs to be considered. The data, we hold for reference is from the United States (Nzbcbsd, 2003), and it suggests following points:

- The low and middle income drivers who travel at peak times, and who pay congestion charges end up better off in economic values, if the value of the their time spent in traffic is taken in to account (unless they are commuting for long distances);
• Low income travellers who use public transportation and rideshares also benefit from the introduction of congestion charges or HOT lanes, and these provide improved service and reduced travel time.

In general the above mentioned levels of sustainability are reached by placing more emphasis on travel choices squarely, that is not out of the hands of the individual traveller. The usage of cars for travelling is considered to be the most convenient way of travelling, which directly or indirectly stays as a strong means for the traffic congestion. However with some pervasive changes, people may find it fruitful to change their travel behaviour, that may be through the consolidation of trips, ride sharing or by using public transportation, or may be travelling at very less congested timings. Implementing congestion pricing is a definite way to control congestion because it carries out a sequence of steps that may influence the travel behaviour.

**In London**

The congestion charge, together with developments in public transit bankrolled with revenues from the pricing system, led to a fifteen per cent traffic reduction in central London, with no significant displacement to local roads outside the area. The vast majority of ex-car users have shifted to public transport. Travel delays in the central part of London have been reduced by 30 per cent (Litman, 2006).

**In Singapore**

Singapore is a well-developed small country, where population graph is unbound in the recent days and the use of cars has become a passion. In 1998 the city implemented the fully automated electronic charging system, with the charges set during the day time to ensure free flow of traffic. This system has contributed in reducing 13 per cent of the traffic and thereby increased the vehicle speed by 22 per cent (Sun, 2010).

**In Stockholm**

Stockholm has become one of the largest cities in the world in the recent days, and the congestion pricing method was implemented on a trial basis from January 2006 to July 2006. There was an instant 22 per cent drop in travel, a decrease in timings, and a mass shift to public transit and the inner-city bus routes rose 9 per cent. This system attained its ultimate success when the residents of the Stockholm city voted for the continuation of the system in a referendum in September 2006.

Thus from all these cities it has a clear proof that congestion pricing leads a way to the congestion reduction, thereby attaining equity for accessibility from the perspective of both economic and social. This ultimately throws on the principles of transport sustainability.
Chapter 6-Real time Information- ITS Solution

This subject area is mainly analyzed with the help of reports from the Federal Highway Administration (2006) and IBM’s literature sources on ITS solutions and it strives to answer the second research sub question.

In what ways the real time information sharing solutions help in reducing the traffic congestion?

The subject area of real time traffic information is of a cooperative traffic system and is definitely a ubiquitous form, which makes use of data led operations starting from data collection, transforming it to information and sharing the information at all levels of transport decision making (ICT SHOK, 2009). This gives an abstract meaning that, we should have an understanding on the transportation sector as a concrete entity of decision making, where the quality and quantity of travelling are influenced by individuals. All the levels of travel and transport decision making can be regulated by the timely and rich information on the impacts, choices and other things that may influence the situational awareness of the driver and a commuter. “The cooperative aspect is embedded in the capability of different actors either passively or actively to acquire data and share it with other parts and players of the traffic system” (ICT SHOK, 2009).

6.1 Concept

Transportation operations in this modern era need some ways to efficiently manage traffic congestion. Traveller information is considered to be an important factor in many programs aimed at mitigating congestion—a real application of “21st Century Operations using 21st Century Technologies” (Hepworth & Ducatel, 1992). The option of providing real time information helps the commuters in rescheduling trips, which may act as a major factor in reducing the traffic congestion. Traffic incidents, construction on the roads, road closure and the road transits act as main barriers for free flow of traffic, and rerouting from situations like these can convey much for traffic, thereby improving reliability and quality of travel. The ideal information flow to the travellers is required, to allow them to access consistent information of pre-trip and en-route with the assistance of wide variety of methods through different ICT devices across the nation.

Traffic management systems are usually controlled on the basis of real time data provided by monitoring systems. Typical data required includes, e.g., areas of extensive traffic congestion, cross-section traffic data (speed, volume and occupancy), and cross-section road surface condition data (dry/wet/snow/ice), cross-section weather data (wind/gusts, precipitation), automatic incident detection, and travel time data (ICT SHOK, 2009). Operators at traffic management centres operate and supervise the traffic management plans that are usually developed for typical recurring situations & scenarios, and verifying the status of the road network under their responsibility via CCTV cameras. Traffic management centres are usually operated by the respective road operator or the police.

6.2 How it works?

The most-recognized ICT application provides drivers with real-time travel and traffic information, such as transit routes, schedules, navigation directions, congestion areas, accidents, weather conditions, or road repair work. Advanced Traveller Information Systems (ATIS), the most effective traveller information systems are able to inform drivers in real-time of their
precise location (Shekar, 1996). They also inform the traveller of current traffic or road conditions on the route they choose and surrounding roadways, and empower them with optimal route selection and navigation instructions, ideally making this information available on multiple platforms, both in-vehicle and out. As Figure 13 illustrates, there are three key facets to the provision of real-time traffic information: collection, processing, and dissemination (OECD, 2002), with each step entailing a distinct set of technology devices, platforms, and actors, both public and private.

![Figure 13: Conversion of traffic data to real time information- A three step process (Yanagita, 1930)](image)

The first step of data collection involves gathering of data from a variety of sources like the webcams, the ALPR that is mounted on the poles or gantries on the road side, from the express monitoring advisory systems, from floating car and many available ICT sources. The second phase involves processing of the information gathered. This is done by the control centres which may involve technicians and customer service agents. The third phase involves the dissemination of the processed data through an assortment of ICT devices like the web portals, Radio broadcasting, navigation device, smart phones and others.

The above diagram (fig 13) gives a clear essence on the three levels of functions that is carried out in the real time information sharing. But still we have taken our own approach of providing a clear picture of the process that happens in the real time information sharing, with the help of Event-driven process chains in fig 14. The real time information being a very big field has various methods of the data collection, data processing and data dissemination. To limit the scope of the discussion we have considered just an outline of the three functionalities, and made it a very simple process to understand. In the process we modelled the data collected as a form of cross-section traffic data (speed, volume and occupancy) that is collected from the roadside and the floating car method. The EPC diagram states the process cycle right from the collection of data from a vehicle to the dissemination of data to the vehicle.
In this chapter we intend to explain the three basic functionalities bound to the delimitations mentioned in chapter 1. Here we do not aim to provide an exhaustive review of this very dynamic field. It rather aims to make a snapshot of the recent developments and discuss the
potentials related to new technologies as well as some short-term perspectives. We hereby discuss the outline of the processes that happens in the three phases in order to provide the real time information to the travellers. There may be lot of methods in collecting data but we have discussed most potential and the one that is much in use in present day applications.

6.3 Data collection

The development of information and communication technology demands very high quality of real time data. Under the growing pressure of traffic management, collecting traffic data method has been rising considerably and the access of real time information becomes routine worldwide. So through this thesis we have presented some ways of collecting data more efficiently compared to the traditional ways.

**Conventional ways**

Most of the technologies described in this part, are the ones that are used to measure the traffic data by means of the detectors that are located on the road side. The traffic count technologies under conventional ways can be split into two parts, the intrusive and the non-intrusive (Leduc, 2008). The most potential and widely adopted technology that comes under intrusive is discussed below:

- **Magnetic loops**: It is the most conventional technology that is being used to collect the traffic data. The data is collected by embedding the loops on the roadways in a square formation that generates magnetic field. The information is then passed to the counting device that is placed on the road side. This technology has been widely implemented in Europe for data collection.

Non-intrusive are remote based observations. New technology has come in which seems very promising.

- **Passive and active infrared**: The speed, type and presence of the vehicles are detected based on the infrared radiations from the detected area.
- **Microwave Radar**: This is the most advanced form of sensor which can detect the moving vehicles and their speed, and it is not placed by the road side. It is much advanced in vehicle classification and their speed.

**Floating Car Data**

The working principle of FCD is to collect the real time traffic data from the location of the vehicle by means of some ubiquitous technologies such as GPS or mobile phone from the entire road network. This basically means that every vehicle follows the rule of having GPS or mobile phone equipped to the vehicle which can act as a sensor for the entire network of the road. Information that is sent anonymously to the control centre includes data speed, location, time, and the direction of travel. After processing the collected data, until it reaches the level that the real time data should have (status of traffic, alternative routes); it is then re-distributed to the drivers or travellers on road. FCD is considered to be an alternative or rather complement source of providing potential high quality data to existing technologies. In this thesis, we have put our focus mainly on floating vehicle technologies such as mobile phones and GPS (Leduc, 2008).
• **GPS-Based FCD**

GPS is found used in various places more extensively and it is also becoming an artefact that is quite affordable, but so far only a limited number of cars are equipped with this system, especially the fleet management systems. The data that is obtained from the trucks and the private cars are suitable and it assists the traffic condition by providing the information about the rural areas and the motor highways. The data that is obtained from the private vehicles and the taxi fleets are much helpful in providing information about the traffic congestion, and it also helps in avoiding congestion by providing information pre-trip.

![Figure 15: FCD data collection method using GPS as in-vehicle unit (Leduc, 2008)](image)

GPS probe data is taken as a concrete source of real time information by many service providers, but the only disadvantage right at the moment is the consideration about the vehicles that are not equipped and the high cost factor of the equipment’s i.e. the GPS based FCD compared to the Cellular based FCD (Leduc, 2008).

• **Cellular phone based FCD**

Most of the vehicles today are equipped with mobile phones, so it is a good idea to use mobile phones to send data more anonymously. The positioning of the mobile phone is usually transmitted to the network by means of triangulation or at times even by other techniques (e.g. handover). Then the data that has to be sent for processing, like travel times and further data can be projected over a sequence of road segments, before being converted into useful information by traffic centres. The only condition of this technology that seems to be perquisite would be to keep the mobile switched on and not necessarily in use. This approach is much helpful when delivering the data accurately in the urban areas, where traffic data is needed.

The vantage point with this kind of a technical implementation is that, unlike other setup like GPS or any immovable systems, it does not need any special hardware or devices which would be expensive to implement. Traffic data are obtained continuously rather than receiving it from an isolated point data. It is faster, compatible, easier to install and needs very less maintenance. Whatever the benefits might be, still there is a need for the refined algorithms to extract and deal with the high-quality data, before it is been sent to the end-users. Even though the location is not precisely detected, the gift of advance devices has compensated this loop hole. This way of
gathering the data is more effective, when the network hold its hand with the UMTS (Universal mobile telecommunication system) technology (3G) (Leduc, 2008).

Currently FCD is involved in multiple applications worldwide dealing with real-time traffic information and traffic management. At present FCD is used in many applications around the world, to deal effectively with the real time traffic information gathering and traffic management. It also has various influences in controlling traffic congestion. We in order to limit the scope of our thesis have not discussed the emerging commercial applications using FCD as a data collection method (especially the ones that are based on the cellular phone network).

6.4 Data Processing

Once the data has been collected from different sources, both intrusive and non-intrusive, by the traffic management centres, it goes to the next level of processing and providing service. This is a section which functions 24/7 and in addition to ICT operations, some manual functions also take place. The control centre provides up-to-date information on the road congestion, which helps the travellers to make decisions, which obviously results in the reduction of traffic congestion. The influence of real time data processing also has an upper hand of the advancement of ICT. Travel information is provided before and after trips. The services provided by centre are as follows:

- **Pre-Trip travel information service:** This service provides information to the commuters that would be more helpful before beginning the trip, for instance the traffic congestion information. The trip planning service also allows the user to set trip routes, so that the traveller is provided with the estimated travel duration and the known advisory. An advisory for a planned event provides the traveller with the list that may interfere with normal travel routines, and help them to avoid traffic congestion. Pre-trip planning also helps in providing the public transport information such as bus timing, bus schedule and bus route information. By this way the real time information also helps in
promoting the public transportation and this gives hand for the reduction of traffic congestion.

- **Route guidance service:** This service gives information on the routes and also recommends the most favourable routes from the starting point to any destination. This trip planning functionality help user in maintaining the primary and alternative route information, so they can avoid the risk of getting caught in congestion.

- **En-Route Travel advisory service:** This service provides information while the commuter is on the road or in other words while the person is travelling, and the information includes traffic congestion, traffic incidents, construction zones and the weather information. The information is received and displayed using real time location specific incident information from a fixed end server. Incident information includes the areas of the extensive traffic congestion (Federal Highway Administration, 2004).

### 6.5 Data dissemination

The data dissemination is done with the help of a wide variety of devices and applications, but we have put focus on few applications that have a real potential of providing the valuable information in reducing the traffic congestion (Trafikverket, 2008).

- **Radio and TV:** This is a traditional method that is followed in many countries and this method is followed from a long period. The information about the road incidents and other factors that are considered to be obstacles for the travellers are broadcasted through specific channels and stations. Most of the information that is broadcasted through the television is of the text format.

- **Mobile Services:** The commuters can also keep track of the information while they are on road, with the advancement of the mobile devices. The processed traffic data has the functionality of reaching the mobile phones and other similar devices like the PDA’s. This functionality requires the mobile phones with an internet connection. There are also specific mobile applications designed for this purpose. In some cases the network operators act in collaboration with the traffic management service, and provide text messages about the vents on road.

- **Internet services:** There are lots of private service providers in tag with the transport management centres, who provide the real time data through the web portals. The web service provides overall accessible real time picture of the traffic situation on their web portals. There are also options to customize settings and adapt to the presentation.

- **Navigation Devices:** This is one device, which has a very high potential in disseminating the data to the end-user. This requires the GPS devices with the support of the TMC (Traffic message channel) (Trafikverket, 2008). TMC is an interesting technology and protocol for supplying real-time traffic information to drivers. Normally used in dynamic route navigation where traffic information allows Global Positioning Systems to route drivers around congestion, the technology is growing 'increasingly popular'.

### 6.6 Sustainability Potential

In many parts around the world the real time systems are still not in proper use. The information that is been exchanged between the public and the private sectors can be made compatible by the use of open exchange standards. Infrastructure based traveller information systems can be much helpful in conveying the real time information to the commuters. The goal of controlling traffic obviously leads to a sustainable transport flow. This way of sharing the dynamic information can have an upper hand on the traffic congestion reduction. This also contributes much to the two levels of sustainability; economic and social.
Social and Economic sustainability

Real time information sharing can set a foot on economic sustainability of a city for the reason it helps the users to save a lot of time by making a quick and right decision on choosing the route, travel mode and alternative time, so that they can avoid congestion. The saved time can help in making more money and the liveability is seen high. The real time information can also help traveller to locate the areas that are carried out with road works, so that there is lesser chances for road accidents which is further a major step for social sustainability.

Traveller information systems have record for demonstrated benefits. In San Antonio, Texas deployment of incident management systems with the dynamic message signs, resulted in 2.8% decrease in crashes, thus the fruit of traffic congestion reduction is obtained. In Glasgow, Scotland it was found that 40% of the commuters changed their route as recommended by the dynamic message signs. With the effort of interagency to provide multimodal information, can help in promoting public transportation and thereby reduce congestion (Ezell, 2010).

The option of providing real time data collected by the public sector to the information service providers allows the information to be personalized, thus increasing the value of the data to the commuters. A simulation survey that took place in Washington, DC found that the individuals that are prone to use the real time traveller information, could make on-time and reliable trips by 5-16 per cent, when compared to the others who do not use the service. Another example that proves the sustainability potential, is the change in travel plans from 45 per cent of the San Francisco commuters, and 85 per cent of the commuters belonging to the same region, who receive specific route information from the travelinfo® internet site result in a changed travel behaviour (Federal Highway Administration, 2004).

The Federal administration of United States, envision that the traveller information system will be capable of providing time based information, about the whole transportation networks in the near future. Conditions about all major routes and transit facilities will be made available, so that users can make the best choices about their available alternatives and therefore it leads way to a better social sustainability. Traveller information services has the potential to provide users with, transportation conditions ahead on their trips at the present or even in the future, through various methods like PDA’s, mobile phones, and telematics-equipped vehicles. The availability of such an ICT on field can relieve the tension amongst the drivers, and thus can implicitly change their behaviour on road leading a way to a congestion free road, thereby contributing a lot to the betterment of social sustainability.
Chapter 7- Extensible ICT applications

What is the role of extensible ICT applications (VPN networks or e-business) in reducing traffic congestion?

To analyse this subject area we dealt with a lot of literature sources and the main literature that gave us the idea of centre and periphery is from the ‘The Information city for the future’ a book written by Sullivan Frost (2008). In this section we mainly deal with the idea of how the ICT can help in forming the virtual business so that there is no need for a Travel, and thus helping in reducing the traffic congestion. This subject area is theoretically analysed to answer the third research sub-question we have dealt with this session

7.1 Extensibility in ICT

In ICT domain, extensibility can be referred to as a set of principles when the implementation is done with a more holistic approach of taking into consideration the possible future usage of the developed application by other not so related applications. Often the challenge in bringing extensible usage of ICT has been this desire to provide relevant change or usage to the independent applications without making (or minimizing) an impact to the host application in terms of factors like infrastructure (soft/hard). However, with the gaining popularity of service oriented architectures & related interoperability technologies of enterprise application integration for the potential of making services available for totally independent applications through web, the reach of ‘extensibility’ of ICT presently is breaking all barriers. This concept must not be confused with the so called old phrase of ’side benefit’ or with ‘forward compatibility’ as unlike side benefits there is a deliberate attempt to improve the situation of benefiting party and as unlike ‘forward compatibility’ the development is not done with an aim of what advantages the benefiting system will get if there is a change in the host application. In clearer terms the aspect which we keep in mind for our study is how some totally independent ICT applications built for totally different purposes (or business), can be used to control the problem of traffic congestion in the present day scenario, or if it could be extended in future to address the traffic congestion problem.

Intelligence

As augmented in the next section of this chapter, the extensibility features of varied applications often doesn’t necessarily results in a sustainable transport system. As a counter fact it can actually lead to an increase of the problem. The characteristic that plays vital role in building extensible opportunities is ‘intelligence’. This refers to the capability to collect, process, distribute, steer and monitor value chain processes in distributed places. This leads to various types of reorganization of value chains for efficiency reasons, i.e. related with time, cost-effectiveness or product quality. (Black &Geenhuizen, 2006)

Paperless Office

Traditionally workplaces have always had filing systems which are primarily based on usage of paper and have always involved the usage of hardware components to store them like filing cabinets, shelves, folders etc, which has always had an impact on the physical space occupied. It was late in the 1970s , that the emergence of phrase ‘paperless office’ came into picture through a magazine article (Business Week, 1975), where it was argued for the future state of the offices based on storage systems which would be ‘soft’ in nature so that the routine tasks of book
keeping could be eliminated. However, it was not until recently till the last decade of the previous century, that the concept came into prominence with the coming of age of the personal computing systems when organizations started to realize the potential of it.

_**E-World**_

With the advent of web there is this whole concept of e-world and e-life which has emerged where an individual can do everything over the internet like e-shopping, communication, meetings, government services, banking, networking, even e-learning and e-working (also referred as tele working).

### 7.2 Role of Extensible Applications

Building up on this background on the third research question we deal with what can be termed as extensibility (Black & Geenhuizen, 2006) aspect of ICT, and the role it plays in the reduction of traffic congestion. At this stage it is important to look at what ICT really is, and what parts we don't consider as direct ICT products meant for traffic sustainability. ICT on a very open definition can be viewed upon as a collaborated system of varied, either homogenous or heterogeneous, components (both hardware and software) which helps in transmission of information amongst different parties involved, situated in independent locations aimed at creating a networking between the communicating parties. Such a form of communication can be quiet varied, and range from very simple systems like email systems to sophisticated data transmissions systems installed in cars like GPS etc. Thus any such communication, which is originally not built as a part for transport infrastructure solution but that can indirectly improve the process of traffic reduction, is the point we address in this question. And as termed by Black & Geenhuizen (2006), we continue referring to such functionalities as extensible impacts of ICT.

Though this feature of extensibility has played a major role in growth of business and creation of businesses like e-shopping, social networking etc, these can have a major influence on the traffic congestion control. The fact that real time information sharing can help in further making choice decisions in the future can have a great impact on the problem. The advent of systems like video conferencing has opened up opportunities to work from home and thus reduce the traffic burden on the roads. Now this is actually a two sided affair as often we tend to think that the extensible features will lead to a reduced usage of transportation, but in reality they sometimes turn to actually increase the traffic congestion at specific places. As an example the increasing usage of last minute air ticket or train ticket sales leads to a renewed demand of such services thereby actually causing a new unexpected travel, and that too such road traffic which is focused right at a fixed location, like near to the airports, and can become a potential reason for traffic congestion. This example delves into a plain definition of traffic congestion that we use throughout our research and that is ‘volume of traffic demand over cedes the space supported by the existing road infrastructure’. As an another example which though doesn’t causes congestion at one point but surely increases the net traffic flow is the coming up of e-shopping business. It can be quiet deceptive in the reduction of traffic as mostly such business demands delivery of a product within a stipulated time frame, which further leads to delivery pressures and thus demanding to send products in smaller quantities to different locations, especially when considering the overseas delivery. The varied studies going around in supply chain and logistics are presently working on optimizing the way to do so. This is where other ICT solutions have started to come to peril and optimize the net delivery time as a function of net fuel consumption. The ongoing research in this field has lead to the development of varied products and ICT solutions based on aspects like Resource Optimization, Video analytics, traffic prediction (IBM,
The point to be observed here is that such products are considered ‘extensible’ applications as their direct aim is nowhere to reduce traffic congestion but is to reduce the overall business operational cost. For a positive example, it is also important to note as a sceptic that though a certain innovations in ICT like video conferencing can reduce the travel demand substantially, but they can’t become a complete substitution in all situations. However it can surely be one of the most important substitutions.

We categorize our study into two major parts. To understand the same better we refer to the work of (Black & Geenhuizen, 2006) and their layered model of a transport system. Now being focused more on the traffic flow we avoid referring to the layers 1 & 3, mainly dealing with the infrastructure aspects & direct (not extensible) solutions of ICT for traffic control. We work on the layers 2 & 4 which works on extensible applications primarily involving the actors that we are concerned with in road traffic congestion, namely the private car owners, the public transport users and freight carriers along with ICT manufacturers. It is in these two layers that we work on finding what ICT solutions presently can help in determining driver’s behaviour by providing him real time information for a choice decision to be taken, for the freight company to work on optimizing the load with the promised delivery times, and for public transport users to make a smart decision in the real time.

### 7.3 Consideration for traffic effectiveness

Considering these areas of opportunities which can help in addressing our problem we address that the following set of question could give us directions to finding a solution.

a.) How extensible applications can lead to a reduction in traffic congestion?

The modus operandi for this could be varied like how they can bring change in driver behaviour or how can they help in reducing the travel demand itself by bringing in solutions like e-banking, e-commerce which can help in reducing the travel for monotonous activities, which do not necessarily demand a physical presence of the actors involved. The following table organizes the points discussed above about relation of some of the existing ICT with travel demand.

<table>
<thead>
<tr>
<th>Type of ICT use</th>
<th>Impact on transport demand (persons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of E-services: shopping, banking, education, entertainment, government services</td>
<td>Reduces travel needs for routine transactions, but may cause increase of travel demand to central places with high-level services (e.g. to enjoy “shopping experience”). May add extra mode. Causes new travel demand due to lower consumer prices.</td>
</tr>
<tr>
<td>On-line, last minute, booking (flights, hotels, holidays, theatre)</td>
<td></td>
</tr>
<tr>
<td>Use of E-networking in social relations: personal communication, chat rooms, network games</td>
<td>Reduces travel needs for routine networking, but may cause new travel demand due to successful social networking.</td>
</tr>
<tr>
<td>E-working (at home or tele-center)</td>
<td>Reduces travel needs for individuals concerned but is nation wide very modest (0.8% reduction in annual vehicle miles, in US). May cause secondary impacts that counteract first impacts (substitution of work travel by not-for-work travel, and moving further to work).</td>
</tr>
<tr>
<td>E-office (internet, e-mail, portable computers, tele-servicing)</td>
<td>Possibly reduces travel during work. May cause increase of long distance travel because of more on-the-move working options.</td>
</tr>
<tr>
<td>E-meeting (tele- and videoconferencing)</td>
<td>Reduces travel needs to a limited extent, cannot substitute key-meetings (evaluation, preparation of major decisions, kick-off meetings, etc); maybe just adds an extra mode.</td>
</tr>
</tbody>
</table>

*b.)* How do we identify if the application being built can have any role whatsoever in assisting to reduce the traffic congestion problem?

The *identification* involves the role of intelligence in ICT to analyze how the ICT can contribute in the stages of *collect, process, distribute, steer or monitor* in the bigger value chain processes.
The point to note here is that like before here as well, we refer to the extensible applications which directly don’t have the destined goal of transport sustainability. This doesn’t mean that such extensible applications can only be of the form like e-commerce, e-working, distance education, leisure etc. It could also be for example the ICT applications developed for a freight management company to use intelligent control methods to manage delivery of its products at desired location as a function of time and money (delivery time and operation cost).

c.) This leads us to the further question, which is if every such identified application can have a more holistic view of the traffic congestion problem, and be developed keeping in view this problem taking into consideration the extra effort that every such development would need.

This probably is the bigger stage of a challenge, even more so than the stage of identification, because transport sustainability if at all would be amongst the last desired goal of the organizations developing or using the extensible applications. Now this stage involves the question of how can we motivate the organizations directly involved to incur cost to consider the contribution at all stages of IS development (right from requirement gathering to analysis to design to development to implementation and operations). This could potentially involve initiatives to be offered at governmental level with tax exemptions, or cost share or diverting revenue generated from congestion pricing to promote such initiatives.

The quest for answering these takes us to the point if the suggested methods contribute in bringing sustainability (economic, environmental & social), and are they themselves sustainable. Keeping focus on the sustainability points described in the first chapter we work with the aspects of social and economic sustainability.

Social Sustainability

Bringing social sustainability is the key most aspect of developing extensible applications. They have a direct focus on two things, first reducing the travel demand, and second distributing the traffic whether in terms of spatial distribution or distribution across different times. As we will see further in the section of analysis, one observation that stands out is how the collaboration of extensible applications with real time information systems can add to the concept of traceability, to bring change in driver behaviour pattern, giving them a choice in real time of the various modes of available travel options. This results in an increased accessibility and improved quality of urban environment leading to a socially sustainable system.

Economic Sustainability

The one direct consequence of usage of extensible applications can be the tendency of businesses to move their operations out of the city to the places where rents are low, or reduce the level of physical operations in the city. As an example, consider the advent of monotonous banking operations over the internet like transfer of money, bill payment etc. The banks can reduce its operations within the city for relatively high end operations, or for customers who are not so internet savvy. Thus this has resulted not only in reduced travel demand but has moved the major operations of such organizations like banks out of the city, thereby resulting in a spatial distribution of the traffic to different zones. However, there could now be economical sustainability challenges that might emerge out of such movement outside the centre. As an example, with e-commerce business of essentially monotonous (shopping) businesses growing up, the organizations when they opt out to move out to low rent zones, can face a pressure on delivery challenges within the stipulated times in a cost effective manner.
Chapter 8- Theoretical Findings

8.1 Summary of findings

RQ1: What can be the ICT solution that best fit for congestion pricing or ERP that can help in reducing the traffic congestion?

Congestion is also growing rapidly in small and medium sized metropolitan areas. Based on present trends, it is expected that congestion in a medium sized city in 10 years is going to be worse than, that is currently experienced by a large city. There are a lot of TDM measures for controlling such congestion, and congestion pricing has turned out to be a potential measure in reducing congestion. Congestion pricing works by fluctuating purely optional congestion filled route travel to other transportation modes or to off-peak periods. There are various technological implementations as seen in the chapter 3, which have been implemented in various countries to make the system more effective.

Even though the technological components of congestion pricing differ, the concept is going to remain the same i.e., the collection of payment. In order to perform this functionality of ‘payment’ properly, there are set of other eight functionalities that have to be followed by the system. They are detection, information, identification, classification, enforcement, exemptions, verification, classification, system reliability and accuracy. In addition to the eight functionalities, the proposed congestion pricing system should also have the support of some secondary technology. From the theoretical study we identify that the VPS based congestion pricing is the only solution that can stick to many functionalities, e.g., classification, identification, enforcement, detection and with some incentives all the functionalities in parallel, and it does performs those functionalities more effectively compared to the existing systems. At the same time it can also be supported by some secondary technologies like the ITS integration by collecting the gathered pricing information to process it in to the real time information and disseminating it to the commuters. Therefore from the theoretical study by comparing most of the present state technologies we identify that VPS is the best solution that can best fit the future state of congestion. For the reason it provides more accessibility from both the social and economic perspective, the principle of transport sustainability is therefore attained.

RQ2: In what ways can real time information sharing solutions help in reducing the traffic congestion?

The real time information sharing is one technological gift to reduce traffic congestion, and from the theoretical study it is clear that real time information is the sharing of the dynamic road or travel information with the commuters. This real time data sharing is carried out in three steps which are the data collection, data processing and data dissemination. There are various ways the data can be collected and the collected data can either be cross sectional traffic data, cross sectional road surface data and cross sectional weather data. The information gathered from these areas are sent to the processing centre and then disseminated.

The most potential way of data collection would be the data that is collected from the floating car data; this gives the entire cross sectional traffic data, which would be more promising in providing the real time information. Then in the data processing step, the gathered data is converted in to useful data and provided in terms of services. The three potential services that can be offered are the Pre-Trip information, Route guidance and En-Trip information. These services can be much helpful in reducing the traffic congestion. Then comes the last step of
disseminating the data. To do this task there are many potential devices but for the reason mobile phones and internet connection plays a major role in a normal human being's life, it would be a best solution to provide the information over the web portals and designing mobile and iPhone applications to control the congestion.

The main role of real time information in reducing congestion is by helping the traveller in making decisions, and potentially at times it also changes the driver behaviour. This is carried out by providing the alternative options to a traveller, and the options that are provided can be broadly segmented as of alternative time, alternative route and alternative mode of travel. The same is explained in the below diagram.

![Diagram of real time information in changing driver behaviour](image)

By getting the real time information, the traveller makes the decision well in advance so that he doesn’t gets locked in the traffic congestion. This technology helps both the social equity and economic equity, and finally the sustainable transport principles like accessibility and quality of the urban life are improved.

**RQ3: What is the role of extensible ICT applications like VPN networks or e-business in reducing traffic congestion?**

The first and foremost discovery about extensible applications that came up was the change of perspective, which was very limited at the time when we began our study to applications like e-shopping, banking, education, leisure etc., that looked very direct in terms of reducing or increasing travel demand. The point of change of understanding got elaborated in the due course of time, when the observations came suggesting that making use of such extensible applications, can lead the way for businesses offices/shops of essential monotone shopping to move out of the centre. This lead us to a further investigation that how the same creates a challenge for freight management companies to transport in the cost effective manner and within the stipulated time frames (the critical factor being that ‘customers expectations’ of delivery time is still the same and can’t be compromised with). Thus, emerged the need of building extensible applications for these companies to handle the problem. Such applications being developed will still fall under the purview of our definition of extensible applications, thereby expanding our initial limited thought set on the subject.

The following causal loop diagram is what we suggest describes the cyclical challenge associated with implementation of congestion pricing system. The question is simple, the place
you choose to apply congestion pricing is the one which is congested, which leads to the question as to why is the place congested. The answer being that because people want to travel through that path, which further leads to the question why people want to travel through the same path; because they are going to offices, and there are lots of businesses located in or near the zone. Now because of congestion pricing if the people chose not to go into the zone where these businesses are operating from then the very economy itself gets affected. This is where we point out that extensible applications of ICT can play a vital role in reducing the travel demand but not affecting the businesses by providing their successful substituted models over the options like web.

![Figure 18: Cyclical Loop of Choosing Congestion Pricing Zone](image)

The one not so visible observation which came out was that the success of such applications primarily depends on the successful penetration of them through well informed means. There are studies which have suggested that tele working hasn’t contributed to reduction in travel demand too much, because of its limited penetration and thus the potential is far from reached yet, and holds a great scope in the future. The contribution of the extensible applications to sustainability aspect got more and more focused on the social sustainability factor of improving the accessibility, both by travel demand reduction and splitting of traffic, leading to the reduced traffic congestion on any given point. The economic sustainability challenge that came out as a hurdle is the need of freight management companies to use intelligent transport systems for cost effective transportation of goods.

### 8.2 Arguments for an empirical study

Our main stress in developing theories has been kept to secondary data sources. However to understand the present state of art and the implementation challenges of ICT to reduce congestion and to get a clear evidence for the theoretical findings, we chose to do primary research of our own, by conducting relevant interviews and questionnaires. There were a few sections, which demanded a better understanding of the subject, and more of an opinion from the practitioners who are presently working on these systems. We believe the empirical study can provide more concrete information that we seek to answer our research questions. We felt that the idea of conducting the empirical study can give space for new knowledge and to validate the theoretical findings. And since the subject areas considered in our thesis are wide areas, we conducted the empirical study with a more forecasted way. We planned to conduct phone interviews with the experts in the concerned subject areas, and then a general questionnaire to gather the view of the heterogeneous group, which may all together act as a better support for the getting a better result.
Chapter 9-Empirical Study

9.1 Purpose of empirical study

The purpose of the empirical study was to answer few concepts that we were unable to produce from the theoretical study, and at the same time to develop a solid base of evidence to the theoretical findings. The empirical study helped us to get comprehensive response from the respondents’ experiences, and opinions about the influence of ICT in controlling traffic congestion. To collect the empirical data, triangulation method was used, which involves the combination of more than one method of data collection method. The gathered data is checked and analysed with the theoretical framework to bring some new results.

9.2 Sampling

It is good to sample the population before conducting the empirical study, and it can see more betterment, if the sampling is related to the group who come across the structures every day. Sampling for an empirical study can be discussed under two sections 1> Probability sampling 2> Non probability sampling.

We intend to use the non-probability sampling method, and for this we designed a set of questions for the interview. The phone interview was a semi structure one for the discovery of new information and it was conducted with the transportation experts, who have documented experience in the field related to our study and the interview was limited to two people. There was also a need for a heterogeneous sample of respondents for the questionnaire to support our results, so we designed a questionnaire only with open ended questions, which helped us in getting some interesting data.

9.3 Interview

The interview is considered to be the most efficient way of getting some information in particular. A qualitative research interview seeks to explain the meaning of central theme in the life world of subjects (Sekaran, 1992). Interviews are finished by interviewer based on what the respondent says. Moreover, interviews are time consuming and they are resource intensive. Open-ended interviews were asked to all interviewees, and this type of approach facilitated faster and better interviews that could be more easily analysed and compared. Our main motives were:

- Interviews with practitioners to get a direct opinion from the personnel in centre, and understand the pros & cons of the implemented congestion pricing systems, the loopholes in the present system, operational procedures and upcoming improvements in the new systems.
- Interviews to understand the role of real time information in reducing the travel demand, and the ways in which the information is distributed to commuters on the road.

Therefore we send an email that briefed the interviewees the reason for the interview, and the subject area that the thesis deals with. It also requested the interviewees to provide a convenient time and date. When the interview date was confirmed, an agenda was sent, that consisted of question’s that were to be asked and the subject areas that we wished to discuss. The selection of questions was more to derive answers to the research questions, and to create knowledge and insight towards the subject area. The first interview was conducted on Jan 12, 2011’ with a person who has a relevant experience in the field of Real time information sharing with the help
of ICT and second interview on Jan 17, 2011’ with a person who has a vast experience in the Congestion Tax department. Both the interviews were conducted over the VOIP, and with the permission of the interviewees the calls were recorded for our reference. The discussion took place in English.

9.3.1 First Interview

The first interview was conducted with Eva Soderberg, who works as a communication officer in Transportstyrelsen (Swedish transport agency) in the congestion tax department who has a relevant experience in the field from the time the congestion tax was implemented in Stockholm (nearly 4 years). Eva is responsible for the internal and external communication of the congestion tax department. The Swedish Transport Agency works to achieve good accessibility and their motive is to represent high quality, secure and environmentally aware rail, air, sea and road transport. They take complete responsibility for the implementation and maintenance of the congestion tax system related to collecting charges and changing plans. However, they do not take care of the physical equipments of the congestion tax, and at present they are working towards the implementation of the similar congestion tax system in Gothenburg. The Swedish transport agency is funded in two different ways, first they collect charges from the users for their services, and secondly the government allocates some funds for the maintenance of the congestion tax. Finally, the charges collected from the congestion tax is been given to the government as the revenue. The interviewee stated that the main reason for congestion tax implementation is primarily to reduce congestion and the secondary reason is to collect revenue. She further suggested that collecting revenue is also important for the reason that it can be used for many other steps in reducing congestion. Finally, regarding the collection of charges she simply stated that “The goal of collecting money is equal to the goal of reducing the congestion”.

There are a lot of ERP schemes that have been implemented throughout the world and in some areas the system has been successful, whereas in some areas like Hong Kong the system was a failure. The Electronic Road Pricing Scheme in Stockholm with the name Congestion Tax was a successful implementation, and when we asked the main reason for its success the interviewee told that, it is vital to first “define the problem inside the city” and to define the problem three steps has to be followed “where, what and how”. The problem in Stockholm area was defined with these three keywords and then a solution was presented by the politicians in synchronization with those problems, and this she feels to be the main reason for the success.

When we asked her about the main technological components in the congestion tax system, she said when the system was implemented in 2006 as a trial it had a dual system i.e. the OBU and the video camera to charge the vehicle, but later on to make the system more simple the OBU’s were removed and just the cameras were kept. This was done because the cameras were more reliable, and were more convenient in charging the vehicles. Therefore the present system has an equipment to emit the laser beam which is kept on the gantries, and once the vehicle crosses the laser beam, the front and the rear cameras are activated to take photographs of the license plates, which is further processed to charge the vehicle owner. Then she continued to say that once the commuter is charged they are sent with a monthly invoice where the commuter can either pay in shops like Pressbyrån, or they can also pay it over the internet.

The discussion was interesting and then we continued with some important concepts which were the underlying areas that motivated us for this interview session:
• Compare the existing ICT solutions of the congestion pricing in Stockholm with the planned one in Gothenburg, to better understand the ICT advancements and the points of loop holes discovered, where we believe the experience gained from this study can set a path for the future cases.
• Understand the all-round sustainability (social, economic, environmental) factors affected by the congestion pricing implementation.
• Understand the role congestion pricing plays in changing the driver behaviour trends.

She told that the primary goal of the pricing system in Stockholm is to reduce the traffic congestion and partially confessed that there are few loop holes in the present system in Stockholm, like the failure of detecting vehicles when it comes to the damaged number plates and the foreign vehicles (vehicles from Lithuania and Finland have a similar number plate system like Stockholm, in those cases a wrong owner is being charged). She told that the Swedish transport agency is considering the VPS based pricing system for Gothenburg, for it is a place which has the floatation of more foreign vehicles. Therefore the system entertains the OBU and the vehicle is traced or can use the prepaid system.

When asked her about the all-round sustainability factors of congestion pricing she told that the congestion has a definite influence towards the three levels of sustainability. She said that there are a lot of positive impacts of congestion pricing towards the social and the environmental levels of sustainability, and at the same time it has a few negative impacts on the economic sustainability. When we discussed with her about the influence of present congestion tax system in Stockholm on the driver behaviour, she feels that in many countries the congestion pricing system has the in vehicle unit with a pre-payment method of payment and that might make the system more simple, but the congestion tax method that is followed in Stockholm is successful in reducing traffic mainly because of the post payment method. The main reason she interprets is that the post payment method allows the driver to take decision before travelling, wherein with the prepayment once if the driver loads the card with money he might try to use it and thus causing an increase in congestion.

9.3.2 Second Interview

The second interview was conducted with the Joakim Barkman, who works as a Technical manager in Trafikverket (Swedish Transport Administration). His main duty is to handle the department of Real time information, and the sections that actively work under him are the technical maintenance people for sharing the real time information. He has seven years of experience in the field of real time information sharing and his current project is to maintain the Trafiken.nu website for providing the information of road over the internet. Swedish Transport Administration (Trafikverket) is a new agency responsible for all modes of traffic and their main aim is to increase accessibility, improve road safety and reduce environmental impacts. They also take care of the technical and physical infrastructures around the Stockholm city which also includes the congestion tax system. Trafikverket is directly supported by the Ministry of Communications and is funded by the government. Trafikverket also has partnership with some other organizations like the Transportstyrelsen.

Traffic congestion being a term that still does not have a proper definition, we thought it would be a very good idea to discuss this with the interviewee. Joakim gave a very good technical explanation about his views on traffic congestion and how it occurs; he said that traffic congestion occurs when there is an additional vehicle in to the traffic flow where the road infrastructure does not have enough space to accommodate that new vehicle. He feels that in
Stockholm the main reason for traffic congestion is that there are a lot of bottlenecks in and around the city so that congestion happens all of a sudden at an unexpected situation.

When asked him about the influence that the real time data has brought about in reducing the traffic congestion, he said that there was a survey conducted recently by the Trafikverket about the real time information systems and its role in their daily life, in which nearly 78% of the people are happy about the way the it is being carried out and most of the people agrees that this technology has helped them in avoiding the congested areas, and also to choose an alternative time to avoid the peak timings. He also said most of the people are comfortable in using the real time applications, for example the trafiken.nu website is been used by a lot of youngsters today and they are really comfortable using it.

We knew that real time information sharing under ITS is a very big concept and the dissemination of real time data can be done through different ways, so we asked the interviewee about the modes of real time information transfer other than the internet and mobile devices. The interviewee said that there are a lot of ways to transfer information, and some of the present methods followed in Sweden other than the internet and mobile are through the parking guidance systems, information through the navigation systems, the text format through television, real time display units in & around the city to display the timings of the public transport, and the messages about the road construction areas.

The above discussion carried out with him gave us a lot of basic information and then we continued to discuss few key concepts that motivated us for this interview session, and they were to help in:

- Understanding the potential method of real time information sharing, and to know the active methods of sharing the real time information that can control traffic congestion.
- Understanding the role that real time information sharing can play in collaboration with the congestion pricing system, to support the economically less supported people by providing information about public transport options.
- Identifying the expectations from the people when it comes to the real time information.

As per Joakim the potential real time information depends on the problem definition, and there are a wide variety of ways information can be collected and disseminated to the public. He also said that the Swedish Transport Administration handles the information sharing in three modules: Real time information along the road, Information inside the vehicle and the information before the trip. He feels that the most potential one among these three would be to get the information before the journey i.e., the real time information about the traffic conditions, road works and about the delays of the public transport, for the reason it can have a definite influence towards the driver behaviour. He also added that this piece of real time information before trip can help them in choosing the travel.

When asked about the role real time information plays with the collaboration of the congestion pricing, for the economically less supported people by providing a better public transport system. He revealed the fact that it is really difficult for some economically less supported people to pay for congestion tax on every day of commute, therefore the present policy in Stockholm is to collect the charges from the congestion tax and the money is put more towards improving the real time information infrastructures. This idea of improving the real time infrastructures can divert a guaranteed number of crowds towards public transportation, which further sets path for the reduction in traffic congestion.
When asked about the expectations that are amongst the public about real time information, he said that the Trafikverket handles a website for providing the real time information called “Trafiken.nu”, which is very much active in providing the real time information to the public. He stated that the website has around 22000 visitors on a daily basis on an average throughout the year. He confessed that the commuters wish that the website should be more reliable and it would be helpful for them, if there is an application for iPhone.

9.4 Questionnaire

We thought it would be good to conduct a close ended questionnaire with a heterogeneous group of people to know their perspective of handling the extensible ICT devices. We framed out a set of 12 questions that we considered relevant to our research. We also clearly mentioned in the questionnaire about the purpose of the research, and the subject areas that we are dealing with. We then sent it to 65 people and got response from 36 people. The questionnaire were conducted during the period from 5 Jan, 2011’ and 14 Jan, 2011’. The results were gathered from the active respondents and then they were analysed for results.

9.4.1 Presentation

i> Gender

Out of the 36 respondents, 41% were male and the remaining 59% were female. The number of male respondents was less compared to the female respondents.

![Gender](image)

ii> Age

In this, we found out that the number of participants was high between the age group of (20-30) which was 42% and the next highest was from the age group between 30- 40 which was around 37%.
Out of the 36 respondents, 51% were students and 38% were employed. So the respondents belonged to the target group that do travel often. Thus we were happy that the results would be much helpful for our research.

The information given above with the help of the graphs were some general information about the respondents. The table below gives a clear account of the questions that were asked and the responses that we got; it is given in numbers about the response.
iv> Rate how important the following factors are in preventing you from using public transport:

Lack of information, Distance from stop, Cost, Length of Journey, Weather, safety

From the above graph the three factor that are highly recorded that prevent the respondents from using public transport are 1> weather (33%) 2> Length of Journey (50%) 3> Lack of info (44%).

v> How much have the e-services helped you in reducing the travel?

From this question the response was in that 41% of the respondents said that the usage of e-services for the shopping was low, and 33% of the respondents said that e-services have helped the respondents reduce travelling under high category, and 27% of the respondents say that e-services has helped in reducing travel highly when it has come to entertainment.
How does the concept of paperless office sound to you?

![Paperless office](image)

The concept of paperless offices took more interest from most of the respondents that 89% of our respondents said that it sounds good and they believe it would be helpful. Wherein only remaining 11% of the respondents thought that it won’t be helpful.

9.4.2 Statistical view of the rest

We took an effort of sending the questionnaire to 65 people and got reply from 36 people. The questionnaire results were collected through email. From the 36 responses, we got we found that 59% were male and 41% were female, and there was a large reply from the age group of 20-30 which was 42% and then the next highest was the age group 30-40 which was recorded to be around 37%. From this we analyze that the age group 20-30, who are generally more internet savvy, are much interested in responding and the next highest was from the age group 30-40. This is the group of people who are prone to travel a lot and we are happy that we have got more response from these two groups. All the respondents in our list had internet access. And when asked about which device they use for internet connectivity, the response rate was high for Mobile which was 52%, and then the laptop 30%, and it was found that the response rate was less for the desktops 16%. From this we found that most of the people use compatible devices which can be carried out wherever they go, and the advent of real time application can be of much use to them throughout their travel.

When questioned about their mode of transport for their daily trips we also provided the option of a single respondent selecting multiple modes. The travel to university recorded highly under the mode cycle which was 47%, and next highest under this division is BUS which is found to be 41%. Next when it came to leisure the highest mode of transport is through bus which is 36%. Then the next category shopping recorded 30% of respondents choosing to go by car. Finally in the category work, most of the respondents were on the side of train and bus which were documented to be 38% and 40% respectively. Therefore from the response to this question on an average the travel through bus seems to be very high.

When our questionnaire asked how often the respondents book the last minute tickets online, the response was high for “Don’t prefer it”, which was recorded to be 44% and then the next high level was “occasionally” and this recorded 36%. When we asked for the interest of the respondents on e-working the response rate was high for ‘yes’ which was 72%, and for ‘no’ it was 27%. And for the question about their views on ‘paperless offices’ the response rate was high for “helpful” which was 88%.
We were surprised about the advent of e-meeting and its extensibility when we received answers for the question ‘How much has e-meeting (tele and video conferencing) been helpful in reducing travelling in the past?’ and 58% of the respondents made it high, wherein 33% of the respondents found it average. Finally we just thought of exploring the behaviour of the travellers with the question ‘Would you be interested in choosing public transport if it provides more facilities than going by car or taxis?’ The response rate was high for a “Yes” and it was documented to be 69% and remaining 31% were still interested going by cars and taxis.
<table>
<thead>
<tr>
<th>Table of Results from the questionnaire</th>
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</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
</tr>
<tr>
<td>Male 15</td>
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<tr>
<td>Female 21</td>
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<tr>
<td><strong>Age</strong></td>
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<tr>
<td>Below 20 2</td>
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<tr>
<td>20-30 15</td>
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<tr>
<td>30-40 13</td>
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<tr>
<td>40-50 6</td>
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<tr>
<td><strong>Occupation</strong></td>
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<tr>
<td>Student 18</td>
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<tr>
<td>Employed 14</td>
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<tr>
<td>Unemployed 4</td>
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<tr>
<td><strong>Where do you live?</strong></td>
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<tr>
<td>Urban 28</td>
</tr>
<tr>
<td>Rural 8</td>
</tr>
<tr>
<td><strong>Do you use internet?</strong></td>
</tr>
<tr>
<td>Yes 36</td>
</tr>
<tr>
<td>No 36</td>
</tr>
<tr>
<td><strong>Which device do you use for internet connection very Frequently?</strong></td>
</tr>
<tr>
<td>Mobile 19</td>
</tr>
<tr>
<td>Desktop 6</td>
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<tr>
<td>Laptop 11</td>
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<tr>
<td><strong>Do you own a car?</strong></td>
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<tr>
<td>Yes 11</td>
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<tr>
<td>No 25</td>
</tr>
<tr>
<td><strong>Which method of transport do you prefer most frequently for the following trips?</strong></td>
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<tr>
<td>i&gt; Travel to university</td>
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<tr>
<td>Walk 12</td>
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<tr>
<td>Train 8</td>
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<tr>
<td>Bus 15</td>
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<td>cycle 17</td>
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<tr>
<td>car 2</td>
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<tr>
<td>Motor cycle 5</td>
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<tr>
<td>ii&gt;Leisure</td>
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<tr>
<td>4 8</td>
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<td>7 12</td>
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<td>8 2</td>
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<td>4 10</td>
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<td>iii&gt;Shopping</td>
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<td>5 2</td>
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<td>11 4</td>
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<td>iv&gt;work</td>
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<td>13 5</td>
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<td>5 8</td>
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<tr>
<td>10 12</td>
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<tr>
<td><strong>Rate how important the following factors are in preventing you from using public transport:</strong></td>
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<tr>
<td>(1- prevents more, 5- doesn’t prevent)</td>
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<tr>
<td>Lack of information</td>
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<td>One 12</td>
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<tr>
<td>Two 8</td>
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<tr>
<td>Three 11</td>
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<td>Four 3</td>
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<tr>
<td>Five 2</td>
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<tr>
<td>Distance from stop</td>
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<td>4 8</td>
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<td>8 15</td>
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<td>5 5</td>
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<td>4 10</td>
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<td>Cost</td>
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<td>6 6</td>
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<td>10 8</td>
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<td>length of journey</td>
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<td>16 4</td>
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<td>4 6</td>
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<td>6 2</td>
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<td>8 8</td>
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<td>8 10</td>
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<tr>
<td>Weather</td>
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<td>18 12</td>
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<td>12 6</td>
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<td>6 0</td>
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<td>safety</td>
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<td>3 5</td>
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<td>5 8</td>
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<td>7 7</td>
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<td>13 13</td>
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<tr>
<td>Frequency of service</td>
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<td>11 2</td>
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<td>2 8</td>
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<tr>
<td>8 6</td>
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<td>6 9</td>
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<tr>
<td><strong>How much have the e-services helped you in reducing travel?</strong></td>
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<td>Shopping</td>
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<tr>
<td>High 8</td>
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<td>Average 7</td>
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<td>Less 15</td>
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<td>No 6</td>
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<td>Education or Seeking Information</td>
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<td>12 10</td>
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<td>10 8</td>
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<td>8 6</td>
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<td>6 10</td>
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<tr>
<td>Entertainment</td>
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<tr>
<td><strong>How often do you book last minute tickets online?</strong></td>
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<tr>
<td>Very Frequently 5</td>
</tr>
<tr>
<td>Occasionally 13</td>
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<tr>
<td>Don’t prefer it 16</td>
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<tr>
<td>Would you be interested with e-working from home rather than doing the same work at home?</td>
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<td>---</td>
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<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>How does the concept of paperless office (internet, e-mail, portable Computers, tele-servicing) sound to you?</th>
<th>Helpful</th>
<th>Not Helpful</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>32</td>
<td>4</td>
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</table>

<table>
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<tr>
<th>How much has e-meeting (tele and video conferencing) helpful in reducing travelling in the past?</th>
<th>High</th>
<th>Average</th>
<th>Less</th>
<th>Nil</th>
</tr>
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<tr>
<td></td>
<td>21</td>
<td>13</td>
<td>2</td>
<td>0</td>
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</table>

<table>
<thead>
<tr>
<th>Would you be interested in choosing public transport if it provides more facilities than going by car or taxis?</th>
<th>Yes</th>
<th>No</th>
</tr>
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<tr>
<td></td>
<td>25</td>
<td>11</td>
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</table>

Table 3: Results of the questionnaire
9.5 Empirical findings

Sub Question 1: What can be the ICT solution that best fit for congestion pricing or ERP that can help in reducing the traffic congestion?

The interview section we carried out with Eva Soderberg from Swedish transport agency helped us to validate the answer for this question. We have discussed the information shared by the interviewee in two categories and thereby we have shown the findings

Existing Stockholm vs. Planned Gothenburg (ICT Advancements and Fixed loopholes)

On discussion about the growing trends in ICT and the changing demands of users since last implementation of the congestion pricing at Stockholm, the major points that came up were:

Payment
The decision of post payment versus pre-payment options is a cultural choice, as in some countries the presence of ‘credit’ (post payment) increases the usage of service. As per Eva, it is the pre-payment system, which can lead to more usage of the vehicles in Sweden. She also suggested that the post payment method can have a definite influence towards the decision making, and hence it has been very much helpful in reducing traffic in Stockholm. However she also pointed out that this may not work in nations where there is a fear of revenue leakage because of post payment options. At the same time she confessed that this method of post payment cannot be suitable for cities like Gothenburg because, being the second largest city in Sweden city it gives access to a lot of foreign vehicle on a daily basis and it is highly difficult to charge the foreign vehicles with post payment. Therefore the one main difference that has been planned for Gothenburg from the existing Stockholm system may be the method of payment. She also made it clear that in-vehicle unit with a pre-payment card is a very contextual system and its need of usage can vary from countries to countries.

Detection, Information, Classification and Enforcement
According to Eva, she feels that the present system with the ALPR system is nowadays much reliable and accurate in detecting the vehicle, but in cases of foreign vehicles and vehicles with damaged number plates it is difficult to carry on the functionalities like detection, information, classification and enforcement and there are lot of chances for revenue leakage. As per Eva, one concrete solution for this problem can be moving the domain set of benefits towards VPS as that helps in detection, identification, classification & enforcement. It does not require any kind of an infrastructure and it can also help in distance based charging. Eva also suggested, that it is more accurate in tracking the vehicle so that the information of the vehicle location can be used in providing real time information, which involves more of an ITS integration, which was learnt to be a secondary technology in the theoretical study. We found out from her that there are few drawbacks with the VPS system, one potential problem suggested with VPS is the growing need of data storage capacity (setting up new data centres is a big operational cost) as that will increase the data amount by manifolds. Therefore from the empirical study it is clear that if there is a solution to overcome the above stated drawback VPS would be a solution.
**Congestion pricing vs. Driver Behaviour**

According to Eva, the most deep rooted cause for congestion is ‘driver behaviour’, and any sustainable system should try to focus on that. With congestion pricing system it hits straight to the pocket and leads the drivers to change with mainly three options really showing up i.e., they change or combine modes, change routes leading to less congestion during peak hours, or when they consider that it is not very necessary to do the journey during peak hours they change timings making the traffic more spread out during the day.

**Sub question 2: In what ways can real time information sharing solutions help in reducing the traffic congestion?**

The interview session with Joakim Barkman from the (Swedish transport administration) Trafikverket, and the questionnaire that was sent to a diverse group helped us in validating our theoretical findings. The findings of the empirical study is discussed under the following categories

**Existing method in Stockholm**

As per the Joakim, the Swedish transport agency follows here steps as we have seen in the theoretical study; Data collection, Data processing, Data dissemination. As per Joakim, there are lots of ways it collects data and it depends on the problem statement or the solution for the problem. He gave us the information that the data collection at present is done both manually (policemen) and with some automated systems. He further suggested that the data collection would be more appropriate if all the vehicles inside the city have the navigation system, so that from this system all sorts of cross sectional vehicle information can be gathered in an efficient way.

He suggested that the data dissemination is more important because that is the final stage, and it should be conveyed in a better way to the commuter. He said the most potential way of disseminating the data is by sharing the data through the web portals. At present the web portal that is maintained by trafikverket i.e. trafiken.nu is doing well with a continuous increase in the counts day by day. If there is any problem in the road network, the visits in this websites goes really high. He also mentioned that a survey was taken by trafikverket with regards to the trafiken.nu site, and most of the people were happy with its performance.

Therefore we found that collecting information through FCD, and sharing all those information through web portals and provide more customization like iPhone apps and mobile application can take the real time information sharing a step ahead in reducing traffic congestion

**Real time information Vs. Commuter Behaviour**

When discussing about the real time information and its role in changing commuter behaviour, we identify that the real time information sharing has the capability of providing overwhelming options about the road congestion and any cross sectional road data in a single picture. They provide the three main options of changing time, travel mode and route.

As per the questionnaire response, the method of travel that most of the respondents use for their regular activities like going to university, work and shopping is found to be high with the public transportation mode. At the same time there were very less rating on lack of real time information,
when questioned about the factor that prevents them from using the public transportation. This questionnaire is conducted within the circle of Sweden, and this verifies that the real time information systems are promoting the public transportation, and thereby there would be a huge reduction in the traffic congestion. There was very high rating on the factor weather as the one that prevents them from using public transport. Though real time information cannot help directly in overcoming weather, it can provide information on road condition with relation to the weather. This can help the commuters to not get locked in the traffic, thereby providing an ease of accessibility, and helps improving a good quality of urban lifestyle which are the ultimate principles of transport sustainability.

**Sub Question 3: What is the role of extensible ICT applications like VPN networks or e-business in reducing traffic congestion?**

There were few aspects that have been discussed in this section on the same subject about the cases where extensible applications can increase traffic demand as well. To understand and analyze the overall view from both sides better, the questionnaire was designed. The observations that came out were of great relevance as we observed that only 16.6% stated that with the advent of e-shopping, distance education and availability of information on websites, has not reduced their travel demand. Thus, suggesting that a huge proportion of interviewed groups have actually felt a reduction in their travel. Travelling for entertainment however still remains a point which hasn’t seen a great travel demand reduction. The idea of paperless office sounded helpful to 90% of the interviewed group. To understand the other side, one observation about options like last minute ticket bookings that has a negative effect does seems to be gaining popularity as 50% of the respondents said ‘yes’ to having used them, out of which only 14% said that they use it frequently indicating that such applications are growing slowly but surely. The one aspect which gives a weight to our argument is that 26 out of 36 respondents expressed their interest in working from home, and 21 said that e-meeting has helped them a lot, which together is a sign that travel demand during peak hours has a great potential of getting reduced if organizations start promoting the work from home options.

**9.6 Summary of Empirical Findings**

Though the findings are analysed much elaborately in the previous section, we in this section have made a short description which speaks directly of what our empirical findings are supposed to be,

**Research sub question 1: What can be the ICT solution that best fit for congestion pricing or ERP that can help in reducing the traffic congestion?**

From the interview section we have got a new data in analysing the best solution for the congestion pricing system. The VPS based congestion pricing systems helps in detecting the vehicles with damaged number plates, and in case of charging the foreign vehicles it is much better to have a VPS based pricing system along with a prepayment system, so there will not be any leakage in the revenue. From the respondents view, the VPS based pricing system can also be used in case of distance based charging. Therefore this system can improve the efficiency of the pricing system, so there is a definite influence on traffic congestion control.
**Research sub question 2:** In what ways can real time information sharing solutions help in reducing the traffic congestion?

From the interview we got an idea of how the real-time system functions, and how the data is collected and disseminated. The interviewee suggested that the most potential way of collecting the data would be the method of FCD and the better way to disseminate the data would be through the internet portals. This is for the reason that most vehicles are equipped with the GPS so collecting the data would be more flexible, and this being an internet era people most of the time have their mobiles connected to internet, and therefore disseminating the information through the web portals would be much more efficient. The main role the real time information plays is in changing the driver behaviour and making them select the alternative modes, so that the ultimate goal of traffic congestion is reduced.

**Research sub question 3:** What is the role of extensible ICT applications like VPN networks or e-business in reducing traffic congestion?

The data observed from surveys suggested that the in cases of essentially monotone activities like e-banking or daily shopping, and seeking information about a process are some of the areas where the users do not themselves prefer to travel. Thus this holds a key potential point in deciding which businesses can move out from the zone with the help of ICT, and without having a great effect on revenues. The idea of e-meeting is one point which has already had a great effect on reducing the travel demand, and with improved ICT systems in future this surely will further help in reducing travel demand.

### 9.7 Validations of the Theoretical findings with the empirical evidence

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Theoretical Findings</th>
<th>Empirical Findings</th>
</tr>
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<tbody>
<tr>
<td>What can be the ICT solution that best fit for congestion pricing or ERP that can help in reducing the traffic congestion?</td>
<td>VPS based congestion pricing because it satisfies the most of the functionalities which are needed for pricing automatically, and also for some ITS integration.</td>
<td>The empirical findings validated that VPS based congestion pricing with a pre-payment system can help in charging the foreign vehicles, and VPS based systems can be much helpful in detecting the damaged license plates and it is much reliable in charging a vehicle on distance base.</td>
</tr>
<tr>
<td>In what ways can real time information sharing solutions help in reducing the traffic congestion?</td>
<td>The theoretical findings suggest that the most potential information is about the kind of service provided and it is of three categories pre-trip, en-trip and route guidance information, which has a direct influence on the driver behaviour and tends them to choose alternative options.</td>
<td>The empirical findings validated that most potential way of collecting and disseminating the information is by the FCD and web portals effectively, and the data disseminated can have a direct influence on the driver behaviour in choosing alternative modes.</td>
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</tbody>
</table>
**What is the role of extensible ICT applications like VPN networks or e-business in reducing traffic congestion?**

The extensible applications can be a good substitute for ‘essentially monotone’ businesses whose ‘customer expectations’ do not require a touch & feel experience, to bring about a change in dimensions of cities resulting in the distribution of traffic.

The empirical findings validated that there is and can be a big reduction in travel demand for some of such businesses like e-shopping, distance education etc.

| Table 4: Empirical evidence to validate the theoretical study |
Chapter 10 - Analysis and Result

A short gist of the findings of the three sub questions is jolted here. A detailed description of findings of each and every sub question with a thorough comparative analysis of theoretical findings with empirical findings, along with its influence on the social and economical sustainability aspects, leading to the results mentioned here is described in the section that follows on analysis and results.

- VPS based congestion pricing is the best suited solution for future of congestion pricing as it serves most of the nine functionalities mentioned as judging criteria in a better way than the present day systems. Furthermore it removes the pressure of building infrastructure at one point, and can be used for mileage based congestion pricing. It improves accessibility and lends to social sustainability by having an immediate control in congestion.

- The real time information sharing systems can have the most influencing effect on changing driver behaviour at all stages by providing pre trip, en route and route guidance information on a real time basis. The three options that a commuter can chose in real time could be changing route, mode or time. The revenue generated from congestion pricing could lend to improve real time information systems, and the more fundamental hurdle of improving public transport systems, which together can lead to an improved accessibility by not effecting other systems, lending to strong social and economic sustainability.

- The horizon of extensible applications can be kept not only to basic applications of e-commerce, but it can be extended to all applications that can help in reduced travel demand which could be as varied as information providing websites, or logistics and freight management applications. The role of extensible applications when combined with congestion pricing has the potential to curb the present day expansion rate of cities. It can lend to completely change the dimensions of centre and periphery, thus lending to distribution and channelizing of the traffic across different centres, and help avoiding concentration at one point. Thus helping in an improved accessibility and an increased overall quality of urban environment to lend to social and economic sustainability.

**Sub Question 1: What can be the ICT solution that best fit for congestion pricing or ERP that can help in reducing the traffic congestion?**

**A comparative analysis**

In the theoretical section, we have identified that the congestion pricing scheme can be one potential TDM meseasure for controlling traffic. The technological implementations that support the scheme should be promising in order to deliver the high rated performance, and to mark the TDM measure a success. For any system to be identified as potential for the present and future needs of congestion control, it is a good idea to check whether the proposed technology gets to do well with all the nine functionalities. The secondary technologies also lay a good support to the primary technologies in adopting those nine functionalities. More care should be taken that operational cost for the planed solution should be reasonable and that the expenditure for the system should not exceed the revenue generated by the same. Considering all these factors in to account we found out the VPS based system to be more efficient and potential than the others that are present in already existing systems.
We discovered that the Stockholm congestion tax charging system is one of the most successful implementation around the world for collecting the charges. So we believed that conducting interview with a practitioner working under such kind of a successful implementation, can give us some needed information to validate our theoretical study. We discussed about the plans for the congestion tax system for Gothenburg which is going to get implemented in near future. At the same time we took it as an opportunity to understand the growth of recent ICT from the Stockholm implementation in 2006, to the Gothenburg which is planned for 2013 where the technological gap is around 7 years. In an attempt to investigate the loopholes in the present system and the ways to overcome them in a technical way, we got an information that the loop holes in the present system are that the ALPR system at times goes under the 'error of judgement' in classifying the foreign vehicles, and the system needs the help of human when it comes in recognizing the damaged license plates either for charging or for enforcement. The interviewee also finally suggested that the VPS based congestion pricing can overcome these problems, and she also said Gothenburg being a city with lot of foreign cars floating around, the VPS based congestion could be a better option. The interviewee also felt that there should be some other secondary technologies to support the primary like the integration of ITS, so that the same VPS method can be used for pricing and the information gathered can be provided as real time information that could help in attaining better sustainability.

After a clear comparative analysis in this session, we have determined that the potential solution can be the one that can face the challenges not only in the present but also in the future. The best way to evaluate the potential technical solution for congestion pricing can be the one that coincides effectively with most of the functionalities out of nine, and at the same time a system that can be better than the one present in Stockholm at least in four aspects of functionality. This we have evaluated with the help of a table where we also took the effort of comparing the manual and existing systems with the nine functionalities to derive a potential system.

<table>
<thead>
<tr>
<th></th>
<th>Manual</th>
<th>Existing ICT</th>
<th>Potential ICT</th>
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<tbody>
<tr>
<td>Information</td>
<td>The person gets to know only when he faces the situation</td>
<td>Mobile SMS updates, Internet</td>
<td>VPS systems can provide exact information on travel (route guidance and charging information)</td>
</tr>
<tr>
<td>Detecting</td>
<td>Checking official (might end up with more traffic)</td>
<td>DSRC, RFID (Requires road infrastructure like gantries)</td>
<td>VPS system doesn’t need to be detected because the vehicle is tracked with the links in the map database</td>
</tr>
<tr>
<td>Identification &amp; classification</td>
<td>Simultaneously done with detection (might end up with more traffic)</td>
<td>Cameras, ALRP Information Database (In case of damaged license plates the system fails to detect)</td>
<td>With VPS based pricing, the vehicle can be easily identified and classified by just tracking giving out even options of distance based charging as well.</td>
</tr>
<tr>
<td>Verification</td>
<td>No practical solutions</td>
<td>Front &amp; Rear Cameras ((\text{Not reliable and requires road infrastructure}))</td>
<td>VPS based pricing system uses a vehicle id for each in-vehicle unit</td>
</tr>
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<td>---------------------------</td>
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<td>---------------------------------------------------------------------</td>
</tr>
<tr>
<td>Payment</td>
<td>Boom gate system with a Cash/Credit Cards payment option ((\text{Time consumed in taking payments Causes further congestion}))</td>
<td>Post payment sent as per invoice cycle with payment options using Web, Mobile Phone Balance, utility stores like 7 Eleven</td>
<td>Direct Debit from Bank (Reference) and Multimodal, multi-media payment methods (fare cards, cell phones, etc)</td>
</tr>
<tr>
<td>Enforcement</td>
<td>With the checking officials ((\text{Causes congestion in cases of attempt to escape without paying}))</td>
<td>The ALPR systems are used in and the enforcement is carried out with the help of picture and matching it with the database for the owner. ((\text{difficult to track the escaped vehicles}))</td>
<td>VPS based system detects all vehicles even with damaged number plate.</td>
</tr>
<tr>
<td>Exemptions</td>
<td>With the checking officials (Causes congestion when the manually check on the exempted vehicles is done)</td>
<td>Done with the help of data matching from the information database and vehicle detection</td>
<td>Both VPS and ALPR technologies are good in handling the exemptions</td>
</tr>
<tr>
<td>System Reliability &amp; Accuracy</td>
<td>Highly reliable and accurate</td>
<td>The ALPR system is accurate and reliable if the character recognition software is good</td>
<td>With the Launching of Galileo satellite, then the VPS based congestion pricing would be more reliable and accurate.</td>
</tr>
</tbody>
</table>

Table 5: Comparison of the existing systems and nine functionalities to identify the Potential system
**Result**

From the above discussion in the table it is quite understandable that the VPS based congestion pricing system can be the one that can best fit to the future needs of controlling the traffic congestion. Some main reasons behind this are that it does not really need an infrastructure, and it is more companionable when it comes to the information, identification, detection and verification. The world is moving fast and there is a prevailing situation for the barriers to be completely broken down between countries as a result of globalization, and there would be need for cars moving in to different countries and with the present system it is difficult to identify those vehicles by maintaining a database for the records of the foreign owners and charging them. However, if the congestion pricing system is based on the VPS with an in-vehicle unit with a pre-payment option, then such problems can be easily evaluated. The vantage point for the VPS based pricing systems is that it has wide range of coverage, and a very few check points that makes it distinguished from the other primary technologies. It is expected that this kind of VPS supported OBU will become a standard unit in the vehicles in the next 10 years, and this criteria fits to the cars in the European Union. The VPS systems require very less road side equipments than the other technologies mentioned above.

The other thing we found out regarding increasing the potential of ICT in congestion pricing is about the secondary technologies which can play a vital role along with the primary technology. The ITS integration is a secondary functionality that we feel could make the VPS based charging more effective. In these system in-vehicle units mobbing around the area can be tracked to gather real time information so that the major advantage would be to collect the charging information, and after processing it can be used to provide real time information on websites.

Therefore, VPS based congestion pricing would give a definite solution of reducing traffic congestion which ultimately leads to a sustainable city by meeting the present needs of the generation which holds for the key point of the sustainable development. By its aggressive approach in reducing the traffic congestion there are more chances of enjoying accessibility which is an underlying principle of transport sustainability. Therefore the “role of ICT in sustainable transportation” in this context can refer the VPS system under congestion pricing which is a potential system that can offer a social equity.

**Sub question 2**

*In what ways can real time information sharing solutions help in reducing the traffic congestion and help in the real time choice decisions?*

**Comparative Analysis**

It was clear from the theoretical study that the real time data sharing involves three stages data collection, data processing and data dissemination. As mentioned in the theoretical study the real time information sharing is a huge concept that involves wide variety of information types. The data is first collected from many methods that may be either under conventional or non-conventional. Whatever the collection method it might be, the data is about the road condition, congested area and timing information. Then the collected data is processed and disseminated. One potential type is collecting data from a floating car that would either equip with a GPS tracking device or a cellular phone. Once the data is collected there are several potential services to provide
information to the commuter in reducing the congestion, and above all it depends on the quality of information provided along with service, which can have definite influence towards congestion. The services are as follows:

- Pre-Trip Travel advisory
- Route Guidance
- En-Trip travel advisory

These services should have a quality that they should influence the driver behaviour. Once the driver behaviour is changed there are lots of chances for traffic congestion to get reduced. Driving behaviour can be linked close to a person’s choice of drive and it results mostly from what he/she thinks and feels; it has very less to do with what he/she knows or can do. The main thing that we identified from the theoretical study is that the services provided through the real time information sharing have a definite influence over the driver behaviour. From the theoretical study we also analyze that one potential way of data dissemination is through the internet portals.

To validate the result we obtained from the theoretical study, we conducted the interview section and the interviewee also told the driver behaviour is the most important factor and suggested that the real time information has a pure effect on the driver behaviour. From the questionnaires that were conducted, we identified that most of the customers find lack of information to be the main factor for not choosing the public transport. So if proper real time information is provided, then there are lots of chances that the traffic congestion can be reduced. The interviewee also gave some interesting information on data collection and dissemination that was the same floating car method and the data dissemination over the web portals respectively, which was similar to the one we identified in the theoretical study. The interviewee said that the website trafiken.nu is gaining popularity, and he also said that people are active in using the real-time information through web portals and they expect much more customization. Joakim finally said that it could be really appreciable to improve the real time infrastructures by investing more revenue from the congestion pricing, because real time information sharing has the potential of influencing the driver behaviour a lot like the congestion pricing.

**Result**

Doing a comparative analysis, the first thing we suggest is that the potential way of collecting the data should be the FCD. If this technology is equipped in all the vehicle inside a city then the real time information can be a lot more diversified than now. In this modern era there is a very close acquaintance between the mobile devices and the human being, therefore we identify that the most potential way of disseminating data would be to convey information through web portals, and providing mobile applications to access the real time information. Then coming to the context of ‘what real time information sharing contributes for congestion reduction’, and after a comparative analysis between the theoretical and empirical study, we derive that the forms of services that are important to be given as the real time information. It was found that the potential services could be pre trip advisory, route guidance and en trip advisory. We also suggest that these three services have some control over the traveller, and can help the traveller in taking the decisions of going towards alternate options. We in the below diagram have took efforts in showing that the revenue from the congestion pricing can be put in developing the real time infrastructure.
From the above diagram we try to portray the result of our analysis, about the influence of real time information on the driver behaviour, and the ways the real time information infrastructure can be developed. From the practitioner’s point of view the idea that has been gained is that the revenue generated from the congestion pricing can be put in improving the real time infrastructures with more ITS options. This revenue can also be used to improve the quality of the public transports. The advent of real time information gives the commuters with three main options Travel mode (with better public transports), Travel route and Travel time, which all together have lot of possibilities in reducing the traffic congestion. The three potential services (Pre-Trip, Route Guidance, En-Trip) have the capabilities of influencing the driver behaviour in to these three alternatives (Mode, Route and Time), which at last attains its goal of sustainability by providing more accessibility under both social and economic perspective, and helps in improving the quality of urban environment. This way of attaining sustainability does not have influence or effects on other industries therefore this ‘Role of Real time information in sustainable transportation’ is purely a strong sustainability.

Sub Question 3

What is the role of extensible ICT applications like VPN networks or e-business in reducing traffic congestion?

Comparative Analysis

With the empirical analysis, one important observation that came up was that most people believed that in certain work cases involving governmental agencies, they travel only to seek information about the process flow. Thus their demand of travel is inversely proportional to the quality of information available on the web. Many suggested if they had the complete information available on the web for certain processes (e.g. visa extension, tax registration), then they can completely avoid the associated travel.
However since this movement into creation of a virtual city is in a nascent stage, even with our surveys, it is difficult to make strong recommendations at this stage but for one observation that, everything that is ‘essential monotonous’ business like retail banking, e-shopping of certain commodities like music, movies, books etc. that don’t have a great psychological factor of ‘feel and touch’, has a huge and not completely tapped scope of being substituted with extensible applications. There is an imperative need to change the viewpoint on these applications, and look at them holistically as an essential part of the greater system playing an important role in preventing traffic congestion. With every development of ICT applications, it is outwardly growing necessary that we must identify the role it can play towards traffic demand creation/reduction, and how it can lend to the creation of a more sustainable system. This however will result in an increase of many man hours and associated development cost of all such extensible applications. Thus it leads us to a conclusion that there is a growing need of promoting such organizations with options like tax exemptions or by investing the revenue generated from congestion pricing.

**Result**

The diagrammatic effort (fig 20) for understanding the area to be chosen for congestion pricing lead us to the greater problem at hand where the role of ICT can come into picture. It is the problem of existence and expansion of ‘cities’ which is one of the biggest debates of mankind of last century, often referred to as the changing dimensions of centre and periphery. (Yanagita, 1930) There has always been the issue of centre (cities in contemporary times) taking up the resources, not only natural also human resources from periphery (villages), which has lead to a growing movement of citizens from periphery to centre causing a lot of congestion in the centre. Thus the phenomenon that has been noticeably happening is the ’growing size of the centre’, leading to further congestion problems which as per predictions will further grow. It is important to note that traffic congestion is majorly an urban problem only. With this grows the need of more and more infrastructure to cater the growing consumption demands. This is where we cite out the ICT has the power to change the complete dimensions of centre and periphery given the constraint that this needs an overall holistic solution of which congestion taxing, real time information, and thus extensible applications providing transport sustainability is only one part of the solution and not the complete solution itself. The collaboration of these three factors can lead to a situation where the businesses can be replaced with substituted extensible options, with centres need not to be located at the same place leading to a creation of virtual centre (web). Congestion pricing can create that necessary pressure and ICT can create that necessary solution for the formation of a virtual city. As an example organizations doing e-business (or mixed with traditional physical) need not necessarily keep their sales offices right in the middle of the city and pay heavy rents. Instead they can move out towards the periphery or shift majorly to electronic modes leading to a huge reduction in traffic.
Figure 20: Growing sizes of cities & Role of extensible applications in splitting the centre

(In the above diagram the inner circle shows the centre and outer circle being periphery. The dotted lines inside the small circles depict the traffic and the green circle is a sustainable city).

The above diagram describes our standpoint on the role of extensible applications in creation of virtual cities. The first part of the diagram shows how congestion pricing can create the necessary pressure for creating economic challenges in the zone, thereby forcing the *essentially monotone* business to move out with options like switching to *extensible applications*. Now this switch to extensible applications takes such businesses to outside the zone, and takes us to the second part of the diagram showing the splitting up of traffic movement and reduced traffic congestion at any point. The horizontal part shows the present day growth of centre and how it is growing more and more. The circle below shows how the switch to extensible applications can lead to a more distributed set up where in the same centre gets split up to different small sub centres. Thereby it reduces the size of main centre, to make the traffic movement more channelized and distributed, thus reducing an overall pressure of traffic congestion at any single point. In line with the principles of sustainable transportation, the extensible applications creates challenges for economic sustainability for freight companies to potentially use cost effective methods for transportation of goods, but more importantly it lends to social equity aspect by improving the accessibility and overall quality of urban environment with the traffic reduction.
Chapter 11- Discussion

11.1 Conclusions

The study has found the role of existing and the potential ICT in reducing the traffic congestion problem. The observations and findings of the theoretical part of the study were verified in the empirical part. The traffic congestion problem has been growing at an unsustainable rate. The suggested solutions have kept a focus on creating sustainability with two aspects, social and economical. The arguments for social sustainability have targeted for social equity aspects to increase accessibility and the quality of urban environment. While the arguments for economical sustainability take into account the challenge of cost-effective transportation of goods. It is important to realize that for ICT to play an important role in traffic congestion, the most important factor that was needed to be addressed was to bring the change in ‘driver behaviour’, which in standard has three ways to do so by changing their mode of transportation, changing their time of travelling or bringing a change in the routes, with all three leading to a reduction in traffic congestion at any point.

The study investigated the role of congestion pricing in changing driver behaviour patterns, and formed a theoretical basis of a good congestion pricing model based on the nine functionalities. The existing state of art ICT was then compared with the suggested solution of VPS based system to implement the same. The highlights of suggested solution came out to be the contribution it can give in improving aspects of information, detection, identification & classification, verification and enforcement, and how it can even handle the cases of damaged plate, foreign vehicles etc. The argument got stronger with empirical analysis, by conducting the interviews which suggested that it can help in implementing a future model of congestion pricing system based on net mileage inside the zone, instead of the existing setup working only at the entry points. Thus it can further solve the problem of congestion control in the intra zone region. It was further argued that the VPS system can even contribute to the second sub question at hand by helping in providing a channel, for getting the real time information to be distributed to the commuters. This solution was also found to be socially sustainable with its contribution to social equity by improving the accessibility factor.

The next aspect of the study took us to the question of how real time information can help in making real time choice decisions. It was argued that the process of real time information sharing required three stages namely data collection, processing and dissemination to the commuters, whether they have already started the journey (en trip) or are about to start to it (pre trip). It was recommended that this aspect has the highest focus on changing driver behaviour in a real time situation giving them the three options described above of changing route, time or mode. The strong part of this aspect with collaboration of VPS solution is that it doesn’t affects, or is influenced by other industries thereby making it a point of strong sustainability with its contribution to increase accessibility.

The work on potential role of extensible applications leads us to the role it can play in changing the existing expansion of cities with the focal point observation being that commuters often avoid to travel in two cases, one being when they are looking to purchase essentially monotone products or services; and the second being when they seek for information on a specific subject or a standard institutional processes. The diversion of revenue generated from congestion pricing for promoting
organizations using and developing extensible applications brings a channelized distribution of traffic from one single centre to small distributed centres. This brings in with a challenge from economic sustainability point by demanding that freight management organizations should work to apply intelligent methods for cost-effective transportation of goods. The distribution of traffic helps in bringing social sustainability by improving the overall quality of urban environment and improving accessibility.

The main question of the study ‘What are the potential ICT solutions that contribute to minimize the traffic congestion to attain a social sustainability’ has thus been answered by answering the aspects described above for the three sub questions.

11.2 Implications of Informatics

UNESCO defines “informatics as the science dealing with the design, realization, evaluation, use, and maintenance of information processing systems, including hardware, software, organizational and human aspects, and the industrial, commercial, governmental and political implications of these.” (Akahori, 2005). In relation to the above stated definition the implications of informatics in our thesis are as follows:

- **Realization and evaluation** of the potential ICT systems which we feel that could have definite impact on the present and future states of the traffic congestion.
- Our thesis puts more emphasis on the use of the advanced information processing systems and its influence towards the human aspects like changing the driver behaviour to choose the alternative modes, purely comply with informatics.
- Moreover in this thesis we have given some ideas of linking the realized technologies and their use in order to make the systems more effective in its function, which can lay a support in favour of commercial, government and political implications.

11.3 Method Evaluation

We before collecting the data were pretty sure about the set of concerns and the ways we could overcome those concerns e.g.:

- What information do we already have?
- What procedures are feasible in relation to collect the determined data?
- Do we have the time to implement the data collection?

After dealing with the above questions, we understood that the ICT and its relation with the transport sustainability is a very big area, which has lot of sections under it. So we declared that the data we have in hand is not sufficient, and came to a decision to further collect data and look out for procedures to collect the desired data for our research. In the process of analyzing the procedures in collecting the data, we found that there are lot of ways that data could be collected for our research. But considering the last question whether we have time to go through all the possible ways of collecting data, the answer was ‘No’. Therefore we decided, first to create a theoretical base for our study with the help of the text analysis. Collecting information with relation to the text analysis was challenging. The concepts and subject areas that we dealt with like congestion pricing, Real time information sharing, information and communication technology, and sustainability all being very
big concepts with varied dimensions, made it difficult for us to get the exact information with relation to the idea of our research question. We overcame this difficulty by first taking information from all the material we found that could be more or less related to our study and finally sampling that information which was found to closely relate to our study. The approach we took to for sampling are:

- We chose few companies who have depicted their ICT brand on the implemented TDM measure, and checked their websites in the related column for the corporate reports about the concerned technology and the ways they implemented it (e.g. The subject area “Real time information sharing” in our thesis is mainly has its text analysis from IBM’s corporate report “ITS a new era in future transports”)
- The area we chose to argue in our thesis i.e., the transportation sector considerably in most of the places around the world is being controlled by the public administration and governmental bodies. We managed to collect more information from the administrative reports and newspapers about the implementation of the TDM measure and its success. (e.g. “Technologies that enable congestion pricing” is a primer from “Federal Highway Administration” that helped us when doing text analysis for congestion pricing).

We also knew that selecting a material from the online computer database cannot be trust worthy. Therefore in our research, we kept a set of guidelines before choosing to retrieve information from the selected database (see chapter 2, section 2.3.1), and we evaluated data accordingly abiding the rules for internet data collection.

To verify the aspects identified in the theoretical study and to get some practical information in relation to the research questions, we approached the practitioners with the help of interviews. As we thought, the interviews helped us to gain additional knowledge and some solid statements which were required to validate our theoretical study. But even through the interviews we faced few problems e.g. the consequences of ‘error of judgment’ lead the interviewees took their own direction of explaining the concepts. In these situations we first listened to their answers, and then repeated the same question by rephrasing it and made the purpose of the question clear. At the beginning of the interview we started with some simple and basic question and later on asked the more complex and open ended questions e.g. in the first interview session “The license plate of cars from Finland and Lithuania is similar to that of the Swedish cars at times. Does the character recognition identify the characters in the number plate and match that exactly to the owner? How the system does handle the foreign vehicles entering the gantries?”

The above mentioned question gave us interesting information about the present system in Stockholm, and how these problems have been handled. On this the suggestions was also that, the most potential system in charging would be the VPS system, and the main reason is that these systems uses an in-vehicle unit and it would have a vehicle identity to find the vehicle. Hence charging would be easy and therefore a wrong owner would not be charged.

Since the area in our research is related to both the professionals (practitioner) and non-professionals (commuter—a common man), we thought that apart from the interviews from a practitioner, there is also a need for the response from the commuter. Therefore the questionnaire was sent to individuals spread across different age groups. The difficulty faced with the questionnaire was that some respondents did not reply at time, and some found it difficult to
understand the questions. Therefore the questions were rephrased the questions without changing the catch to make them simpler and the questionnaire was sent back.

11.4 Result Evaluation

The evaluation keeps a focus on the five criteria described by Larsson in chapter 2, and has kept a base on perspective consciousness and internal logic with all three qualities of richness of meaning (content), structure and theory development (contribution) being tackled together in the study.

11.4.1 Qualities of the presentation

The internal logic is the process of doing a consistency check of research questions with the process of data collection, analysis and presentation. We have kept a main point of defining the same in chapter 1.3 by explicitly defining the main research question and then making use of the three sub questions to arrive at the result for the main question. This was further guided by the work in chapter 2, with the description of approach followed for doing data collection process. The analysis section has been done in three phases namely theoretical findings, empirical findings and the comparison of the theoretical with empirical.

Since it is of utmost importance that the research should be guided by good ethics, and therefore a deliberate attempt has been made of not attaching different meanings or labels to the same phenomena, for solving our own aim. The study has clearly taken care of the same by first describing the important definitions, and has even a dedicated subject area to mention the challenges of defining aspects like sustainability in relation to transport and ICT, and kept a complete focus in it to come up with definitions and understandings used for our study. In every discussion on the sub questions the study has clearly created lines of demarcation for defining labels. It begins first with description of the problem and then with definitions of labels and clearly defining how labels shouldn’t be confused with other similar concepts (e.g. extensible with forward compatibility). The same has been taken care of while doing the empirical analysis done with interviews, as often interviewees also use these labels like sustainability, extensibility etc with their own understanding and not with scientific clarity. We haven’t refrained from mentioning clearly the negative discoveries or potential challenges in the suggested solutions described for the three research sub questions. The study has been based on gathered qualitative data, only the results and conclusions have been derived in a continuous flow from the parts of self-understanding of the subject. In the empirical parts the interviewees were informed with full honesty about the research being conducted and by providing interview questions to them beforehand.

11.4.2 Result quality

The result quality has been evaluated on the criteria of richness of meaning, structure and theory contribution, basing it on the two pivots of rigour and relevance. The first stage in evaluation of quality of result has been done to find richness of meaning i.e., the stage of gathering content from different sources and integrating them all with a holistic hermeneutical perspective to treat it as a whole. Our study has worked precisely on this at all stages and has bring forth the knowledge based on sound interpretation, and has kept a large picture open of combining sustainability aspects even with not so visible concepts like driver behaviour. The different perspectives add a great value to the research. The several perspectives gathered from secondary data sources, and primary sources like interviews and questionnaire, have added a great understanding of the subjects at hand of
sustainability, driver behaviour, extensibility etc and these have been combined to create our own understanding and views on the subject. It is indeed possible to find additional meanings to these contexts and include more theories for a greater understanding of the subject. We have at every stage however kept a hermeneutical perspective and tried to join different theories and views in to one whole concept to highlight the research questions.

The data usually travels through three stages to get to the richness of meaning. The first stage is processing of data which led to information, second is processing of information giving knowledge and third being processing of knowledge giving wisdom. Structure plays a pivotal role in this value chain as it brings in clarity and decreases the level of complexity of gathered data, information and knowledge. This demanded a critical balance between the two from our end i.e., decrease the complexity, and at the same time provide a good structure, bearing in mind that the richness of meaning shouldn’t get compromised. Specifically to avoid this situation we created different chapters for all the three sub questions, where in the beginning of all of them, the important concepts were explained more at the level of providing information. To maintain the structural flow the results weren’t derived in these sections and a separate section on analysis has been written for all three sub questions. Finally to reduce the complexity and bring all the study together a standard separate chapter on findings, analysis & results has been written. The underlying idea being in this flow that the pressure of structuring content shouldn’t put pressure on the information and richness associated with it.

The theory contribution as described in section 2.5 was based on the principles of rigour and relevance. The cyclical chain Acquire -> Validate -> Reliability -> Contribution was followed to reach to the desired goal of theoretical contribution. The processes of acquiring data was done in line with the plan of gathering information from secondary resources, and interpret it to then follow up with its validity by conducting empirical research. The data collection was done exactly in line with the points mentioned in section 2.3.1 of checking resources available and basing their credibility considering author’s credibility, complete embodiment and accuracy of all sources in the base research. To further check relevance it was checked for every secondary source about the last time it has been used or referred in practice or research. The relevance part was also discussed with various researchers and practitioners involved in the field. The approach of thematic analysis helped as a good guideline of putting constraints on finding the relevant sources of data.

11.4.3 Result validity

The intention has been to contribute to the find out potential ICT for reducing traffic congestion. The contribution got weight with the empirical research as it helped in validating our work from the practitioners. The criterion for validity and consistency was kept on the principles of comparative analysis by comparing theoretical findings with empirical findings. The discourse criterion relates the consistency factor of the study with how the same conclusion can be viewed from a different perspective. There can naturally be various arguments that can contradict our opinions and findings, and it is in this quest that the interviews were conducted and a constant communication was kept with the practitioners. Therefore the structure has been kept to form the emerging basis of our rationale for analysis and results. The hermeneutic perspective was kept initially with the reductionist approach of answering and working on each sub question independently. It was at the later stage of analysis that the whole was considered and compared with parts. The practical usability was verified in the empirical findings giving influence to the result of being close to reality. Our stand on the subject suggests that our observations may not be the only results, and
different researchers when working with the same material might come up with their own results. However, our ontological view based on the exploratory approach (Marshall & Rossman, 1989, p3-6) supported with semi structured interviews suggests that there would be a high degree of correspondence in such results.

11.5 Ideas for future research

Our perspective has been hermeneutical of considering the whole picture. It would be though interesting to see how the same problem can be viewed upon with the reductionist view. One of the key methodologies which we believe would be of great interest to join with the suggested solutions especially in the already existing systems of congestion pricing and real time information sharing would be the ‘lean’ methodology. The lean mainly works with the target of continual improvement by clearly demarcating wastes in the processes using concepts like value stream map, key performance indicators, levers (Ohno, 1988). Using lean by categorically finding out the factors that causes traffic congestion, fixing levers could be applied to reduce the same. The other important aspect that lean can work to further enhance our theoretical study is the fact that it deals with numbers and measurable KPIs, where our work could act as a base for understanding the flow of processes.

The one factor that needs to be addressed in our works is the prevailing idea of handling contingency which is of importance in traffic management, as the predictability of human behaviour stuck in traffic congestion is a huge challenge and thus having an approach to address all the possible cases demands that we need to have probabilistic measures to be quantified which often isn’t possible, making it land into the classical paradox of ‘certainty about uncertainty‘. This is one area of research that needs to be further investigated into for applying the suggested real time information solutions which are aimed at predicting the driver behaviour.

One more area of interest that comes up is the environmental sustainability challenge of meeting needs of present and future generations, and how ICT can help in improving public transportation system, which can provide the stated ability of meeting future needs using the limited natural resources.
Bibliography


CST. (2003). Sustainable Transportation Performance Indicators.


Appendix

Interview 1

1. What is your role or responsibility in your organization?

2. How many years have you been in this field and what is your perspective about this job?

3. What is the role of your organization in reducing traffic congestion?

4. Is your organization government funded?

5. What do you think the main reason for congestion tax to be a successful implementation?

6. What was the primary purpose for the implementation for revenue or to get more accessibility?

7. What are the main technical components of congestion tax system?

8. How are the commuters been charged for using the road? In other words how is the payment made by the users?

9. The license plate of cars from Finland and Lithuania is similar to that of the Swedish cars at times. Does the character recognition identify the characters in the number plate and match that exactly to the owner? How the system does handle the foreign vehicles entering the gantries?

10. Which one do you think to be the more effective the pre-paid system or the post-paid system?

11. What is the role of the control centre or the central computer system?

12. There is news for congestion tax implementation in Gothenburg in 2013. Is the same idea of system present in Stockholm is planned for Gothenburg or does the idea fit some technical advancement?
Interview 2

1. Is your organization supported by government? If so in what ways your organization is supported?

2. Are you having partnership with any other organization in controlling Traffic?

3. How long have u been this field?

4. What do you think to be the main reason for traffic congestion?

5. How does your agency support in reducing the traffic congestion in other words what is the role of your organization?

6. What is your role in your company?

7. What influence has this kind of real time information brought about in reducing traffic congestion? Any statistical data before and after implementation?

8. Are people comfortable using the real time information through internet?

9. How many people approximately visit the website trafiken.nu on a daily basis? Is it increasing day by day?

10. What are the potential methods of real time information sharing, and to know that active methods on sharing the real time information that can control traffic congestion?

11. What are the issues that still people are not comfortable regarding this technology?

12. What are the future plans to make this technology more reliable?

13. What The roles that real time information sharing play in collaboration with the loop Congestion pricing – economically less supported people – public transport

14. Other than internet what are the alternative communication ways that you use to transfer real time information?

15. Is there anything else that u find important for reducing the traffic using recent technologies?
 ROLE OF ICT IN SUSTAINABLE TRANSPORTATION
This questionnaire is for a master thesis in the University of Borås, Sweden. This questionnaire is for a research that is conducted in the field of sustainable transportation. We seek to identify the need of the travellers with regards to the information and technology (ICT) and with a main motive of reducing the traffic congestion.
Your participation in the research is completely voluntary
Your comments and responses will be treated with utmost confidence
The process of answering will take a few minutes and if any query feel free to contract us at kumarneel@hotmail.com degaurav@yahoo.com

Name: Click here to enter text.
Gender:  Male □  Female ☒
Occupation: Choose an item.
Email: ____________________________
Date of ________________

1> Where do you live? Urban ☒ Rural ☒
2> Do you use internet? Yes ☒ No ☐
3> Which Device do you use for internet connection?
   Mobile □ Desktop ☒ Laptop ☒
4> Do you own a car? Yes ☒ No ☐
5> Which method of transport do you prefer most frequently for the following trips?

<table>
<thead>
<tr>
<th></th>
<th>Walk</th>
<th>Train</th>
<th>Bus</th>
<th>Train</th>
<th>Cycle</th>
<th>Car</th>
<th>Motorcycle</th>
</tr>
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<tbody>
<tr>
<td>Travel to university</td>
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<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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</tr>
<tr>
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</tr>
<tr>
<td>Shopping</td>
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<td>☐</td>
<td>☐</td>
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<td>☐</td>
<td>☐</td>
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<tr>
<td>Work</td>
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<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Other: Click here to enter text.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

6> Rate how important the following factors are in preventing you from using public transport:

<table>
<thead>
<tr>
<th>Factor</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of available information</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>Distance from the stop</td>
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<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Cost</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Length of journey</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Total time taken</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Weather</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Safety</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Frequency of service</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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</tbody>
</table>

7> How much have the e-services helped you in reducing travel for

<table>
<thead>
<tr>
<th></th>
<th>High</th>
<th>Average</th>
<th>less</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shopping</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Education</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Entertainment</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
8> How often do you book last minute tickets online?  
☐ very frequently  
☐ occasionally  
☐ Don't prefer for it

9> Would you be interested with e-working from home?  Yes ☐  No ☐

10> How does the concept of paperless offices (internet, e-mail, portable Computers, tele-servicing sound to you?  
Helpful ☐  Not helpful ☐

11> How much has e-meeting (tele and video conferencing) helpful in reducing travelling in the past?  
High ☐  Average ☐  Less ☐  very less ☐

12> Would you be interested in choosing public transport if it provides more benefits than going by car?  
Yes ☐  No ☐
University of Borås is a modern university in the city center. We give courses in business administration and informatics, library and information science, fashion and textiles, behavioral sciences and teacher education, engineering and health sciences.

In the School of Business and Informatics (IDA), we have focused on the students' future needs. Therefore we have created programs in which employability is a key word. Subject integration and contextualization are other important concepts. The department has a closeness, both between students and teachers as well as between industry and education.

Our courses in business administration give students the opportunity to learn more about different businesses and governments and how governance and organization of these activities take place. They may also learn about society development and organizations' adaptation to the outside world. They have the opportunity to improve their ability to analyze, develop and control activities, whether they want to engage in auditing, management or marketing.

Among our IT courses, there's always something for those who want to design the future of IT-based communications, analyze the needs and demands on organizations' information to design their content structures, integrating IT and business development, developing their ability to analyze and design business processes or focus on programming and development of good use of IT in enterprises and organizations.

The research in the school is well recognized and oriented towards professionalism as well as design and development. The overall research profile is Business-IT-Services which combine knowledge and skills in informatics as well as in business administration. The research is profession-oriented, which is reflected in the research, in many cases conducted on action research-based grounds, with businesses and government organizations at local, national and international arenas. The research design and professional orientation is manifested also in InnovationLab, which is the department's and university's unit for research-supporting system development.