UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

Master of Science Thesis in Logistics and Transport Management

Real – time Information and Travel Behavior

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GM0560 Spring 2019 Master Degree Project in Logistics and Transport Management

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Master's Thesis

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Abstract

This research study was conducted to explore the possible relationship between real-time information and travel behavior of urban citizens. The study was performed through an exploratory-triangulation research method using both qualitative and quantitative data. The study was performed in three stages: the first stage aimed to confirm the possible connection between real-time information and travel behavior in Gothenburg. The second stage allowed the understanding of the different types of information that can possibly influence traveler's behavior and the preferable means to receive this information. The third stage aimed at identifying the different barriers that might prevent transport providers from providing travelers with increased access to real-time information. The validation of the study was done through an extensive literature review on relevant topics that was used as the theoretical framework of the research. Furthermore, several interviews were conducted in two phases: the first phase included pilot interviews conducted mainly in the UK to gain knowledge on the subject of smart transport solutions. The second phase took place in Sweden and included the main interviews that aimed to build on the knowledge gained from the pilot interviews and the literature review. On top of that, a questionnaire survey on 158 citizens in Gothenburg was performed in order to validate stage 1 and stage 2 of the study. The results from the questionnaire survey were further reinforced by a pilot survey on traveler behavior conducted by UbiGo company in Gothenburg, 2014. By analyzing the primary and secondary data collected, the relationship between real-time information and traveler behavior was identified. However, the study also identified that the type of information demanded by travelers differed according to age and socioeconomic background. Consequently, the study indicates the importance of providing personalized information in real-time through mobile applications to influence travel behavior. Lastly, two main gaps that prevent transport providers from achieving the above were identified as legal and collaborative barriers.

Keywords: *Real-Time Data, Real-Time Information, Travel Behavior, Public Transport*

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Acknowledgments

This thesis was conducted at The University of Gothenburg, Sweden, during the spring of 2019 as a final part of the Master Program of Logistics and Transport Management. The thesis has been a cooperation with Coobom which is a multidisciplinary collaboration between CGI, Stena AB and Volvo Cars.

We would like to thank our thesis advisor Professor Michael Browne of the faculty of Industrial and Financial Management & Logistics at University of Gothenburg. Prof. Browne was always available throughout our work and was a valuable sparring partner whenever we needed to discuss how to proceed with the research. Prof. Browne allowed us to explore the topic to find our own path, but at the same time he was able to help us narrow down the main research when we needed to do so.

We would also like to thank all the experts that contributed in the validation of the research through interviews: Hannes Lindkvist, John Wedel, Brian Matthews, Professor John Miles, Martin Högenberg, Jari Tammisto, Professor Enrico Motta and Hans Aarby. Without these passionate people contributing to this research the study could not have been done.

Finally, we would also like to thank University of Gothenburg and our classmates that we have worked closely with throughout the last two years. This accomplishment would not have been possible without them.

Thank you!
Alex and Philip

Abbreviations

Automatic Passenger Counting APC

Automatic Vehicle Location - AVL

Advanced Travelers Information Systems - ATIS

Artificial Intelligence - AI

Global Positioning Systems - GPS

Mobility as a Service - MaaS

Real-Time Data - RTD

Real-Time Information – RTI

Traveler Information Systems - TIS

Internet of Things – IoT

Greenhouse Gas – GHG

1. Introduction

Urbanization is a present trend around the world leading to a higher densification of urban areas as more people decide to move to cities (Browne et al., 2012). Throughout the last century, the urban population has grown from 13% of the world's population in 1900 to 49% in 2005 and it is expected to reach 60% by 2030. This development creates significant economic, social and environmental challenges, both in the long term and in the everyday lives of businesses and people. For example, the average commuting time for people in Stockholm increased by over 20 percent between 1995 and 2013. Furthermore, traffic density in urban areas continue to rise developing higher pressure on current transport and road networks.

The overall impact of urbanization on transportation networks such as increased traffic density, congestion and pollution is a global challenge. However, finding solutions that can have a positive influence on these particular challenges is important both globally and locally. To solve such challenges locally, public transport providers need to understand what people want in order to stay an attractive alternative in the future where travelers have more transport options than ever before. For cities facing increased population growth, having an attractive public transportation network becomes vital to maintain sustainable travel options that can reduce congestion and pollution levels that are caused by private car use.

The potential negative impacts of urbanization have led many researchers to investigate how to influence human travel behavior towards more sustainable travelling choices. According to Pronello et al. (2017) information is a key factor, having the potential to optimize the travelers' choice. Furthermore, Xavier et al. (2017) discuss how real-time information allows passengers to make more informed and effective transportation decisions. In our modern society where most people have access to information instantly through digital devices, meeting customers demand of high-speed services and real-time information becomes more important than ever before. As a consequence, the urban and regional public transport systems of tomorrow must become smarter (Arthur D. Little, 2017).

This research will investigate how urban transport providers can potentially collect and utilize real-time data to develop smarter solutions that can influence urban citizens travel behavior by providing them with more efficient and relevant real-time information.

For public transport providers such research is important to understand how to provide travelers with services and information that are able to solve their needs and demands in the future. In cities facing a high degree of urbanization, a higher degree of real-time information sharing can possibly lead citizens towards using more sustainable transport modes, something that is crucial when fighting against the potential negative impacts of urbanization.

1.1 Background

Gothenburg is a city in Sweden that are facing challenges related to urbanization, with the city is making room for approximately 150 000 additional inhabitants in the next 15 years. Consequently, the increased level of urbanization will have a huge impact on the transportation network with an estimated growth in private car transport around 25% between 2010 and 2030 (City of Gothenburg, 2014). Furthermore, the inner-city areas are facing a rapid population growth, with certain neighborhoods such as Lindholmen making room for up to 8000 new inhabitants in the same time period. To deal with such developments several ongoing projects related to urbanization and urban mobility has been introduced by the city's various planning committees and stakeholders in order to facilitate and stimulate flexible travelling. The background and future development of Gothenburg makes room for this particular research as it is highly relevant in this area.

1.2 Problem Description & Analysis

According to the UN, cities are responsible for 75% of global carbon emissions. That percentage is estimated to rise by 2030 due to urbanization and continuous growth (UN, 2015). One of the major problems in cities which is responsible for a big part of carbon dioxide emissions is traffic congestion. It is indeed the most visible, immediate and pervasive transport problem (Chen et al., 2017). The growth in vehicle ownership and usage during the last decades, has resulted in the dramatic rise of transport congestion which subsequently creates problems both in terms of greenhouse gas (GHG) emissions but also in citizens transportation, since the waiting times are highly interlinked with traffic congestion (Bharadwaj et al., 2017).

Furthermore, as the mobility needs became greater, the urban traffic congestion, carbon emissions and citizens' transportation service quality will become more challenging. Until recently, building additional road capacity was considered a possible solution. However, due to the immense technological development, along with the urbanization problem, there is more reliance today, in tackling the problem form a more innovation and technology perspective and less from a perspective of expanding the current network (Bharadwaj et al., 2017).

1.3 Research Purpose

The study aims at identifying if increased access to real time information (RTI) will have an impact on travelling behavior of people in Gothenburg. The ultimate goal is to contribute with valuable information to urban transportation providers as well as other stakeholders. By contributing with such research, findings can be used to develop more efficient systems suited to deal with the increased urbanization and the negative impact in terms of congestion and pollution.

1.4 Research Question

The following research questions are formulated, in order to make the objective of the study clear:

RQ1: "Does access to real-time information affect travel behavior of people in Gothenburg?"

RQ1 will be validated through a questionnaire survey conducted in Gothenburg, talking to experts on the field and by conducting a literature review on previous research. After evaluating a possible connection between access to RTI and traveler behavior, the various interlinkages and trade-offs of that possible connection through RQ2 and RQ3 will be furthered explored.

RQ2: "What information is important for travelers and how do travelers want to receive information?"

RQ3: "What are the barriers preventing transport providers from providing travelers with increased access to real-time information?"

1.5 Disposition

The disposition for this study is outlined in Figure 1.

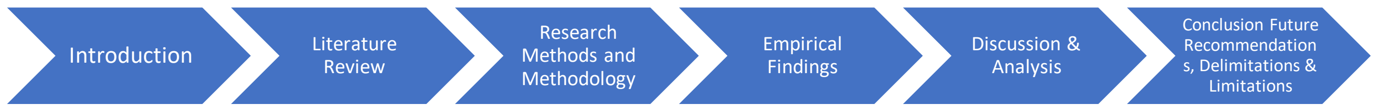

Figure 1: Disposition of the study. Own model.

2. Literature Review

In the following chapter previous studies conducted on the main topic will be discussed. In addition, factors influencing how public transport providers work today and how public transport providers might work in the future are evaluated to develop an overall understanding of the current status and future potential. The below figure (figure 1) visualize the six different categories that will be analyzed in the literature review and how they connect with each other.

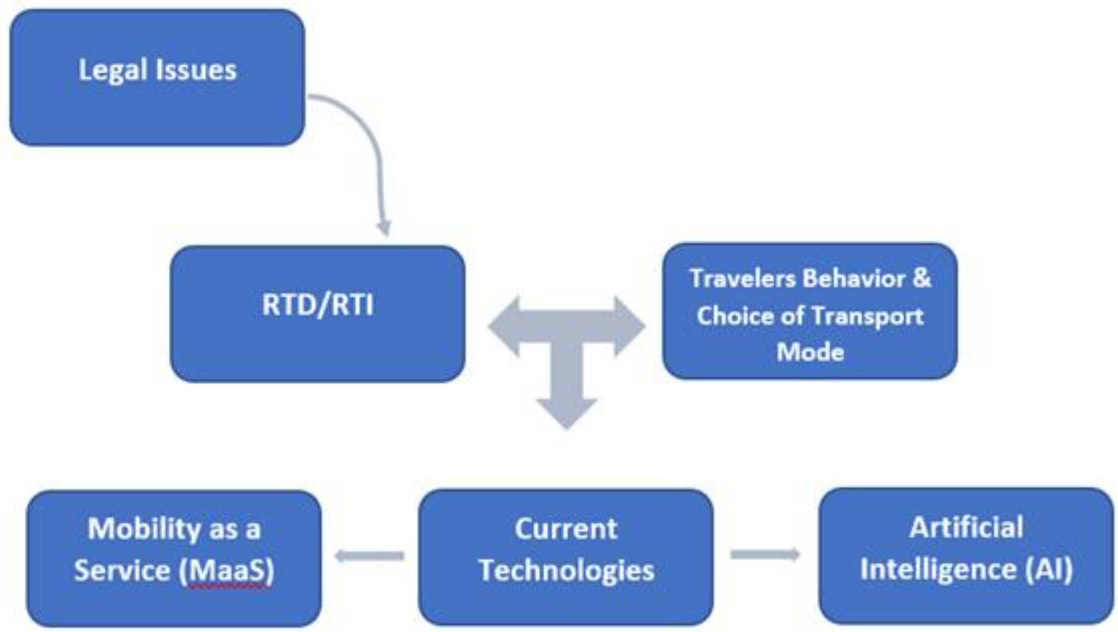

Figure 2; Literature Map, Own Work

The figure was made to give a visualization of how all categories connect. Legal issues are considered to have a direct impact on how public transport providers can collect data and how they can use data to provide travelers with information. Furthermore, it is evaluated how real-time data (RTD) collected and information provided connects with traveler's behavior & choice of transportation mode, thus the researcher has connected these boxes with arrows leading into each other. The researchers have further connected this with the current technologies that influence how it is possible to work with RTD & RTI today in order to potentially influence traveler's behavior. Thus, an arrow is connected to the current technologies box. Furthermore, through interviews with experts on the subject, the researcher decided to further investigate the future potential of innovation. Both Mobility as a Service (MaaS) and Artificial Intelligence (AI) was frequently mentioned in interviews with experts and was consequently considered to be connected with current technologies, with a potential of influencing RTD, RTI and traveler's behavior in the future. This is the reason these boxes only have arrows coming out of current technologies.

2.1 Real-Time data and Real-Time Information

Data is recognized as an indispensable enterprise asset in the modern information era, thus data and information are the lifeblood of the contemporary economy. However, it is important to understand the difference between data and information as these often are confused or used interchangeably (depending on the context) but there is a subtle difference between the two (Enofe, 2017). According to the Data Management Association (DAMA) data is "a representation of facts as text, numbers, graphics, images, sounds or video" (Mosley et al., 2009). Meanwhile, information is contextualized data with meaning, relevance and purpose (as shown in figure 2).

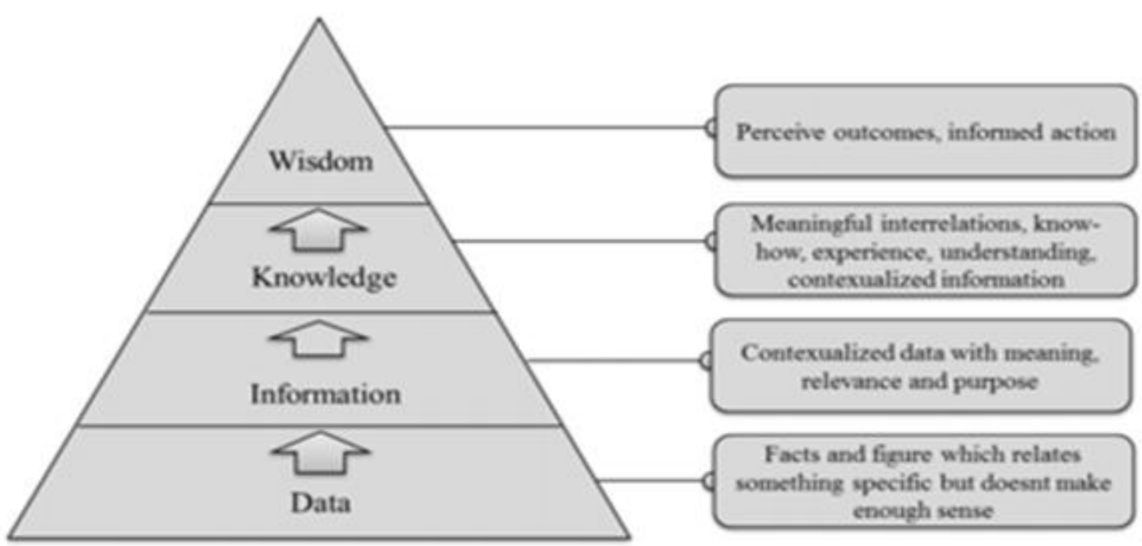

Figure 3; Data, Information, Knowledge, Wisdom (DIKW) model (Ackoff, 1989)

As visualized in the figure above, data can be considered the source of information. Data is the ground base that gives people information needed to develop knowledge and wisdom.

In business, RTD can be used to provide managers and stakeholders with raw facts through texts, numbers, graphics, images, sounds or videos that can be used to develop instant frameworks to build and develop information valuable to make more reliable decisions. Without RTD, the risks of making poor decision increase due to outdated information. Kekre et al. (1995), early stated that information technology is one of the most important issues discussed in management, and that there is high chance of improving the performance of organizations by adopting the appropriate information system. In urban areas, using RTD to deliver RTI to decision makers is important to understand what direction networks and systems are moving.

Monzon et al, (2013) discusses the challenge of sustainability in regards to a shift of the demand for mobility from cars to collective means of transport. On that note, they provide an assessment methodology on how real time passenger information systems improve the quality of bus services and consequently how that helps citizens change their travel behavior toward more sustainable modes of transportation due to higher reliability of public systems.

The interconnection between gathering RTD and sharing RTI to develop more intelligent transportation systems (ITS) is strong. Early studies conducted by Bristow et al., (1997) underline the importance of ITS applications and systems for public transport (PT) providers to increase attractiveness and improve services. With the increasing amount of technologies influencing the digital ecosystem, there has been an increasing amount of studies on ITS and how digitalization has been and will continue to influence PT in urban areas. Politis et al., (2010) conducted studies that showed that the provision of information is definitely the most important service ITS can offer, from a passenger's point of view. The increased accessibility to information about all aspects of PT can in fact assist in decreasing both the actual waiting time and the help to reduce the perceived waiting time (Daskalakis & Stathopoulos, 2008).

Further studies on the impact of providing RTI to travelers conducted by Cats et al. (2013) on the trunk lines network in Stockholm's inner-city analysis indicate that RTI provided to travelers underestimates the remaining waiting time by 6.2% on average, and 64% of all predictions are within +/- 1-minute error interval. The performance of RTI in this research was further evaluated by comparing its projections with the respective expectations that could be derived from the static timetable. It was found that the difference between passengers' waiting time expectations derived from the timetable and RTI is equivalent to 30% of the average waiting time. The study clearly shows the positive impact on actual vs. expected waiting times for travelers when advanced travelers information systems (ATIS) are implemented.

Furthermore, the gap between information demand (what type of information is desired) and information supply (what type of information is actually provided to transit users) is a relevant part of urban transportation as it can be used to analyze data gathered by transport providers and be compared with that information shared with travelers. It is therefore important to be able to understand trends and expectations from travelers, as well as looking into where to develop new solutions that can help PT providers continue to stay competitive in cities where there is increased utilization of private cars as well as private firms such as Uber and Lyft who have penetrated the market in recent years.

Research conducted by Harmony et al. (2017) have been done on actual information demand vs. information supply. The study shows that regarding information demand most transit users show a desire to receive information about vehicle location, meanwhile information about the vehicle itself, such as seating availability, is less interesting. However, there are limitations to this analysis as it shows an overall result of different modes of transportation. Meaning, preferences related to specific information might vary from one mode to another, as well as between demographics and socioeconomics. Regarding the information supply the analysis showed that the information that public transport operators provide to transit users were similar to that demanded from the users. However, as mentioned above, what is demanded on trains might not be relevant on buses and so on, giving room for further research on the subject. Thus, a closer evaluation of information supply and information demand are needed to get a clearer picture of the current situation.

Contrary to the positive impacts discussed it is also argued that even though service disruptions have negative effects and RTI may have significant positive influence, counter examples also exist due to secondary spillover effects. Research found that RTI actually worsened the impact of disruption on a network in Stockholm. The reason to this was due to spillover secondary effects

that was caused by supply interactions (e.g. upstream and downstream stops, vehicle scheduling) and passenger rerouting (e.g., delays, denied boarding due to capacity constraints).
It is therefore argued that it may be beneficial to customize the nature and extent of information provision to the characteristics of the location (e.g. capacity on alternative lines) and the disruptive event (Cats and Jenelius, 2014).

Furthermore, an interesting point was raised by Xavier et al. (2017) whose research showed that older travelers were much less likely to want information about seating availability or the transit vehicle type or capacity. It was argued that this could be because they either do not see the benefit of the information or they do not want informational overload. This does of course raise an interesting question related to information overload and shows that PT providers must closely evaluate what information and how much information travelers actually want and need.

2.2 Travelers Behavior & Choice of Transport Mode

The last decade, there has been a substantial shift, from product-based organizational structures, to customer-based organizational structures. The same shift is apparent within the logistics and transportation arena. Travelers' needs and demands are increasing continuously (Labedowicz and Urbanek, 2016). Even though reliability of transportation services is always a contributor to travelers' satisfaction, the expectations are now focused on personalization, flexibility and ease of use. More specifically, the global on-demand transportation market size is on the rise and is expected to expand at 19.8% for the next 7 years (Papangelis et al., 2016). That means that the control and decision making of transportation is slowly moving from providers to users. That phenomenon is highly interlinked with the rising penetration of smartphones and connected vehicles, as well as with advancements on IT and the growing usage of vehicle sharing services. The adoption of on-demand transportation services and the shift on the decision making is making the study and understanding of traveler's choices/behavior more relevant and topical than ever before (Labedowicz and Urbanek, 2016).

According to Axhausen (2007), travelling behavior is defined as the way people move by all means of transportation for any purpose. The study of travelling behavior, goes hand in hand with the ability of understanding and quantifying the choices people make about how, when, why and with whom they travel, as well as the different constraints, habits, options and norms in terms of gender and culture. According to Axhausen (2007), it is important to understand the different interlinkages when analyzing the travelling behavior of people. In the case of understanding how and why people use a specific mode or a series of different modes (multimodality) of transportation to get to work, one must take into account specific aspects such as the time they leave, the duration of the trip, the possible stops they make on their way as well as demographic characteristics, such as age, financial well-being, vehicle ownership, gas prices and so on. The different factors influencing travel decision-making of people was visualized by Singleton (2015) in "The theory of travel-decision-making: A conceptual framework of active travel behavior".

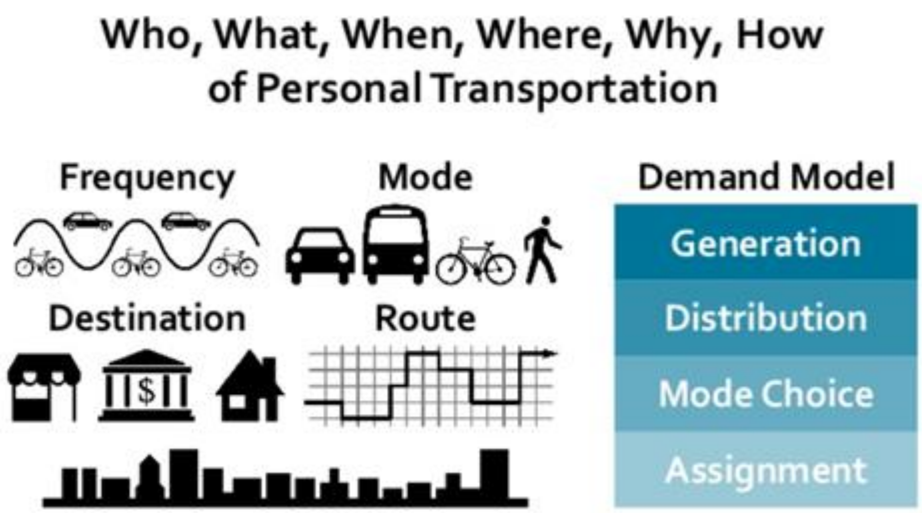

Figure 4; The theory of travel decision-making: A conceptual framework of active travel behavior, (Singleton, P 2015)

In attempting to promote sustainable travel choices in urban areas, understanding why people choose particular travel modes is a prerequisite for encouraging behavior change. Early studies on traveler's choice of transportation mode show that private cars often are preferred due to speed, convenience and comfort (Flink, 1975, Gärling et al., 2002). In addition, several physical factors influence people to drive their private car instead of utilizing public transportation in urban areas. However, with more advanced information systems, more efficient public transport solutions and better infrastructure, the advantages of utilizing public instead of private transport have increased the last decades.

Studies conducted by Meng et al. (2015) on the dynamic interactions between commuters' mode choice and the integrated traveler information have showed that increased amounts of integrated traveler information could enhance the commuters' mode switching propensity. Furthermore, the influence of traveler information in mitigating congestion and incident management has been evaluated. It was found that disseminating traveler information does influence the mode choice behavior. The commuters change their mode of travel from private to public, specifically in the zone that is directly affected due to accidents or disruptions. Travel mode choice behavior, as referring to the manner travelers select their travel mode(s), is inherently influenced by travelers' (perceived) knowledge about travel conditions of available choices; this knowledge about travel conditions is collectively termed as traveler information (Meng et al., 2015).

Furthermore, Brakewood et al. (2018) identify three key behavioral impacts of RTI in public transportation: (1) reductions in passenger wait times, (2) reductions in overall travel time due to changes in path choice, and (3) increases in transit use. Additionally, two important changes in passenger feelings has been identified: (1) increases in perceptions of personal security and (2) increases in satisfaction with overall transit service.

It is discussed by Pendyala and Bhat (2014), that travel behavior of individuals can not be modeled accurately, unless there is explicit consideration of the aforementioned aspects. In addition, it is mentioned that it is crucial to consider the different interactions and interdependencies among households and among its members as well as among a wide range of actors that complete the urban activity system. Those interconnections/interdependencies can vary between modal availability, school or work constraints, personal constraints and so on. Furthermore, information about people's flexibility and trade-offs regarding joint trips, alternative opportunities for destinations and timing of different activities should be thoroughly examined (Pendyala and Bhat, 2016). In the same article, it is stated the availability of information regarding the mode choice, destination choice, residential and work location will allow the identification of the reason behind travel behavior among people in urban areas. Björk and Jansson (2008) highlight that realizing changes in people's travel behavior is difficult without taking into account factors such as the design of transport system, household socioeconomic situation, access to various services, knowledge, habits, attitudes and personal motives. For instance, the authors explain that habits of people can indeed be a constraint regarding the modal choice since RTI can only make a difference if it becomes meaningful enough in order to affect and break people's' routines, which will ultimately result on changing their travel behavior.

Another point when analyzing travel behavior that is highlighted by the authors is related to implications regarding technology/telecommunications, transportation infrastructure as well as the role of transportation in people's quality of life. Pendyala and Bhat (2014) discuss that in order to understand and model travel behavior, a holistic approach is needed. That means that travel should not be studied and observed in isolation, but it should be observed and discussed in the context of different activities, transportation network and land use characteristics, time space interactions and lifestyle variables.

Another study by Pronello et. al., (2016), explores the effects of real-time multimodal information on travel behavior. The study took place in the city of Lyon, France and through survey questionnaires on a sample of 50 people from different target groups, the researchers try to model the travel behavior. Their study shows that after increased access to multimodal real time information, the number of participants who used their car more often, decreased from 16 to 4. In addition, the increased access to RTI, resulted in people finding new/alternative routes and allowed the participants to save time during their trips (Pronello et. al., 2016). Furthermore, the authors concluded that access to RTI resulted to 1% of modal shift from cars to bikes and/or public transport which is equivalent to a reduction of 24,000 tons of CO_2/year in Lyon (Pronello et. al., 2016). However, it is discussed, that in order to affect travel behavior on the long term and achieve sustainable urban mobility, increased access to RTI should be part of a broader strategy that includes more investments on public transport and infrastructure. That is confirmed through another research by Kollmuss and Agyeman (2010), where the intention to use more sustainable modes if RTI was available started to decrease after a period of time which indicates that access to RTI and investments in transportation network and infrastructure should go hand in hand.

2.3 Current Technologies in Public Transport

Brakewood et al. (2018) state that specifically three recent technological changes have made an impact on the transit industry; (1) the removal of Global Positioning Systems (GPS) selective availability back in 2000 made automated vehicle location systems less expensive and easier to implement, (2) the development of the General Transit Feed Specification (GTFS) format for transit schedules began a surge of data standardization that has carried over into RTI, (3) the proliferation of smartphones in recent years has made RTI more easily available in mobile formats.

Today, the main technologies used by transport providers to collect data that can generate valuable information to travelers are automatic vehicle location (AVL) systems that rely on GPS, automatic passenger counting (APC) that rely on sensors and advanced ticket systems and traveler information systems (TIS) that are highly connected with the concept of the internet of things (IoT) ((Oregon Public Transportation Plan, 2017) (Elkosantini and Darmoul, 2013)).

In this chapter we will analyze the different technologies used by public transport providers in more detail, as well evaluating new technologies that possibly can make an impact on urban public transport. The following subcategories related to technologies in PT will be discussed:

- Automatic Vehicle Location Systems (AVL Systems)
- Automatic Passenger Counting Systems (APC Systems)
- Traveler Information Systems (TIS)
- Internet of Things (IoT)

2.3.1 Automatic Vehicle Location Systems (AVL Systems)

In most transportation systems, vehicles are equipped with a GPS antenna, which communicates with four or more satellites to give the location of the vehicle. This system is based on components calculating the geographical location of a vehicle and then transferring this information to a control center using wireless telecommunication technologies (Elkosantini et al. (2013), (Ranic, Predic & Mihajlovic, 2008). Furthermore, AVL systems can collect the location of vehicles usually by broadcasting the sensors' values using an interval of 10-30s depending on the radio capacity and is commonly referred to as automated data collection (ADC) systems (Moreira-Matias et al., 2015). The fact that data can be collected and processed with such an immense speed gives the owners of this data enormous capabilities to optimize systems in real-time and provide valuable information to customers almost instantly.

According to Elkosantini et al. (2013) AVL systems provide decision makers with RTI on vehicles, such as location, speed and direction of vehicles, and information about delays due to disturbances, such as traffic congestion, accidents, bad weather conditions, or road repair work. The amount of data received through AVL systems are immense, giving transportation providers and operators multiple possibilities related to RTI sharing and real-time optimization. However, in relation to communication with travelers, AVL systems are mainly used by public transport operators to provide travelers with RTI on estimated time of arrivals through traveler information systems.

2.3.2 Automatic Passenger Counting Systems (APC Systems)

APC systems today are used to provide data on the number of on-board passengers to estimate the popularity of different routes in a network. In some cases, these systems are also used to count passengers waiting on stops, giving detailed information to decision makers that are valuable when looking at the transportation network to estimate passenger traffic and route optimization. APC systems typically rely on estimation techniques based on door loop counts or weight sensors. Furthermore, computer imaging is also used, which is based on intelligent image detection systems to recognize and count on board passenger (Elkosantini et al. 2013).

Previous literature on APC systems are highly focused on the advantages gained from utilizing APC systems for transport providers such as route optimization and planning (Chen et al., 2007) (Elkosantini et al. 2013) (Moreira-Matias et al., 2015). However, similar and connected with AVL systems, data from APC systems could be proven valuable for travelers making the overall public transport service more appealing for urban travelers. Raju et al. (2017) argue that there is lack of information about the arrival time in public transportation. Along with the uncertainty in time, there is also an apprehension regarding the capacity of a bus. Even if the passenger is aware about the arrival time of the bus, they do not know how many additional people can be accommodated inside the bus. Data collected from APC system can be used to solve such issues providing travelers interested RTI on capacity accurate estimates.

2.3.3 Traveler Information Systems (TIS)

Elkosantini et al. (2013) state that Traveler Information Systems (TIS) provide users with RTI about the state of the network. Furthermore, Moreira-Matias et al. (2015) argue that information provided by the advanced traveler information systems (ATIS) on the short-term travel time may reduce some passenger-centered travel time variability, namely, excessive passenger loading at some bus stops and/or major hub stations. This effect will cause a chain reaction by reducing first the actual departure time and, consequently, the scheduled departure time and the travel time associated with such stops scheduled run time. In Gothenburg today, RTI is not provided to travelers through traveler information systems, the information provided is estimations built on historical collected data. The information provided is consequently based on algorithms providing estimated time of arrival and estimated travel time on specific journeys. Raju et al. (2017) has proposed a system where travelers are provided with information about current location, next location of bus and crowd level inside the bus. This is a step towards a more dynamic and user-friendly information system where users receive RTI on location and capacity. Furthermore, a novel ATIS for co-modal passengers' transportation based on a multi-agent system architecture to answer multi-criteria user requests is proposed (Dotoli et al., 2017). This has a direct connection with the idea of providing mobility as a service (MaaS) to urban citizens giving travelers in urban areas the possibility to utilize a Multi-Agent Advanced Traveler Information System for Optimal Trip Planning. This again connects with the concept of digitalization and the IoT, connecting several service solutions and giving users the opportunity to choose the option that fits their needs.

2.3.4 Internet of Things (IoT) - Concept

Different from the technologies discussed, the IoT is an important concept that explains how technologies now are able to communicate with each other, its owners and its users.

The fundamental idea behind the concept of the IoT is the pervasive presence around the use and connectivity of a variety of things or objects – such as Radio-Frequency Identification (RFID) tags, sensors, actuators, mobile telephones, etc. that are able to interact with each other (Atzori et al. 2010; Giusto et al. 2010).

Vakule et al. (2017) argue that making a transport system intelligent for smart city needs, involve smart solutions to be implemented into the existing transport system and that the concept of creating a smart city is now made easy with the extensive development of the IoT. Meanwhile, Davidsson et al. (2016) argue that we are now in what can be seen as the fourth wave of digitalization. With the fourth wave of digitization, it is not just people who use the Internet to access and share information, but also different types of entities, such as vehicles, appliances, and machinery are also connected to the internet. This creates a higher degree of connectivity through smart technologies, cloud computing, big data and networked machines and processes.

Furthermore, it is argued that IoT can be seen as a powerful enabler of sustainable development in the context of public transport. In particular, the collection of different types of data can be made much easier, more accurate, and in real-time, through the use of IoT. This collection of data can then be used to re-planning actions and decisions that might influence the sustainability both positively and negatively, which is why access to accurate, up-to-date information is important. One example is that public transport can in some cases in fact increase emissions compared to using private car travel if there are few passengers in a bus (in case of low fill rate) (Davidsson et al. 2016). This discussion regarding utilization of IoT to create a more dynamic systems through collecting and using RTD shows how future TIS can be developed through the connection of AVL and APC into IoT specific technological solutions.

(Figure 4) visualize the current and possible connection between AVL, APC and TIS. In public transport there is often a direct connection between the data coming from AVL systems on the vehicles and TIS (apps, screens) providing travelers with updated estimated arrival and departure times. On the other hand, data coming from APC systems to TIS are most often not connected in a similar way. This is historically due to lack of demand of information on capacity or other vehicle specific information from travelers.

However, with the IoT, the opportunities for public transport providers to develop more efficient information systems able to provide more detailed information to travelers has emerged. Consequently, previous barriers related to communication and information sharing has decreased in tact with the increasing degree of digital connectivity.

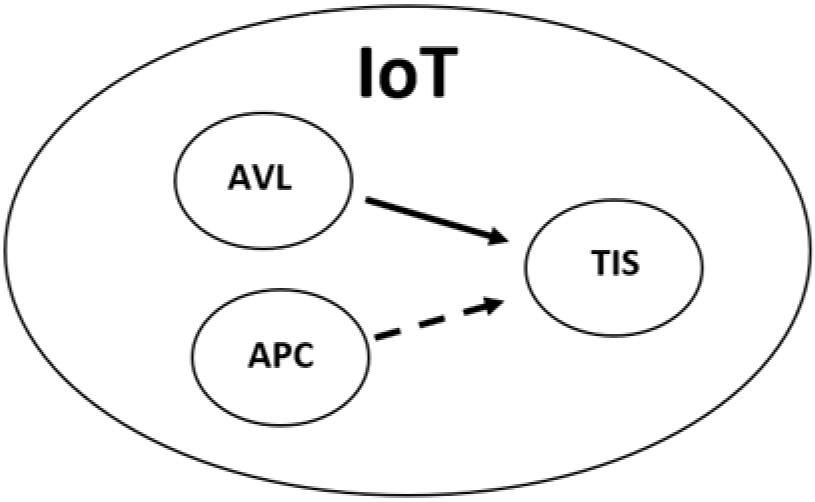

Figure 5; Internet of Things: Public Transport Technology Map, Own Work

The figure illustrates the potential of increased digital connectivity. New technological innovations give public transport providers the opportunity to include RTD from APC systems in their TIS. Such information can potentially be valuable for several groups of people utilizing public transport in urban areas.

2.4 Artificial Intelligence in Public Transport

Often transportation problem can occur when the system and its users' behavior become difficult to model and troubles predicting travel patterns arise. Therefore, AI is deemed to be a good fit for transportation systems to overcome such challenges. AI is considered a possible solution capable of dealing with challenges related to travel demand, CO2 emissions, safety concerns, and environmental degradation.

Studies conducted by García et al. (2014) discuss how AI can be applied in order to make more accessible the public road transport for people with special needs. The importance of developing personal solutions such as (voice synthesis, vibration warnings, touch screen, etc.) that can assist people with special needs before and during trips is stressed. Furthermore, AI can help assist public transport providers and operators in daily operations. By using different elements (on-board computer, sensors, location-determining devices, payment devices and network infrastructure) installed in a transport vehicle, an intelligent environment can be produced. This enables useful information to be obtained that enables the public transport service to be enhanced, improving the punctuality of the vehicle at the various stops, the frequency of the routes depending on demand, and security, by making the drivers' task easier (Padrón et al. 2013).

AI is already positively impacting the public transport sector and the technology is evolving and improving rapidly over time. In a recent study expert gave valuable insights on the likely short to medium-term trends of AI in public transport (Asia-Pacific Centre for Transport Excellence, 2018). The following figure (FIGURE 5) was developed on the base of these experts' viewings, to highlight how AI will influence public transport in the next 5 years:

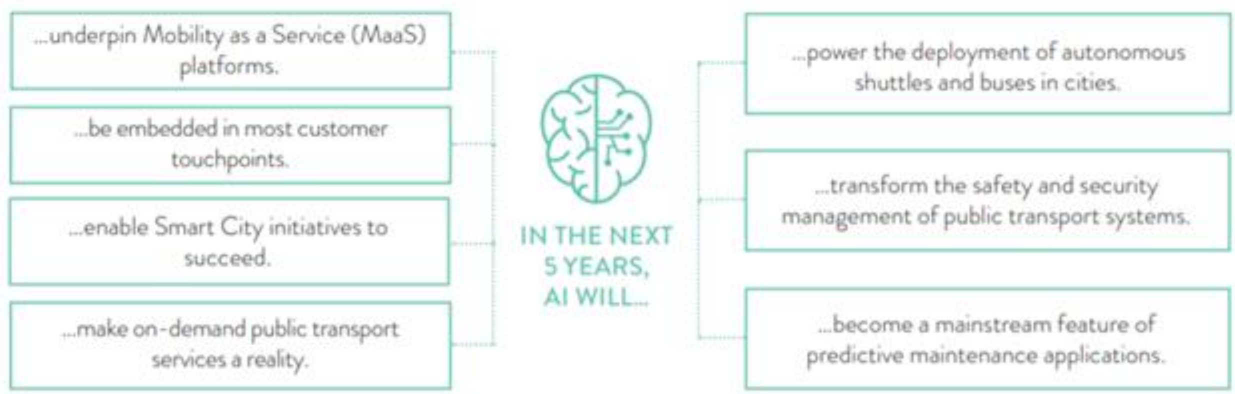

Figure 6; The future of AI in public transport, (Asia-Pacific Centre for Transport Excellence, 2018)

The figure clearly illustrates the possibilities related to AI and how it connects with solving the overall challenges that transportation networks face due to urbanization. The figure shows how AI connects with overall focus of urban network development where smart solutions are stressed in order to increase sustainability, mobility and customer focused solutions. One of the interesting areas shown in the figure is that AI is believed to become a direct solution to the increasing demand of on-demand public transport services by underpinning the development of MaaS in urban areas. Maybe the main reason to this is the development of big data, which is leading to more efficient algorithmic processing of data – in particular by artificial intelligence – and, in turn, making MaaS platforms more and more efficient (Arthur D. Little, 2018).

2.5 Mobility as a Service (MaaS)

The MaaS concept has received ample attention during the last couple of years. The reason for that, is that it addresses the value of real time information in connection to travelling choices. Concurrently, it addresses the phenomenon of urbanization (Swartz et al., 2015). Indeed, since more people are moving into cities, there is a greater need for more roads, trains, buses and spaces. Cities and governments, are confronted with challenging fiscal and environmental situations, so infrastructure development and capital project funding is not always feasible. Furthermore, digital transformation and IoT is more apparent than ever before (Swartz et al., 2015). According to Cisco (2016), by 2020 approximately 75% of the global population will be connected by mobile. That increased level of connectivity and automation along with the increased level of the volume and velocity of data generated by IoT systems is another reason that has triggered the development and implementation of MaaS schemes.

Mobility as a Service (MaaS), is a data-driven, user-centered concept that describes a shift away from personally-owned vehicles towards end-to-end trip planning integration of all modes of transportation. By combining both private and public transportation services, provides the end-user with the option to plan and pay for a door to door trip from a single application and a single account (Kamargianni et al., 2015). Basically, MaaS schemes combine the modes of public transport, public individual transport and soft mobility. Mobility services such as public transportation, bike sharing, car sharing and so on offer to travelers' dynamic solutions based on their needs and preferences.

The key concept behind MaaS, is that it can show that the user can chose a combination of different modes based on cost, travel time, convenience and even CO2 emissions (Kamargianni et al., 2015), (Deloitte, 2017). In order for MaaS to work effectively, a set of requirements need to be fulfilled. Firstly, it requires the presence of smartphone devices offering high level of connectivity. Secondly, dynamic information regarding travel options which are constantly updated along with secure systems that allow digital payment are crucial. In addition, in order for all the aforementioned parameters to be enabled, a substantial range of different actors (transport providers, agencies, local authorities, city planners etc) need to come together (Laine et al., 2018), (Deloitte, 2017).

The mobility platform SMILE in Vienna, Austria and the mobility application called Ubigo in Sweden are two illustrative examples of MaaS. SMILE, brings together fourteen Austrian transport providers and is considered to be the first MaaS initiative that offers booking and digital payment for the whole trip combined in one application (Smart City Wien, 2019). Ubigo combines several modes of transportation such as taxi sharing and car sharing in one application. It offers a flexible monthly subscription with the option have one account per household (Ubigo, 2019). Whim application in Helsinki offers similar MaaS services. Residents of Helsinki have the option to plan and pay for a trip by using all modes of transportation through that single application (Laine et al., 2018).

2.5.1 Using MaaS to reduce GHG emission and Vehicle Kilometers Travelled (VKT)

Since multimodal Maas is a relatively new type of mobility, integrated studies and calculations regarding its potential environmental benefits are not yet available. However, many separate studies have been conducted around the world, regarding the different transportation choices that are offered through MaaS schemes. So, in this section we will discuss the environmental benefits arising from the car and ride sharing within the MaaS concept with a focus on car and ride sharing.

Skjelvik et al. (2017) discuss the potential of MaaS schemes to reduce vehicle kilometers travelled (VKT) and GHG emissions. That can be attributed to car ownership changes. Car sharing users own fewer cars and drive much less on average, compared to non-car sharing users. Car sharing cars are less accessible compared to owned cars and also the cost per trip is more apparent to car sharing schemes which results to less VKT. According to a study made in 2014 by Nijland et al. (2015) car sharing users in Netherlands drove 7500 km/year compared to 9100 km/year before the introduction of the car sharing scheme. Another study made in North America made by Martin and Shaheen (2011), indicates a reduction on VKT by 27% after a car sharing scheme was introduced. A substantial VKT reduction by 28% is also apparent in a study made by Sarasini and Langeland (2017) in Belgium. In addition, according to a Swedish study from Vägverket (2003), car sharing schemes can reduce the vehicle kilometers travelled by 30-60%.

Ride sharing is another option available to users when using MaaS schemes where several persons can share one vehicle. According to many studies, ride sharing has the potential to reduce VKT and result to both urban decongestion and GHG emission reduction. A simulation survey in Helsinki made by ITF (2017) regarding two types of ride sharing services (minivan with a capacity of 8 persons and taxi-bus with a capacity of 16 persons), indicate a substantial reduction of VKT. More specifically, different scenarios regarding the capacity were tested (full, half-full etc). Consequently, the reduction varied between 8% to 33% in VKT, which indicates that even at its lower tested capacity, ride sharing has the potential to reduce the VKT and followingly the GHG emissions. Another study made by Jalali et al. (2017) in China shows that ride sharing can reduce the total kilometers driven by 24%. Ota et al. (2015) studies taxi-ridesharing in New York City where its trip was shared by 2 and 3 people. The outcome of the research was 46% reduction of VKT when the trip was shared between 2 people and 61% VKT reduction if the trip was shared among 3 people.

2.6 Legal Issues – Data Collection

As of May 2018, with the entry into application of the General Data Protection Regulation, there is one set of data protection rules for all companies operating in the EU, wherever they are based (European Commission - European Commission, 2019).The main goal of implementing GDPR is give people a higher degree of control over their personal data as well as making sure companies operate on equal playing fields within each EU member state.

According to Thomas (2019) the consequences of GDPR for actors collecting personal data is that it is now more difficult to gather and process personal data without consent from the user. Traditionally, organizations have relied on consent to process personal data. This has historically been obtained through a variety of (sometimes discrete) means – like terms and conditions or the option of an opt-out or pre-ticked consent box. GDPR introduces a much higher bar for valid consent. Privacy policies will have to be written in a clear, straightforward language and the user will need to give an affirmative consent before his/her data can be used by a business. Silence is no consent (European Commission - European Commission, 2019)

GDPR also applies to video-surveillance, meaning public transport providers are not able to use video-surveillance to collect personal data as efficient as possible. Video-surveillance footage often contains images of people. As this information can be used to identify these people either directly or indirectly (i.e. combined with other pieces of information), it qualifies as personal data (also known as personal information). For public transport providers that want to gather data through video- surveillance the following issues must be considered (European Data Protection Supervisor - European Data Protection Supervisor, 2018):

Data quality - Cameras can and should be used intelligently and should only target specifically identified security problems thus minimizing the gathering of irrelevant footage (data minimization).

Right of information - signs are mandatory because individuals affected by video-surveillance must be informed upon its installation about the monitoring, its purpose and the length of time for which the footage is to be kept and by whom.

Retention period - Although the installation of cameras might be justified for security purposes, the timely and automatic deletion of footage is essential. The EDPS requires all EU institutions to have clear policies regarding the use of video surveillance on their premises including on potential storage.

In the future, this means that public transport actors have to think about how they collect and use smart ticketing data. It also becomes vital to understand GDPR guidelines when storing personal data and how they go about obtaining consent for data processing. In addition, actors need to explain to customers with a clear language what, how and why they want to collect their personal data, as well as showing how this data is being protected from third parties (Thomas, 2019).

2.7 Literature Summary and Contribution to Theoretical Framework

As discussed in this chapter, previous studies show that there are possible connections between information sharing and traveler behavior. The literature evaluated show that travelers who are exposed to increased amounts of information tends to switch their preferred transportation mode more often and therefore have a direct impact on traveler decision making.

In addition, the literature shows that with increased amounts of technological integration leading to higher sense of connectivity between users and providers, the possibilities to influence traveler's behavior are frequently developing. Furthermore, technological development fosters new market opportunities and disruptions that possibly will change the urban transportation dynamics in the future. However, the legal aspects of data collection and information sharing does influence how providers work today and how they will be able to develop their services in the future.

The literature review will be used as a theoretical framework in this study and will further contribute to the development of a research survey that will be conducted in the city of Gothenburg. Research conducted by Harmony et al. (2017) on information supply and information demand, as well as other theories discussed in the literature review will be used when developing specific questions for the survey that will contribute to the overall result of the study. The overall goal is to compare previous research with findings from the empirical analysis and questionnaire survey.

3. Research Methods and Methodology

In this section we will present the methods used to answer our research question(s). Furthermore, the rationale behind the selection of various methods for data analysis are discussed. The type of research analysis/investigation that is followed and conducted by the current authors, is an exploratory-triangulation method using both qualitative and quantitative data.

An exploratory method contains mainly two phases. The first phase is usually a qualitative study followed by a quantitative study (Teddlie and Yu, 2007). However, according to Creswell et al., (2007), researchers don't have to follow a standardized model of combining qualitative and quantitative methods, since one approach can be integrated to another in different stages of the research. An exploratory method, addresses the "how" and "why" questions regarding the phenomenon of interest and illustrates the existence of more variables of interest than data points by relying on multiple sources of evidence in a triangulating form in order to guide data collection and analysis in a holistic way (Teddlie and Yu, 2007).

Triangulation analysis compares the quantitative data and the qualitative results and shows how one set of data can be used to support or inform the other. The triangulation method is used when researchers have the intention to understand a phenomenon by combining different but complementary data regarding the same topic (Teddlie and Yu, 2007). That is also mentioned by Masonet al., (2009) , who highlights that qualitative and quantitative methods should be viewed as complementary and not as rival approaches. According to Creswell et al., (2007), the triangulation method allows researchers to collect both qualitative and quantitative data and then the different results from the data are analyzed and discussed in order to interpret the research findings.

On that note, the importance of an exploratory-triangulation method, is mentioned by Johnson et. al., (2007) by highlighting the advantages of mixing methods compared to single method designs. In addition, Teddlie and Yu, (2007), discuss that in order to ensure a greater validity of the research, the researcher should use more than one method. Furthermore, by adopting the mixed methods approach, researchers will be able to explore a relatively complex phenomenon with different perspectives.

The exploratory-triangulation method will help to confirm the connection between access to RTI and travelling behavior of people in Gothenburg. After confirming the above-mentioned connection, the current researchers will combine the different data from the qualitative and quantitative research and explore “how” and “why” increased access to RTI affects travelling behavior of people in Gothenburg with the ultimate goal of presenting fresh research findings and insights.

3.1 Data collection

As already mentioned, the initial aim is to identify the correlation between real time information and travelling choices for people in Gothenburg. For this study, we will use both Primary and Secondary data. Results obtained with primary data, means that the data is collected firsthand by the researcher. The most common techniques of primary data collection are interviews, field observation, experiments and self-administrative surveys (Hox and Boeije, 2005). Secondary data refers to data that has been collected by someone who is someone other than the researcher who is doing the current study. Secondary data can be classified in published or unpublished. The important thing is for the researcher to have access to it. Published secondary data refers mainly to information collected either from various departments (governmental or non-governmental), public records (companies or other data that has already been collected in another study) or others, through a literature review (Hox and Boeije, 2005). In order to avoid any confusion, it is important to note that both primary and secondary data collection can be classified under both qualitative and quantitative methodology.

3.1.1 Secondary data collection through Literature Study

For this paper, literature study refers to the review and study of literature in order to build a theoretical framework that will be used as a source of knowledge and reference in order to investigate in a holistic scale the current research question. The literature study that was conducted is focused in 6 different areas;

- Real-Time Data and Real-Time Information
- Travelers Behavior and Choice of Transport Mode

- Current Technologies in Public Transport
- Artificial Intelligence in Public Transport
- Mobility as a Service (MaaS)
- Legal Issues

Thus, the theoretical framework was built on secondary data obtained through a detailed literature review on the aforementioned areas that are highly interlinked with the topic of the research question. That was done through a detailed review of academic articles and books as well as more specific review on case studies and surveys related to the topic. It is worth stating that secondary data is usually time saving and cost efficient since most of the background work is already done by previous researchers. The major concern of secondary data is that it may be outdated. In addition, since the literature review is focused both on academic articles and books, but also on case studies and surveys that include numbers and data, the secondary data collection in this section goes under both qualitative and quantitative methodology.

The following methods were used in order to collect secondary data from different sources:

- Search by keywords in the Gothenburg University Library digital sources using "Supersearch". Keywords: "real time information/data", "logistics", "urban mobility", "travelling behavior" "smart city"
- Search by keywords in Libris, the online Swedish library
- Search by keywords in Google Scholar
- Search by keywords in Web of Science and Scopus accessed through University library's databases
- Access to direct online sources proposed by experts from the field of smart city and urban mobility.
- Access to sources found on the reference list of various sources, found while searching with keywords.

The current authors, used a screening process in order to prioritize the different sources according to subject relevance. This was done by prioritizing each source according to:

- Title
- Abstract
- Conclusion

If the above-mentioned information seemed relevant to the research topic, the current authors categorized the source in order to further read and investigate in more depth the possible connection and value of the source. All sources used were documented and are presented in the reference list according to Harvard style denotation.

3.1.2 Primary data collection

For this research, the primary data collection will be done through a series of semi-structured interviews with experts within relevant fields of urban planning and development, information technology systems (ITS) and public transportation solutions and a questionnaire survey. More specifically, the current researchers conducted a pilot study in UK and Gothenburg in order to get inspired and to gain a deeper knowledge and understanding of the broad challenge of urbanization and the potentials within a smart city concept. After defining the topic of relevance, the current researchers conducted a series of interviews in Sweden, with the purpose of getting more advanced, specific and detailed knowledge regarding the chosen area of interest.

The following figure was made in order to give an illustration of the overall interviews conducted. It provides details about each interviewee, the duration and the location of the interview.

Figure 7; Interviews on RTI & Travel Behavior, Own work

The main advantage by using interviews is that the level of accuracy will be very high. That is justified, since the process is very specific and the interviewee is a knowledgeable person regarding the topic (Hox and Boeije, 2005). The aim of choosing semi-structured interviews as our research method is to allow for open discussions between the interviewee and interviewer, while at the same time assisting in keeping the interview within the field of interest and ensuring relevant information for the study (Howell, 2013). Structured interviews were also discussed by the current authors but were not chosen due to a number of reasons. To begin with, since a structured interview is characterized by minimal variations, fixed questions and very little amount of open-ended questions, there would be very little room to build up a relationship with the interviewee (Howell, 2013). In addition, that may result both in leaving out basic elements of discussion and also the whole process might cause the interviewee to feel tense. Furthermore, the quality and the usefulness of the information will be dependent on the quality of the question that is being asked (Howell, 2013).

Generally, the main disadvantages of interviews as primary data collection are that it can be expensive and time consuming. The design could be an issue as well. We need to build a specific interview framework in order to have a harmonized process that will bring accurate results for all interviewees. However, the discussion in each interview can digress which may be positive in the sense that the researchers may obtain additional valuable information from the interviewee, but may also lead to altered results depending on the level of topic digression. Also, there is always the possibility to get fake or socially acceptable answers from the interviewees (Hox and Boeije, 2005).

Alongside, the current authors created a survey questionnaire in order to establish in practice the connection between real-time data/information and travelling behavior of people in Gothenburg and to get data that will be used later to establish different interconnections and propose future recommendations. The motivation behind the choice of methodology regarding both the interviews and the questionnaire survey is analyzed in the subsections bellow.

3.1.2.1 Pilot study through semi structured interviews in the UK and Gothenburg

The research done was narrowed down through pilot studies in the UK and Gothenburg, Sweden. A pilot study (PS) guides the development of the research plan (Prescott & Soeken, 1989). Furthermore, a PS is defined as a small-scale research project conducted before the final full-scale study. A PS helps researchers to test in reality how likely the research process is to work, in order to help them decide how best to conduct the final research study. In piloting a study, a researcher can identify or refine a research question, discover what methods are best for pursuing it, and estimate how much time and what resources will be necessary to complete the larger final version of the study (Ismail, Kinchin and Edwards, 2017).

In our research, PS was conducted through semi-structured in-person interviews. At the very early stages of the research interviews were conducted with with John Wedel, who is a Managing Director of the Logistics and Infrastructure in Business Region of Gothenburg and with Hannes Lindkvist, who is Project Manager at CLOSER at Lindholmen Science Park, Gothenburg. These interviews were conducted in order to narrow and refine the research through increasing the knowledge about the current urban transport situation in Gothenburg.

Furthermore, the researchers had interviews in the UK with Brian Matthews who is the Head of Transport Innovation at Milton Keynes Council, UK and with John Miles who is a Professor at Cambridge University. Professor Miles is also a specialist in the areas of energy strategy and transport systems, and is currently engaged with the development of carbon reduction plans for cities and the introduction of urban electric vehicles through Arup company in London and as consultant on Milton Keynes city council.

An in-person interview is widely acknowledged as a suitable technique for qualitative inquiry to seek insights of those who have experienced or are experiencing the phenomenon (Collingridge & Gantt, 2008; Wimpenny & Gass, 2000). All four interviewees are highly engaged in smart city concepts and sustainable urban transport development. Moreover, the two interviewees conducted in the UK were selected for the PS due to their involvement in the MK Smart Project and their broad experience within our field of study. The MK Smart Project is a project conducted in Milton Keynes, UK, that focus on smart sustainable solutions in one of the fastest growing cities in the UK. Moreover, MK Smart has focused on sustainable transportation solutions to citizens utilizing data to support sustainable growth without exceeding the capacity of the infrastructure.

The data collected from the pilot interviews was used to develop the research question of the thesis and also contributed to the final result.

3.1.2.2 Main semi structured interviews

The semi structured interviews conducted in this research were based on categories connected to the main topic. To be able to evaluate the research question(s) several related factors had to be analyzed. This led the researchers to organize the interviews into separate categories all directly connected to the main topic. The following categories were considered important:

- Public Transportation
- Urban Development (Mobility, Infrastructure)
- Legal Issues
- Smart City Concept (AI, IoT, MaaS, Intelligent Transport Systems, Current & Future Technologies)

Since the research of this paper is narrowed in Gothenburg, most of the interviews were conducted there. Hence, the data collected is very topical and fresh and the researchers obtained a realistic view of the topic. Six interviews were conducted in total. A second interview was conducted with John Wedel focusing mainly on the current situation and the future plans and possibilities regarding city development and transportation in Gothenburg. Two interviews were conducted with Jari Tammisto, who is working as an intelligent transport systems (ITS) specialist at Västtrafik. He is considered one of the key people working with RTI/RTD projects for Västtrafik having hands on knowledge about the current systems and working on future possibilities and technologies. Furthermore, the current authors conducted a Skype interview with Enrico Motta who is a Professor in Knowledge Technologies at the Open University in UK. He is considered very knowledgeable about smart city technologies and AI. More specifically, his research spans a variety of aspects at the intersection of large-scale data integration and modelling, semantic and language technologies, intelligent systems, and human-computer interaction. An interview was conducted with Hans Arby, who is the CEO of UbiGo. UbiGo is a fully integrated mobility service for urban households and businesses. Hans is an expert within sustainable transport and intelligent transport systems (ITS) and has experience working as a strategic support to cities in developing transport strategies and long-term planning and marketing of public transport. The last interview was conducted with Martin Högenberg who is the Vice President Consulting and Head of Innovation CGI Sweden. Martin has wide experience working with technological innovation and leadership and was able to provide many information regarding the technologies that are currently used, but also the future technologies and AI.

3.1.2.3 Questionnaire Survey - Urban Citizens/Travelers

An additional way of primary data collection, was done by a survey through a sample of 158 people living in Gothenburg. In order to better understand the possible relationship and consequently the possible effect of increased access to real time data on travelling choices of people in Gothenburg, we need to examine the parameters of a particular population who share similar characteristics. The chosen population in this case would be citizens of Gothenburg. The aforementioned process is known as sampling. It is of a great importance for the sample to be representative, meaning to have a sample that its outcomes could be generalized. It is important to have a random selection process, so as to have a representative sample (Law, 2016).

In this case the researchers wanted to cover all demographics considered relevant for this particular research. This meant that people in all ages and with different specific needs had to be included to come up with a reliable sample. A relevant sample size was reached by online distribution of the questionnaire through social media and student email via the University's database. However, the researchers found it difficult to cover all demographics online. This led the researchers to do additional street surveys in order to gather the needed data. The response rate regarding the street surveys was approximately 90%. The respective response rate of the online survey could not be calculated since the survey was spread among different social media groups and databases. The goal of conducting questionnaire surveys with the main target groups of the thesis is to gather data on how information is being gathered and processed, as well as developing a better understanding of what aspects of information is considered important. A questionnaire survey provides a fast and efficient means of gathering information with regards to the respondents' perception about the relevant subject in this aspect (Law, 2016). In this case the questionnaire survey was designed by talking to experts about the subject, doing research on previous questionnaire surveys related to the main topic, as well as a literature review on questionnaire design methodology.

According to De Vaus (2002), the questionnaire design should be attractive and clear to the respondents. In addition, according to Vaziri and Mohsenzadeh (2012), closed questions have the benefit of ensuring that the author will have fewer problems and will be more objective when coding the survey since the respondent is replying by choosing fixed responses instead of expressing their opinion through an essay form. The latter was followed by the current authors with the exception of the last question which was open ended in order ensure that the respondent's additional remarks could be recorded in a non-restrictive way. Throughout the entire survey, it was acknowledged that the wording of the questions should be as straightforward and simple as possible in order to avoid any case of interpretation by the respondent (Mathers, Hunn and Fox, 2009). According to De Vaus (2002), many surveys suffer from bias and ambiguous questions which may lead to further questions from the respondents. This is an issue that was recognized and discussed by the current authors and avoided. According to De Vaus (2002), both the length and the number of questions should be as short as possible in order to not confuse the respondent and to keep his interest high.

The authors of the current research took that into account by forming 27 relatively short questions that address the required information and establish the respondent's socioeconomic background. The aforementioned background was established through a series of demographic-oriented questions with the purpose to decode and compare the findings among different groups.
This was followed up by a set of questions sought to discover which mode(s) of transportation the respondent is usually using to move around the city and the reason behind that choice.
Furthermore, a series of questions focusing on evaluating the respondent's satisfaction or perception of satisfaction by the current information provided by the public transport provider (Västtrafik) and the different ways he/she would prefer to receive real time information (application, SMS etc) was tested. The last set of questions sought to discover and define the potential value that RTI will have on the respondent. As already mentioned the final question is open-ended which sought to discover other potential additional information that the respondent might value.

3.2 Research Quality of the methodology

Validity and reliability are very important concepts that need to be addressed when evaluating the quality of a research. According to Briggs et al. (2012) there are different techniques in order to address and enhance the validity and reliability of a research study. In this section, a description of the different techniques used by the current authors is given.

3.2.1 Validity

Validity relates to the extent to which a specific factor is measured and described accurately. In order for our research to characterized as valid, our results need to fulfil all the criteria of the method we used (Briggs, et al. 2012). In addition, credibility and transferability are also part of validity in the sense that reality is connected to the researcher's interpretation and generalization can be achieved. Furthermore, validity refers to the neutrality and objectivity of the research. On that note the researchers are responsible to assess whether the coding and interpretation of data has been conducted in a logical and unbiased way (Briggs, et al. 2012).

In order to achieve that, the current authors used multiple sources of evidence both through literature review and interviews with experts from the various fields of interest. Another technique used by the current authors in order to increase validity is the use of diagrams and illustrations. Moreover, the findings from the literature and the interviews were compared and analyzed in order to produce valid results.

Regarding the primary data collection and analysis, the current researchers used questions related to real time data and travelling choices as well as more general questions about transportation behavior and passenger information and at the same time tried not to digress from the topic and purpose of the interview.

Secondly, the interview itself needs to be well structured. A methodical and organized way of the interview design has a much better chance to provide valid results and present some kind of predictions for the future. Furthermore, it is important for the interviewer to take notes during the interview (Smith & Smith, 2018). These notes will include the performance of the interviewee during the interview. In this case, we were granted the permission to record the interviews and at the same time take notes regarding some key points that we felt we wanted to investigate further. The interview recordings were later converted into text using the software tool "Transcribe by Wreally" in order to have a physical and practical illustration of the replies given to the questions.

3.2.2 Reliability

Reliability refers to the consistency and stability of the measurement and is concerned on whether the results of a research are replicable (Briggs, et al. 2012). Reliability is also reflected on how clear the research question is and whether the research study was conducted carefully. In order to increase the reliability of this paper, the current authors used different academic sources and case studies on their research assuring a parallelism among the various findings.

As for the primary data collection and analysis, since the characteristic of an interview is the human interaction, reliability may prove difficult to achieve. Human judgment is not always objective and different people have very different perspectives. Also, different people answer a question differently and they process an answer in a very different way as well (Smith & Smith, 2018). That level of interpretation from both the interviewee and the interviewer may be difficult to overcome. Human beings answer according to their personalities and feelings which as already mentioned are different.

4. Empirical Findings

This chapter will draw upon the main themes in this thesis and present the findings from the primary data collection which arose out of the interview process, the subsequent data analysis and the findings both from the questionnaire survey and from the pilot survey implemented by UbiGo in Gothenburg.

4.1 Interview Findings

All interviewees are considered experts within fields directly or indirectly connected to the thesis main topic and were chosen to contribute to the overall evaluation of the research question. Consequently, the key themes that emerged from both the pilot interviews and the main interviews are analyzed in the following subchapters. Furthermore, the findings are separated into categories that connects with those analyzed in the literature review (chapter 2). The reason why the interview findings are directly linked with the literature review is to investigate the possible connection or disconnections between previous research and the findings in this thesis. The findings will further be discussed in chapter 5 where all collected data is compared and analyzed.

4.1.1 Real-Time Data and Real-Time Information

When conducting the interviews, the aim was to investigate the importance of collecting RTD and sharing RTI in public transport. In addition, the interviews were intended to examine possible challenges with data collection and information sharing.
Based on this, one of the key topics discussed during the interviews was the potential advantages of collecting RTD for public transport providers.

According to Motta (personal communication, 25-03-2019) it is essential to use data to optimize two things: (a) information sharing and (b) scheduling transportation options. Motta (2019) argue that by collecting data public transport providers can adjust systems in case of special events, as well as optimize systems based on travel data. Furthermore, Motta (2019) argue that this becomes even more important in urban areas where you often have many different modalities in more integrated systems. Processing data to produce more sustainable solutions was also discussed with Miles (personal communication, 20-02-2019) who argued that one of the main issues with public

transport today is the load factor. According to Miles (2019) a more optimal solution would be if public transport providers were able to optimize the occupation levels on buses using data. Miles (2019) argue that a larger number of smaller vehicles, where a number of the total vehicle fleet could be retired during non-busy periods of the day could be a solution that would stabilize the load factor on buses between 50-100%. This would in the end reduce the average CO_2 emission per passenger kilometer and make public transport more sustainable. The potential of data was also discussed with Lindkvist (2019) (personal communication, 12-02-2019) who emphasized the importance of RTD to improve the decision-making process and the user experience of public transport. Furthermore, Lindkvist (2019) argued that the future of public transport and freight transport can face a higher sense of connectivity due to technological data improvements.
This builds upon the theory of developing more intelligent transport systems (ITS) that will increase the attractiveness of public transportation in the future.

However, although it seems clear that data gathering can be used to improve systems and provide more user-friendly services, several challenges related to RTD and RTI was raised during the interviews. Matthews (personal communication, 19-02-2019) argued that understanding the value of data and provide relevant information based on collected data is a challenge. In many cases third parties are involved in gathering data for public entities, then the question related to the value of this data becomes even more relevant as public entities need to evaluate what data they need and how valuable this data actually is in order to move forward. This particular topic was also discussed with Motta (personal communication, 25-03-2019) who said that giving useful information is a challenge. According to Motta "not all information is important – so it is essential to understand what information is actually useful". Miles (2019) was also asked about data collection from third parties and argued that good data does exist, so there can be a solution to pay phone companies for such data, but the question is how do you monetize the service? Developing a information sharing service that beats the likes of Google is almost impossible.

The interview conducted with Tammisto (personal communication, 15-03-2019) focused on how Västtrafik (public transport provider – Sweden, region west) work with data in real time and in general. In Gothenburg, Västtrafik has access to all data gathered on buses, trams, trains, apps etc. The collected data gives Västtrafik the opportunity to process big data sets in order to optimize systems and provide valuable information to travelers. This can be a huge advantage for a transport provider. However, something interesting that came out of the interview with Tammisto (2019) is that Västtrafik actually don't use RTD to provide travelers with RTI. The information provided to travelers is based on historical data sets that are used to estimate history of trips, the result is a system that can be highly vulnerable in the case of disruptions. According to Tammisto (2019) the definition of on time in Västtrafiks system is 30 sec early or up to 2 min late, giving them a pretty high time buffer. In the case of system disturbance such as traffic jams or accidents, it is the vehicle driver's responsibility to send a message to the back office who then again process this information to update screens on stops and apps to inform the passengers waiting that there is a delay. This update usually takes up to 2 minutes. Furthermore, stops with high amount of traffic is equipped with cameras giving operators an instant message in the case of disruptions. However, there is a lack of automation in this system, making human interactions necessary to provide updated information to travelers.

When asked about how Västtrafik work with passenger counting to predict patterns and share capacity information with travelers Tammisto (2019) highlighted the importance of having automatic passenger systems (APC) installed on all vehicles due to safety reasons. The driver has the legal responsibility, so it is important that the driver is equipped with a system that informs him when maximum capacity exceeds. However, when vehicles reach maximum capacity another issue rises, that is how do Västtrafik inform waiting passengers about this in real time? It is almost impossible as the driver will never know exactly how many people will walk off on the next stop. At this point Västtrafik use APC data to better understand the system in real-time, but providing this information to travelers are not something they are willing to do at this point because of such uncertainties.

4.1.2 Travelers Behavior & Choice of Transportation Mode

Travelling behavior was another key topic that was thoroughly discussed during the interviews. Since the current authors are investigating RTI and the possible effects it may have on people's travelling choices, the current researcher's aim was to get practical information in order to better understand the aforementioned topic. In addition, there was a common acknowledgement from all interviewees that travelling behavior is indeed a very crucial factor that businesses need to understand more than ever before. It was also acknowledged, that understanding travelling behavior is one of the greatest challenges, since it is based on the human parameter. The importance of travelling behavior is highlighted by Motta in the sense that it makes it easier for providers to adjust in case of events. In addition, he stated that by understanding and analyzing patterns, it is easier to act intelligently and plan alternatives such as adding more services when needed. However, the challenges as already mentioned are immense.

A very interesting point highlighted is the shift from the current traditional philosophy of transportation services, towards a more adaptive transportation system. Indeed, according to Matthews the current model of fixed routes and fixed timetables offered by operators is challenged and people start to not respond to that. So, it is apparent that people's needs and the behavior behind those needs is constantly changing, which constitutes an ever-ending challenge for the different operators and actors to provide "smart" services. In addition, Motta also talked about dynamic schedules where the schedule is determined by demand. That means that the actual control of schedules and timetables slowly shifts from the operator to the user/customer. On that sense, Miles added that RTI in connection to decision making is at its most valuable when making discretional journeys. Discretional journeys according to Miles are spontaneous journeys that come from an instant decision. So, from the passengers' perspective there is substantial value regarding the knowledge of the travel time needed to get to the destination, but also information about the different transport options available.

According to Arby, increased access to RTI has a great impact on the travelling behavior of people. More specifically, before launching UbiGo, they did a practical pilot survey in Gothenburg in order to test their business idea. According to Arby, during the testing phase which was implemented on 70 households during a period of 6 months, not only people were happy with the service, but they also changed their travelling behavior. On the other hand, Miles highlighted the challenges and trade-offs when providing of information to citizens in real time. Those challenges are mainly connected to the interests between the different actors involved. For instance, real time information regarding the capacity of a tram that goes to a shopping mall can have a different effect on the various actors involved. From the passenger's point of view, a full capacity on that tram can either be an offset to visit the shopping mall, or can lead to the decision to use another mode of transport.

That mode is very likely to be a car which will add an extra environmental externality. So, being provided with RTI can be positive in the sense of transportation services towards the user, but it can also lead to increased CO_2 emissions arising from a decision to choose different mode of transportation. On top of that, the user's decision in connection to the RTI provided can have a substantial impact on the shopping mall owners. The goal of the aforementioned owners is to attract as many customers as they can in order to increase sales. So, if the RTI provided regarding the capacity of the tram offsets the customers to visit the shopping mall, that will impact the shop owners negatively. Consequently, in order to understand travelling behavior in regards to RTI it is crucial to explore the various interdependencies and tradeoffs that arise between the different actors involved.

Miles, thoroughly discussed that from the users' perspective, the RTI provided should be multifaceted. There is little use on informing people about the exact location of the bus/tram, urging them to take it, only to find out the bus is full since it will inevitably lead to frustration. In addition, Arby added that concepts like MaaS rely on good and accurate real time information. That means that the service provided should be impeccable every time the customer is using it. However, in order to achieve that, there are many parameters that need to be calculated. Those parameters include weather, incidents and collaboration between the different actors who offer RTI services. Arby highlighted that a service like that should never fail since customers want reliability and ease of use every time they will use the service. In addition, he added that providing that service comes with great responsibility and many challenges, since from a customers' perspective a delay when travelling to work because their car broke down is acceptable but a delay because the service, they chose to use failed, it is not.

4.1.3 Current Technologies in Public Transport

The technologies used by public transport operators and providers and the possibilities related to utilizing such technologies was a topic brought up throughout the interviews. Matthews (2019) stressed the possibilities surrounding technologies when it comes to reducing congestion, arguing that by putting sensors on roads public transport providers can possibly avoid traffic jams. In that case, sensors should mainly cover main road junctions to give RTI about the traffic situation to operators. Furthermore, Matthews (2019) discussed how sensors can be used to give information about capacity on vehicles, however he argued that such sensors cannot give accurate numbers to travelers because you can never know how many people will walk off on the next stop, making it difficult to provide reliable information to travelers. Conversely, Motta (2019) argued that such issues could be solved by developing algorithms able to predict patterns making the information provided to travelers approximately 97% accurate. Furthermore, both Matthews (2919) and Motta (2019) pointed out how sensors in AVL systems can efficiently be used to provide information about location of vehicles to travelers almost instantly through 4g. This information can be extremely valuable for some specific groups of travelers such as parents with young children, according to Motta (2019).

In Gothenburg, all vehicles operating in the city are equipped with AVL systems, according to Tammisto (2019). The AVL system in Gothenburg is used primarily to achieve efficient transportation. This means that the system never give information to travelers about any specific location of a vehicle. Furthermore, the APC system active in Gothenburg register data on capacity, but this data is not processed frequently, the data I mainly used to optimize timetables and routes for the upcoming term. This means that the current system might struggle in the case of unexpected events, as it is not able to adjust in real-time. Tammisto (2019) expressed that this is one of the focus areas of Västtrafik, so all new trams that are expected to arrive later this year (2019) will be equipped with real-time APC systems that are able to give information instantly on capacity. However, Västtrafik have no immediate plans of utilizing the new system to provide more detailed information to travelers as this is not one of the focus areas.

The importance of using technologies to provide the right information was discussed with Högenberg (personal communication, 12-04-2019) who stressed the importance of personalization. According to Högenberg (2019) the ecosystem is constantly changing and this is happening faster than ever before. So, for public transport providers it is challenging to offer a service that will stay attractive without including new technological innovations in the mix.

The important aspect when it comes to technologies from a user’s perspective is that the technology must be relevant. This means that the technology from a user’s perspective must be more personalized in order to be attractive. So, for public transport providers it is important to understand that users want technological solutions that quickly can answer their needs.

4.1.4 Artificial Intelligence in Public Transport

Artificial intelligence has the potential to transform the way transport networks are operating today. According to Högenberg (2019), AI can be used to predict patterns, but Högenberg (2019) state that AI is still considered to be in an early phase making it a bit immature. However, Högenberg (2019) gave an example of how AI can be used in public transport stating that it can be used to create unique datasets able to develop unique services to specific target groups. This can be extremely valuable for public transport providers dealing with multiple planned and unplanned system disruptions.

When asked about how AI can influence public transport and public transport networks in the future Motta (2019) mentioned four important aspects of public transport that he believes AI has the potential to affect. According to Motta (2019) we will most likely see autonomous vehicles on the roads within 20 years due to technologies and AI. Furthermore, Motta (2019) stated that AI will most likely impact the management of transportation infrastructure. This can according to Motta (2019) develop a network where we see automatic rerouting of vehicles in the case of disturbances, with the goal of creating a system where we see an even higher interconnection between transport systems and vehicles. “Then you have essentially individualized messages that tells different cars to take different routes.”

This particular aspect of AI was also brought up by Matthews (2019) who stated that in Milton Keynes they use sensors to integrate AI into traffic management systems, with the goal of developing more efficient systems with less congestion.

The potential of AI was also discussed with Arby (personal communication, 27-03-2019) who discussed how AI could be used in the future to develop mobility in urban areas. Arby (2019) discussed how the IoT can integrate solutions in a way that makes the whole process of urban passenger transportation more connected. An example made by Arby (2019) was to use smart watches or phones that you talk in order to arrange the most efficient journey using multimodality through AI. Although, this seem to be a future solution that needs more technological developments and a higher sense of connectivity between operators. However, it is a possible solution that shows the possibilities related to data and information sharing, making it easier and more efficient for urban travelers to move around in a city.

4.1.5 Legal Issues

In Gothenburg, most of the buses and trams are equipped with cameras. Cameras can in general provide important information about capacity and detailed information about the availability of handicap seats. In addition, cameras can be used as a tool to count passenger in order to test the accuracy of technological systems. However, according to Tammisto (2019) Västtrafik does not have access to the cameras installed in the vehicles. These cameras are strictly installed due to security reasons and access to the recordings will only be granted in the case of crimes or accidents. Tammisto (2019) state that this is a barrier for Västtrafik as cameras would have given them the opportunity to provide more reliable RTI to travelers on certain capacity aspects. The legal aspects of camera surveillance were also discussed with Matthews (2019) as all EU countries now have to follow General Data Protection Regulations when gathering personal data. Matthews (2019) said that the cameras used in MK Smart had to be in low resolution to make sure there could be no facial recognition. Conversely, when reading the GDPR regulations collecting data from cameras can be extremely challenging as also clothes can be considered a personal recognition making it almost impossible to use cameras in an efficient manner.

4.1.6 Mobility as a Service (MaaS)

According to Arby, MaaS is a concept that uses RTI in order to impact the travelling behavior of people. Arby defined MaaS as an integration of modes or services or both. He also added that Maas is not only a digital service, but a digital tool that enhances physical activities. According to Tammisto, the future of Västtrafik and public transportation will change and it will be based on the integration of systems and services. Specifically, Tammisto highlighted the need of integration of different transport providers and transport modes through one source of information. On that sense he added that MaaS will play a major role in the upcoming future.

On the other hand, Motta disagreed with the assumption that public transport will change in the future. He argued, that although there is a number of transportation options with different levels of prices and with different modalities, public transportation will continue to serve people with the same way as today. However, it is worth mentioning that all interviewees agreed that MaaS goes hand in hand with public transportation since most of the trips are and will be handled in the future via PT. So, regardless of whether PT will change, it will definitely have a key role within MaaS initiatives. Motta added that technologies can be used to essentially improve the integration between the different options and to make it easier for people to take decisions. Furthermore, Motta stated that private companies are not interested in serving rural areas, so public transportation will always be there to fill the gaps.

One of the biggest challenges of MaaS according to Arby is the cooperation with the different actors involved. There is a constant need from each actor’s perspective to have as much control as possible. However, in order to achieve a successful MaaS scheme, it is important to share resources and to give away some control. That will result in long term value and profitability of the MaaS cooperation, which according to Arby, not all actors realize. When discussing about UbiGo, Arby stated that its’ success lies on their ability to show the value of PT and the contribution to the development of cities in a sustainable way. He highlighted that UbiGo and MaaS in general do not aim to replace public transportation but to cooperate with them in order to incentivize citizens regarding car ownership. On that note, he stated that MaaS will never be the machinery, it will be the grease that the machinery needs in order to perform.

4.2 Questionnaire findings

In this section, the most important findings from the questionnaire survey will be presented: These findings have emerged by analyzing the responses of a sample of 158 citizens of Gothenburg. The authors obtained those responses in two ways. The first way was online distribution of the questionnaire through social media and student email via the University’s database. The second, was through a street survey in the city of Gothenburg. The researchers received 64 responses online and 94 responses via the street survey. The street survey took place in four different areas of Gothenburg from 29-31 of March 2019. More specifically, the authors spent approximately 2 hours on every location each day separately. The locations chosen for the survey, were the areas around Haga, Linneplatsen, Kungsportsplatsen and Lindholmen since they are considered central and crowded places.

In order to have a representative sample, the researchers wanted to include all the different target groups that live in the city of Gothenburg. Consequently, the aforementioned sample of 158 people contains a wide range of different ages, social status, people in a wheelchair, parents with children below 12 years old and so on. More specifically, 68 people were between the age of 18-34, 30 people between the age of 35-50, 30 people between the age of 51-69, and 30 people were above 70 years of age. On top of that, 15 people out of the 158 were people that were travelling with a baby wagon, 10 people were handicapped (wheelchair), 34 people had children below 12 years of age and 42 people were living in the suburbs.

4.2.1 The value of RTI for citizens in Gothenburg

The figure below (figure 7) depicts the responses of 158 citizens in Gothenburg, when asked how valuable RTI is regarding capacity of the tram/bus, location of the tram/bus, traffic jams/delays of the tram/bus, vehicle specific aspects, all possible transportation options from one specific location to another and estimated CO2 emissions emitted from each transportation mode.

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[1] Note: one respondent can belong to several target groups.
Example. Female 18-34 with young children.

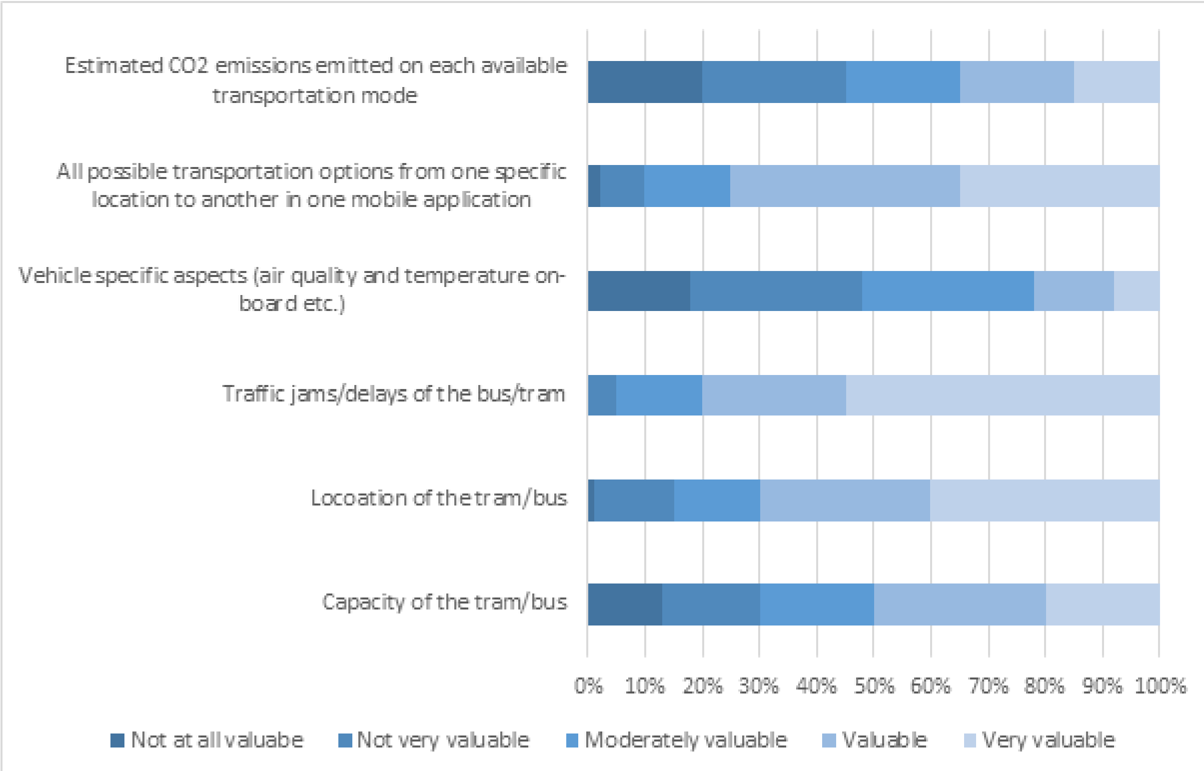

Figure 8; The value of specific RTI for travelers, Own work

Capacity of the tram/bus

50% of the total sample considers RTI regarding capacity “valuable” or “very valuable”. On top of that, 9 out of 10 people in wheelchair and 12 out of 15 people travelling with a baby wagon, value RTI regarding capacity substantially, since they consider that type of information as “very valuable”. In addition, 19 out of 34 people with children below 12 years old consider capacity “valuable”.

Location of the tram/bus

The researchers found that people in all target groups find this type of information important. More specifically 70% of the sample considers RTI regarding the location “valuable” or “very valuable”. However, the target groups noticeable interest was parents with children below 12 years old, people living in the suburbs and young people between the age of 18-35. Actually 26 out of 34 parents with young children, 30 of 42 people living in suburbs and 49 of 68 people in the age 18-34 considered this type of information “valuable” or “very valuable”.

Traffic jams/delays of the tram/bus

80% of the sample considers RTI regarding traffic jams or delays “valuable” or “very valuable”. With such a high number there was a evenly spread interest for this particular information among the different target groups, showing that this type of information is important to most travelers.

Vehicle specific aspects

Only 21% of the sample considers RTI regarding vehicle specific aspects such as air quality and temperature “valuable” or “very valuable”. That percentage consist mainly of people with children below 12 years of age and people above 51 years old. More specifically, 12 out of 34 people with children below 12 years of age and 14 out of 60 people above the age of 51 find that type of information important.

All possible transportation options from one specific location to another

75% of the sample considers RTI regarding all possible transportation options from one specific location to another in one mobile application “valuable” or “very valuable”.
There was an overall high interest for this particular type of information, with people in all target groups included in the 75%. However, people living in the suburbs showed a particular interest in that type of information with 35 out of 42 in this target group answering “valuable” or “very valuable”.

Estimated CO2 emissions emitted on each transportation mode

35% of the sample considers RTI regarding CO2 “valuable” or “very valuable”. The target groups 18-34 and 35-50 proved to show a particular interest in this type of information with 22 out of 68 in the group 18-34 and 16 out of 30 in the group 35-50 answering that they consider that type of information “valuable” or “very valuable”. The rest 65% of the respondents which consist mainly of people above the age of 50, finds this type of information either moderately valuable (20%) or not valuable at all (45%).

4.2.2 The preferred ways of receiving information

Another important aspect of the survey conducted in Gothenburg was to evaluate how travelers process information and in what way they want to receive information. The figure below (figure 8) are the results from the survey when participants was asked: “How do you want to receive real-time information?”

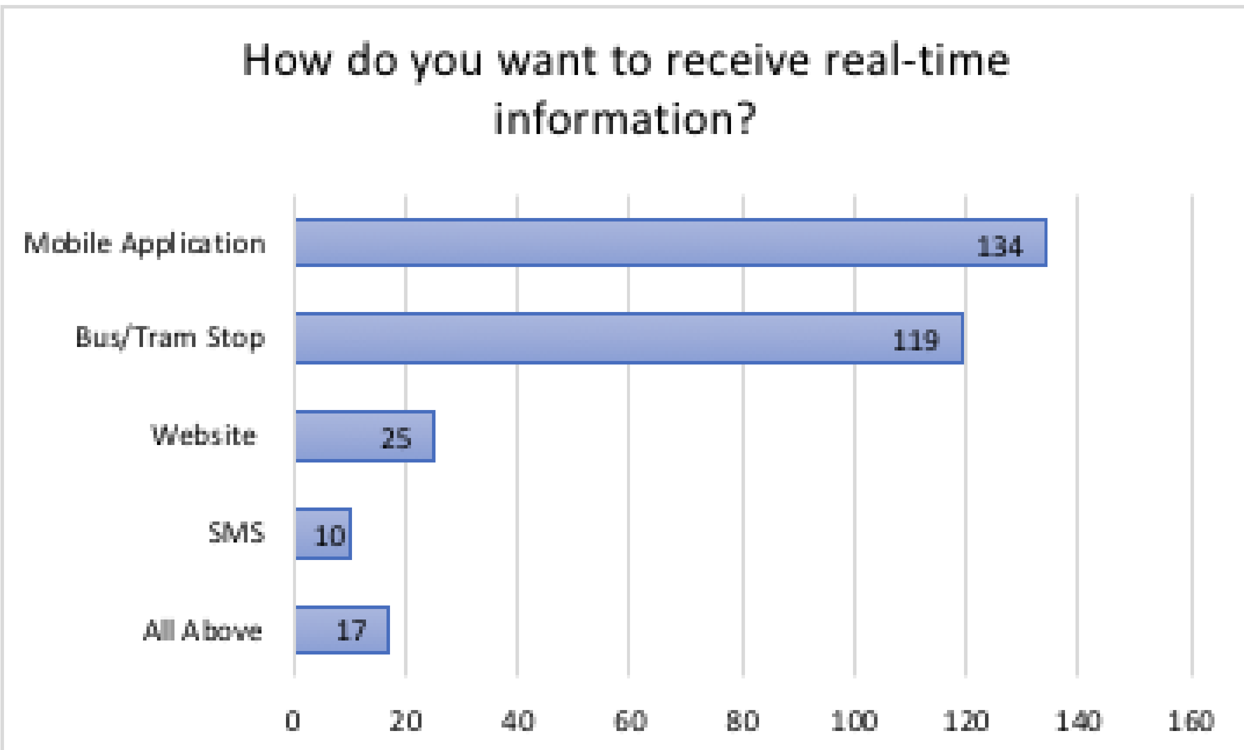

Figure 9; The preferred way of receiving RTI for urban travelers, Own work

Approximately 85% of the travelers asked in the survey answered that they want to receive through mobile applications, clearly showing that this is the most requested way to receive information. When looking closer at the numbers, the most astonishing findings from this question was that actually 68 out of 68 in the age 18-34 said that they want to receive information through mobile applications. Contrastingly, only 12 out of 30 in the age group above 70 answered mobile applications to this particular question.

4.2.3 The impact of information on traveling behavior

The figure below (figure 9) depicts the responses of 158 citizens in Gothenburg, when asked whether access to more RTI would influence their choice of transport mode.

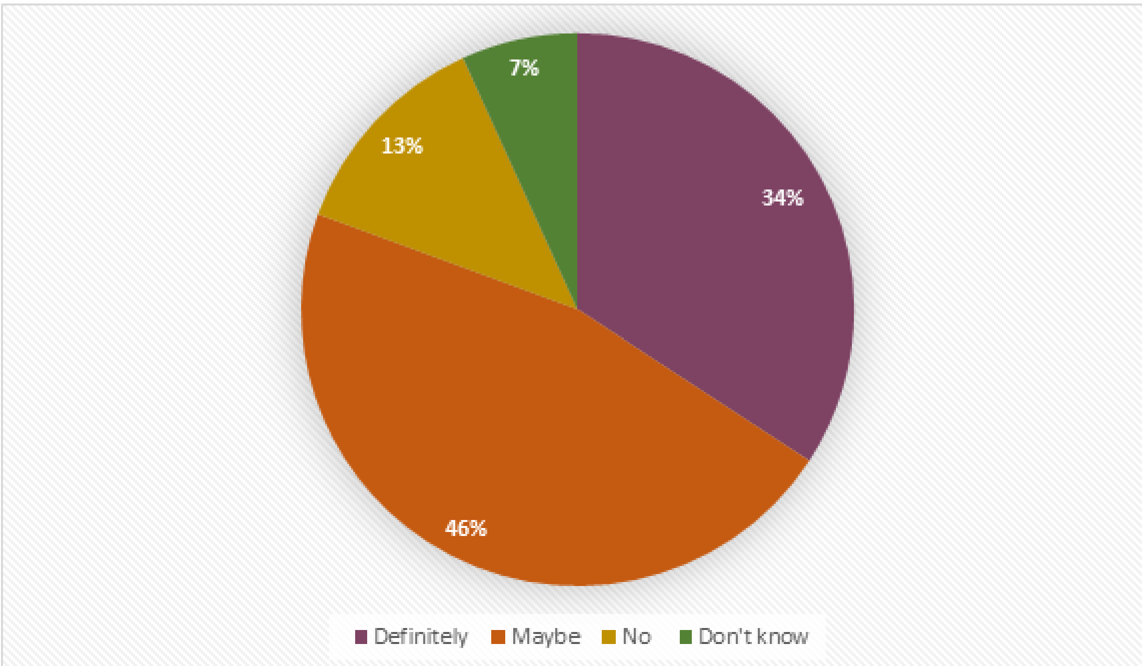

Figure 10; The impact of RTI on traveler behavior, Own Work

The findings above show that 34% of the whole sample thinks that increased access to RTI would influence their travelling behavior. It is worth mentioning, that out of the 34%, 28% were people between the age of 18-50. Among those, there are 8 people with baby wagon and 19 people with children below 12 years old. Out of the 10 people in wheelchair only 2 of them would change their travelling behavior if they had more access to RTI.

46% of the sample thinks that access to more RTI might have an effect on their choice of transport mode and consequently on their travelling behavior. That category includes all the different target groups who seemed to be positive but not very certain.

13% of the sample thinks that access to more RTI would not have any effect on their travelling behavior. That category is represented mainly by people above 70 years of age. Specifically, 17 out 30 are certain that access to RTI would not influence their choice of transport mode.

Lastly, 7% of the sample was unsure whether increased access to RTI would impact their travelling behavior. That percentage in mainly represented by people living in the suburbs (8 out of 42).

Furthermore, when people were asked whether increased access to RTI would influence their choice of transportation towards more sustainable modes they responded as shown below (figure 10):

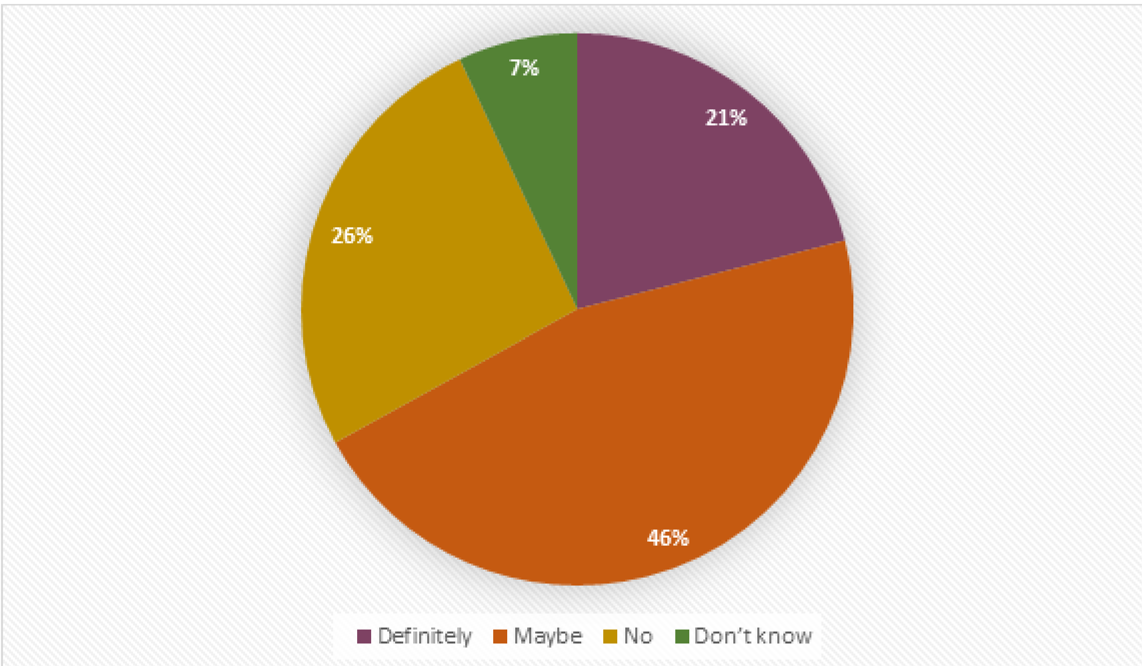

Figure 11; The impact of RTI on sustainable traveler behavior, Own work

From the above figure, it is clear that the percentage of the people who answered "Don't know" is still 7%. In addition, the percentage of the people who answered "Maybe", still remains at 46%. However, an interesting point is that the percentage of the two opposite opinions ("Definitely" and "No") is very different. The percentage of people who answered "No" (26%) is higher than those who answered "Definitely" (21%) and is substantially different from the results presented in figure 9. The 21% (Definitely) is mainly represented by people between 18-34, since 29 out of 68 people from that target group think that increased access to RTI would change their travelling behavior in a more sustainable way. The 26% (No) is mainly represented by people from 51 years old and above. More specifically, 35 out of 60 people in that target group think that more RTI would not influence their choice of transportation towards more sustainable modes.

4.2.4 Personalized Information

The last question on the survey was a question that gave the participants the opportunity to add personal opinions about information sharing aspects in transport system. The question “Other than discussed, is there any other information that would be valuable to you when travelling in Gothenburg?” was asked in order to ensure that the respondent’s additional remarks could be recorded in a non-restrictive way also after answering all the specific questions in the survey. The findings from this particular question showed that in the age group 18-34 many of the respondents touched upon the subject of more personalized solutions, answering that more personalized information in real-time is important to them.

4.3 Findings from the Questionnaire survey in Gothenburg by UbiGo

As described in chapter 2.5 and 4.1.2, a company named UbiGo has recently launched a mobility application which combines public transport, car-sharing, rental car services and taxi to one intermodal on-demand mobility service. It is based on a flexible monthly subscription with an account that is shared among all members of a household, easy to top up and with the option to save what has not been used to the next month. Before officially launching the application, UbiGo did a very successful and thoroughly evaluated MaaS pilot project with 70 paying households in 2014 in Gothenburg during a period of 6 months.

So, the findings from this pilot survey were consequently used to successfully launch the application. In addition, this pilot survey is particularly interesting for the current researchers since the findings/results from this survey are highly interlinked with RTI and travelling behavior which is the main focus of this paper. More specifically, those findings will enhance the researchers to answer RQ1 and establish a connection between RTI and travelling behavior.

The aforementioned findings from this survey are stated below:

- People find it easier to pay for the travel
- The service has given them better control of their travel expenditures
- The service has given them access to more modes of travel.

In addition, after using the service the findings show the following:

- 50% have changed mode of transport
- 40% changed the way they plan trips
- 25% changed the “travel-chains”
- 30% did not change their travels

The results, also indicate that people changed their travelling behavior towards more sustainable transport modes:

Table 1

UBIGO

Travel diaries (all respondents, all trips)

Mode	Before UbiGo	Change with UbiGo
(Walk/run	~25%	Decrease ~5%
Private car	~25%	**Decrease ~50%**
Tram	~15%	Increase ~ 5%
Local bus	~15%	**Increase ~35%**
Bicycle	~10%	**Increase ~35%**
Regional bus	~ 3%	Increase ~100%
Train	~2%	Increase ~ 20%
Car sharing	~2%	**Increase ~200%**

UbiGo - Travel Diaries, (UbiGo Survey, 2014)

The above table, shows a substantial increase of the use of trams, busses, bicycle, trains, and car sharing schemes and a substantial decrease of the use of private cars which is a remarkable sustainability achievement.

When it comes to the long-run success of the service, 50% of the respondents say that the changed behavior will remain, 32% say that the changed behavior will remain under specific circumstances related to the ease of use of the service and 17% say the changed behavior will not remain due to moving which results to limited access to UbiGo on a daily basis.

5. Discussion & Analysis

In this chapter we will analyze the data gathered with the goal of answering the research questions developed. With this goal, initially, we will evaluate the different findings from the interviews, the questionnaire survey and UbiGo's pilot survey in Gothenburg. Concurrently, the aforementioned findings will be compared with the findings from the literature review and finally the complexity, barriers and benefits will be thoroughly analyzed.

5.1 Impact of Real-Time Information on traveler's behavior in Gothenburg

The first research question of this paper was formed in order to understand in a clear way the possible connection between access to RTI and travel behavior of people in Gothenburg. The findings from the questionnaire survey and UbiGo's pilot survey compared to the findings from an extensive literature review show that there is indeed a close connection between the 2 parameters. The results from the questionnaire survey, indicate that the majority of the citizens living in Gothenburg have a substantial interest in accessing different types of RTI. On top of that, when asked whether access to more RTI would influence their choice of transport mode 34% said "Definitely" and 46% were positively skeptical by replying "Maybe". Throughout the literature review, there seems to be common views and findings by the researchers, that show the importance of the provision of information from a passenger's point of view. Findings from Daskalakis & Stathopoulos, 2008 show that increased accessibility to information can assist in decreasing both the actual and the perceived waiting time. In addition, the connection between RTI and travel behavior is also confirmed by Meng et al. (2015) who have showed that increased amounts of integrated traveler information could enhance the commuters' mode switching propensity and that disseminating traveler information does influence the mode choice behavior. Those findings are also in line with Brakewood et al. (2018) who identifies the behavioral impacts of RTI in public transportation through reductions in travel time due to changes in path choice and through increase on transit use. Another practical example was implemented by Pronello et. al., (2016) who explored the effects of real-time multimodal information on travel behavior. Their study shows substantial decrease of car use, use of alternative routes and a shift from car to bike and PT after increased access to RTI.

UbiGo's pilot survey also provided valuable insight that enhanced the current researchers to define the above connection. According to UbiGo, the results from the pilot survey, indicate that people changed their travelling behavior in terms of changing transport mode, the way they planned their trips and also by choosing more sustainable transport modes. On that note, Arby added that increased access to RTI has indeed a great impact on the travelling behavior of people in Gothenburg. When discussing about discretional/spontaneous journeys Miles also highlighted that RTI in connection to decision making is at its most valuable since people find travel time and transport options information crucial. He also added that RTI affects the different actors in different ways by making a comparison to shopping mall owners and shopping mall customers in connection to RTI regarding the capacity of the tram. That type of information according to Miles have a different effect on those two target groups as explained in section 4.2.

5.2 Real-Time Information – what, when, where, how

Regarding the second research question of the study the aim was to evaluate what information that is important to travelers and how travelers want to receive information. When providing customers with information it is always important to understand what type of information that is interesting for the customer. Furthermore, to avoid information overflow, it is vital that you understand when, where and how the customers want to receive this information.

The importance of traveler's demand for information was discussed by Harmony et al. (2017) who stressed that there is a gap between information demand (what type of information is desired) and information supply (what type of information is actually provided to transit users) in urban transportation. The study showed that information specifically about vehicle location is important to customers. However, this study was conducted on a more general level, not providing results on different demographics. The importance of demographics was pointed out to be relevant by Xavier et al. (2017) whose research showed that for example older travelers were much less likely to want increased amount of information as it in this target group was considered information overload.
Such findings prove the complexity surrounding information sharing, as it shows that people with different demographic background tend to demand different type of information.

The complexities related to information sharing and the different demand from different demographic groups led the researchers to point out specific demographic groups when conducting a survey with specific questions related to information demand in Gothenburg. The results from this survey was highly interesting as it clearly showed that people in different ages and with different socioeconomic backgrounds in fact does demand different type of information.

A particularly interesting finding from this survey was regarding capacity onboard the vehicles. The survey showed that only 50% out of the 158 participants found information about capacity to be “valuable” or “very valuable”. However, when asking if information about capacity was valuable to travelers in a wheelchair or with a baby wagon the percentage answering “valuable” or “very valuable” was significantly higher with 90% of travelers in a wheelchair and 80% of travelers with a baby wagon answered that this type of information is “valuable” or “very valuable”, proving that there is a noteworthy difference in information demand between different groups of people. Several other specific findings pointed out in the empirical findings of this thesis support the theory of a gap between information demand and information supply in public transportation.

When conducting the survey in Gothenburg the researchers also wanted to get a better understanding of how travelers want to receive information. The results from this particular question clearly showed the power of digitalization. 100% of travelers between 18-34 years of age and 85% of the total participants answered that they want to receive information through mobile applications. This was the most popular answer, beating information at boards on bus and tram stops. Such findings prove that travelers now demand digital information flows instantly, when needed. Furthermore, the survey included the following open-ended question at the end: “Other than discussed, is there any other information that would be valuable to you when travelling in Gothenburg?” Several of the answers coming out of this particular question touched open more personalized digital solutions. Answers such as: “Personalized daily city transport information should be available on apps” and “push messages when there are disruptions on my daily routes” further prove that people demand better information flows between provider and user. To solve these demands, it becomes vital for transport providers to increase the level of connectivity and offer more personalized services.

This particular issue was discussed with several experts during the research of this project. Both Matthews (personal communication, 19-02-2019) and Motta (personal communication, 25-03-2019) stressed the importance of providing relevant information, as this is extremely important to avoid information overload. However, with advanced technologies emerging combined with a high sense of digital connectivity the possibilities to provide travelers with more personalized information through advanced traveler information systems occur. The possibilities related to more advanced traveler information systems has been discussed by Raju et al. (2017) who proposed a system providing travelers with more detailed information. This has been backed up by Dotoli et al., 2017 who has proposed a more advanced system giving travelers more power to choose. This leads towards a more connected transportation system where the user will have more power than before. The ecosystem is changing as stated by Högenberg (personal communication, 12-04-2019), meaning that transportation providers must give travelers the opportunity to decide what, when, where and how to receive information. Customizing service solutions to suit each individual will become more important for public transportation providers in order to offer travelers attractive services in the future.

5.3 Barriers to increased information sharing

The third research question in this thesis was developed in order to understand the barriers preventing transport providers from providing travelers with more detailed RTI than they do today. As discussed in earlier chapters, the main barrier to increased sharing of RTI is the GDPR regulations that control how companies can collect data. This makes it more challenging for transport providers to collect the data needed to develop their services. However, as travelers want more personalized services transport providers get the opportunity to collect data needed through for example applications where users can give an affirmative consent for specific use of personal data. The key for transport providers therefore becomes to make sure users understand that by accepting such terms, they will receive better and more personalized services that can possibly solve some of the concerns related to public transport today. This was also emphasized by Thomas (2019) who stressed the importance of openness between providers and users with such regulations present.

The impact of GDPR was further discussed with Tammisto (2019) who pointed out how GDPR impact how video cameras are being used in Gothenburg. The regulations make it almost impossible to collect data from video-surveillance, something that can be considered a big barrier to providing RTI related to capacity on vehicles. However, such barriers can possibly be solved by using sensors to count passengers who are going on and off the vehicle and in addition specific sensors that count availability of space at seats for people with special needs can be implemented (wheelchair, baby wagon etc.). Furthermore, as discussed by Elkosantini et al. (2013) another possible solution to such challenges can be intelligent image detection systems able to recognize and count on board passengers. Although, if such systems are to be implemented it is very important that it does not violate any rules or regulations.

Another barrier preventing transport providers from providing travelers with increased access to RTI is the cooperation between the different actors involved. The difficulty of creating synergies is a fact that was discussed by most of the interviewees as well. More specifically, Arby highlighted the constant need from each actor's perspective to have as much control as possible. The risk of losing control over their own company, clients or patents prohibit many actors to engage into synergies and form business collaborations. Those synergies are especially important when providing travelers with increased RTI, since it requires different actors from different businesses to work together. In the case of Gothenburg, transport providers, Gothenburg's Business Region, law-makers, private companies who own data such as mobile companies and so on, need to cooperate in order to create value for the end user. However, according to Arby, not all actors realize the long-term value and profitability of those synergies, and the risk of losing control poses one of the greatest obstacles to move forward. On top of that, even if the risk of losing control is mitigated, a long-term collaborative relationship between different actors requires an alignment of values, moral and ethical standards which makes the whole venture even more challenging.

Besides the loss of control, the ever-conflicting goals and needs of the different actors are also prevalent. Miles made a comparison between shopping mall customers and shopping mall owners, stressing that these groups might have conflicting interests when it comes to information sharing. In example, access to RTI regarding the capacity of a tram that goes to a shopping mall can in many cases indicate how busy the shopping mall is as well. That type of information might be an offset towards the first group to take the tram and visit the mall which will contradict the needs of the shopping mall's owners. In that case, increased access to RTI in not beneficial for a large group of stakeholders in a city which may pose barriers to transport providers in terms of making a decision among the different trade-offs.

6. Conclusions, Future Recommendations and Limitations

In this chapter the conclusions drawn from this study will be presented together with future recommendations for urban transportation providers, as well as recommendations for future research on this particular topic. Furthermore, limitation regarding the research conducted will be discussed.

6.1 Conclusions

This research aimed at exploring and identifying if increased access to RTI has an impact on the travelling behavior of people in Gothenburg. On top of that, the researchers aimed on contributing with valuable information to urban transportation providers and stakeholders in order to enhance the development of more efficient systems suited to deal with the increased urbanization and the negative impact in terms of congestion and pollution. For this purpose, three research questions were formulated: does access to RTI affect travel behavior of people in Gothenburg; what information is important for travelers and how do travelers want to receive information; and what are the barriers preventing transport providers from providing travelers with increased access to RTI.

Regarding research question 1, “does access to real-time information affect travel behavior of people in Gothenburg”, a questionnaire survey was carried on. The findings from the questionnaire combined with the findings from UbiGo’s pilot survey, the literature review and the interviews were used in order to establish the connection between those variables. Throughout this report, it was possible to observe the validity of the above connection that goes hand in hand with the importance of the provision of information from a traveler’s perspective. Even though the findings from the questionnaire survey compared to the findings from UbiGo’s pilot survey have some discrepancies related to RTI and people’s sustainability behavior, both of them confirm that there is possible relationship between increased access to RTI and travel behavior. This is based on the overall study and the specific question asked to travelers in Gothenburg that showed that only 13% out of 158 people answered “no” when asked if increased access to RTI would influence their traveler behavior. Furthermore, this was backed up by the UbiGo survey where 50% of the participants changed their transport mode when being exposed to increased information about travel options. However, the research also shows that even though influencing traveler behavior can be done through increased information sharing, influencing traveler behavior towards more sustainable transport modes might be more challenging. That was clearly proved when comparing figure 10 and figure 11 in chapter 4 that was developed in order to compare the impact of RTI on traveler behavior and sustainability. When asking travelers if increased access to RTI would influence their traveler behavior towards more sustainable transport modes 26% out of 158 answered "no".

Research question 2, "what information is important for travelers and how do travelers want to receive information" was approached in different ways: initially, the research explored the different types of information that is important to travelers. RTI regarding capacity, location, traffic jam delays and information about all transportation options from one specific location to another in one mobile application seemed to be valuable among respondents. However, the research indicates that the type of information demanded by travelers differed according to age and the socioeconomic background. On that note, RTI about capacity was valuable to travelers in a wheelchair or with a baby wagon but not that valuable to other target groups. Those differences and discrepancies point out the importance of personalization and the gap between information demand and information supply. Concurrently, the preferred ways to received that type of information were identified. The importance of digitization seems to be prevalent since the largest portion of the respondents would like to receive information through mobile applications, far ahead from receiving information on boards on tram and bus stops, SMS and websites.

Research question 3, "what are the barriers preventing transport providers from providing travelers with increased access to real-time information" was approached in two ways: legal barriers and collaborative barriers. The research shows that GDPR regulations pose challenges for transport providers in terms of collecting and processing data to enhance and develop their services. However, findings from the literature review and findings from the interviews indicate that such barriers can be addressed through intelligent image detection systems and sensors which have the ability to recognize and count on-board passengers. This shows that even though transport providers are faced with legal barriers there are several new technologies that can be utilized to cope with such challenges. Furthermore, collaborative challenges were also recognized as a barrier, preventing transport providers from providing travelers with increased access to RTI. The difficulty of creating synergies between the different actors that would result in long term value for the traveler is attributed to the risk of losing control, different conflicting goals and needs of the various stakeholders.

6.2 Future Recommendations

Throughout this paper the impact of information sharing on traveling behavior has been evaluated in depth. Furthermore, how travelers want to receive information valuable to them and the barriers to provide such information has been analyzed in order to build extensive knowledge on the subject. Based on this research, recommendations for the future can be made.

First of all, with the findings in this thesis proving a possible positive connection between access to information and traveling behavior it becomes important that transportation providers understand the value of information for travelers. The research conducted show that people have a high demand for personalized real-time information in order to maintain efficiency when moving around urban areas. To be able to respond to such demands one possible future solution can be to utilize data and AI to develop digital services that are able to adapt to each individual personal demand. This can be achieved through more advanced digital applications that provide users with more personalized information than what they receive today. Such services should be developed with the goal of responding to each users' personal demand. Developing such services can be expensive in the cases where new technologies have to be tested and installed. However, with many urban transport providers already sitting on enormously amounts of data, figuring out how to utilize this data is vital in order to develop sustainable solutions in areas facing high amounts of urbanization in the future.

Another way of achieving a higher degree of personal adapted services is to focus more on connectivity between different actors, meaning a more collaborative approach must be considered. One potential solution can be to move towards MaaS as a future solution in urban areas, giving the users the freedom to choose more efficiently and freely. First, future research on how to more efficiently use service innovations to develop more attractive urban transport systems is needed to fill the gap between service providers and users in today´s urban transport systems. For example, research on how public transport more efficiently can develop collaborations with other parties in order to offer more attractive services to travelers can be considered important not only in Gothenburg, but also globally. Furthermore, additional research on the possible impact of AI on urban transport, information sharing and data processing is needed to gain further knowledge on the future possibilities of AI in urban transport.

A third suggestion for future research would be to study how to utilize data more efficiently in order to develop more dynamic transport networks, rather than the fixed system present in Gothenburg today. It would be interesting to see if a more dynamic model could increase the fill rate on for example buses and consequently develop a more sustainable service. In addition, more dynamic solutions can be developed in order to combine passenger and freight transport on particular networks where such solutions are valuable.

6.3 Delimitations & Limitations

The findings of this study have to be seen in the light of some delimitations and limitations. First of all, the survey conducted is limited to Gothenburg and the findings might not be relevant to other urban areas that offer travelers different type of services than what is present in Gothenburg. Furthermore, 68 out of the total 158 participants in the survey was in the age 18-34 giving the overall result of the findings a very positive view on innovative technological solutions, however the high weight of young people might not represent the overall picture. In addition, the fact that 64 of the participants in the survey was from online distribution and 94 was from the streets in Gothenburg might have a slight impact on how the respondents answer each question. Furthermore, the findings from the interviews have some small limitations as well as the researchers were not able to get an interview with an expert within the field of law. This would have been important to further gather data to analyze the legal aspects of the thesis, specifically related to RQ3. It also has to be mentioned that as with many university research papers there are limitations present related to budget and time.

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Appendices

Appendix 1 – Questionnaire Survey

What is your age?
18-34
35-50
51-69
70+

Are you:
Student Employed Unemployed Pensioner

Do you have young children (below 12)?
Yes
No

Which situation describes you best?
Individual using a wheelchair
Parent with baby-wagon
None of the above

Do you live in the city of Gothenburg or suburbs of Gothenburg?
City
Suburbs
Other

Do you have access to a car?
Yes
No

How do you usually move around the city? (tick all that apply)
Bus
Tram
Private car
Taxi, Uber etc.
Train
Bicycle
Walking

How often do you use your car in the city Gothenburg?
Everyday

Three days a week or more
Once a week
Once a month or more
Never

When choosing car, what is the reason for this? (tick all that apply)
Convenience
Price
Safety
Time-efficiency
Reliability
Other

How often do you use Public transportation in the city Gothenburg?
Everyday
Three days a week or more
Once a week
Once a month or more
Never

When choosing public transportation, what is the reason for this? (tick all that apply)
Convenience
Price
Safety
Time-efficiency
Reliability
Other

How satisfied are you with the overall information provided by Västtrafik?
Very satisfied
Satisfied
Not satisfied
Don't know

How do you want to receive real time information? (tick all that apply)
Application
Websites
SMS
Bus/tram stops
All the above

Do you feel the timings provided in the app and on the signs at stops are accurate?
Very accurate (Always on time)

Accurate enough (Within 1 minute +/-)
Not very accurate (Often delays of 2+ minute)

Do you feel routes proposed in the app “Reseplanerare” is accurate?
Very accurate
Accurate enough
Not very accurate

Over the last year, do you think that the reliability of travel <u>by bus</u> has:
Improved
Remain the same
Worsened
Don’t know

Over the last year, do you think that the reliability of travel <u>by tram</u> has:
Improved
Remain the same
Worsened
Don’t know

Over the last year, do you think that the reliability of travel <u>by train</u> has:
Improved
Remain the same
Worsened
Don’t know

How well do the following statements describe you when making travel choices in Gothenburg ? (rate from 1 to 5)

Real-time information regarding the capacity of the bus/tram is valuable for me
0 0 0 0 0 (5 being most valuable)

Real-time information regarding the location of the bus/tram is valuable for me
0 0 0 0 0 (5 being most valuable)

Real-time information regarding traffic jams/delays of the bus/tram is valuable for me
0 0 0 0 0 (5 being most valuable)

Real-time information on vehicle specific aspects (air quality and temperature onboard etc.) is valuable for me
0 0 0 0 0 (5 being most valuable)

Real-time information on all possible transportation options (bus, trams, trains, bicycles, car sharing schemes/uber etc) from one specific location to another in one mobile application is valuable for me

0 0 0 0 0 (5 being most valuable)

Real-time information on estimated CO_2 emissions emitted on each available transportation mode (bus, trams, trains, bicycles, car sharing/uber etc) is valuable for me
0 0 0 0 0 (5 being most valuable)

Would access to more real-time information influence my choice of transport mode?
Definitely
Maybe
No
Don't know

Would access to more real-time information influence my choice of transportation towards more sustainable modes (tram/bus/bicycle/walking etc)?
Definitely
Maybe
No
Don't know

Other than discussed, is there any other information that would be valuable to when travelling in Gothenburg?
Please specify:

Appendix 2 – Date of Interviews Conducted

- John Wedel: January 30th, 2019
- Hannes Lindkvist: February 12th, 2019
- Jari Tammisto: February 12th & March 15th, 2019
- Brian Matthews: February 19th, 2019
- Professor John Miles: February 20th, 2019
- Enrico Motta: March 25th, 2019
- Hans Aarby: March 27th, 2019
- Martin Högenberg: April 12th, 2019