Five empirical essays on the user perspective of the public transport ticketing system: understanding effects, attitudes, and behavioural response to ticketing improvements

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INTELLECTUAL PROPERTY AND PUBLICATIONS

The candidate confirms that the work submitted is his own, except where work which has formed part of jointly-authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

LIST OF PAPERS

The work presented in Chapter 2 through to Chapter 6 of this thesis appeared in the following five papers.

I. Alhassan, I.B., Matthews, B., Toner J. P., and Susilo Y. O. 2019. Revisiting public transport service delivery: exploring rail commuters' attitudes towards fare collection and verification systems. EJTIR 19(4), 2019, pp. 310-331. https://journals.open.tudelft.nl/ejtir/article/view/4283

II. Alhassan, I.B., Matthews, B., Toner J. P., and Susilo Y. O. 2020. Seamless ticket inspection: Proposing and exploring users' reaction to a next generation public transport ticket inspection solution (Submitted).

III. Alhassan, I.B., Matthews, B., Toner J. P., and Susilo Y. O. 2020. The Movingo integrated ticket: seamless connections across the Mälardalen region of Sweden, Transportation Planning and Technology. https://doi.org/10.1080/03081060.2020.1747204

IV. Alhassan, I.B., Matthews, B., Toner J. P., and Susilo Y. O. 2020. Public Transport Users' Valuation and Willingness-to-pay for a Multi-region and Multi-operator Integrated Ticketing System (Submitted).

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MY CONTRIBUTIONS TO THE PAPERS

Under the guidance of the co-authors as my doctoral studies supervision team, I took the main responsibility for all stages in the research - the literature review, research conception, survey design, fieldwork, data processing, empirical data analysis, interpretation of the results, preparation and editing of all the manuscripts included in this thesis. All the co-authors were all actively involved in most stages of the research, particularly, in the review of the results and approval of the final versions of the manuscripts. The only stages where they were not directly involved were the fieldwork and data processing stages.

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Abstract

Public transport (PT) plays a key sustainability role in society due to its significant economic, social and environmental benefits, stemming from the extent of its ridership. Fare policies, often implemented by means of a ticketing system, and service quality help service providers to manage PT ridership. Ticketing thus constitutes the interface between the user and the PT service and adds to the generalised cost of the PT service, thus impacting PT service quality. Yet, very little is known about users' attitudes towards the PT ticketing system and their behavioural response to ticketing system improvements such as integrated ticketing, which is a current PT policy focus area globally due to highly deregulated PT markets, multimodalism, fast urbanisation and regionalisation of PT systems. The overall aim of this doctoral research, characterised by five related research papers, is therefore to contribute to the knowledge on commuters' attitudes to the PT ticketing system and their behavioural response to integrated ticketing. Consequently, an inter-disciplinary psychological and economic approach to understanding behaviour was adopted. Using the Movingo multi-region and multi-operator integrated ticketing scheme in Sweden as a case, three questionnaire surveys were conducted along the corridor with the largest proportion of cross-county commuting in Sweden, Stockholm – Uppsala. Subsequently, exploratory statistical and discrete choice modelling methods were used to analyse the samples. The findings suggested that: a). PT commuters' attitudes to ticketing was influenced by income, commuting route, ticket type and ticket purchase channel. They accepted fare payment more than fare inspection and they showed preference for automatic fare inspection, particularly seamless ticket inspection. b). integrated ticketing increased user satisfaction and made rail commuting attractive to car commuters but did not necessarily improve the overall perceived quality of ticketing due to interoperability challenges. c). users' valuation of integrated ticketing is at least 26% of the average season ticket price. Non-commuters' valued it higher than commuters and males valued it higher than females. d). integrated ticketing has a positive effect on mode choice due to its synergistic effects. The study highlights some policy implications and recommends further research.

Keywords: *Attitudes, behavioural response, fare collection, integrated ticketing, commuters, fare verification, mode choice, public transport, ticket, willingness-to-pay.*

Abstract in Swedish (Sammanfattning)

Kollektivtrafik spelar en viktig hållbarhetsroll i samhället. Dess pris och servicekvalitet är utbudsfaktorerna som styr mot dess operativa och hållbarhetsmål. Kollektivtrafikbiljettsystemet som ett medel för att aktualisera prissättningen är ett viktigt gränssnitt mellan kollektivtrafiktjänsten och kunden. Biljettkravet i kollektivtrafiken som en börda (disutility) för resenären har inte varit ett föremål för detaljerade studier. En generell slutsats skulle dock vara att kravet i allmänhet utgör en nackdel för kollektivtrafikresenären jämfört med en bilresenär, eftersom biljetten inte är ett mål i sig själv utan ett krav för att kunna åka kollektivt. Förbättringen av biljettsystemet har då blivit ett fokusområde. Ändå är kunskapen om kollektivtrafikkundernas och icke-kundernas attityder och värderingar av biljettsystemet och dess integreringsfrågor på en relativt låg nivå. Det övergripande syftet med denna doktorandforskning, som kännetecknas av fem forskningsartiklar, är därför att bidra till kunskapen om kundernas attityder till betalningsmöjligheter och biljettkontroll samt deras värderingar av biljettintegrering. Med det Movingo integrerad periodbiljettprojektet i Stockholm-Mälardalsregionen som ett studiefall, genomfördes tre enkätundersökningar längs stråket Stockholm - Uppsala. Därefter användes bl.a. diskreta modelleringsmetoder för att analysera stickproverna. Resultaten tyder på att: a). inkomst, pendlingsstråk, biljettyp och biljettköpskanal är bland faktorerna som påverkar Kollektivtrafikpendlares attityder till biljettsystemet. Kollektivtrafikpendlarens inställning till betalningsmöjligheterna är mer positiv jämfört med hur biljetterna kontrolleras. De visade preferens för automatisk biljettkontroll, särskilt sömlös biljettkontroll. b). biljettintegreringen ökade kollektivtrafikresandet, kundnöjdhet och gjorde kollektivtrafiken mer attraktiv för bilpendlare. Men den upplevda kvaliteten av biljettsystemet förbättrades inte på grund av interoperabilitetsutmaningar. c). användarnas värdering av ett integrerat biljettsystem var minst 26% av det genomsnittliga integrerade måndsbiljettpriset. Icke-pendlare värderade biljettintegreringen högre än pendlare och män värderade den högre än kvinnor. d). biljettintegreringen har en positiv effekt på färdmedelsval och därmed ökar kollektivtrafikens konkurrenskraft. Studien belyser ett antal utvecklingsmöjligheter och rekommenderar ytterligare forskning.

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List of acronyms and abbreviations

ETI: Extent of PT Ticketing Integration

MNL: Multinomial Logit Model

MNML: Multinomial Mixed Logit Model

NL: Nested Logit Model

PT: Public Transport

PTA: Local Public Transport Authority

PTSP: Public Transport Service Providers

PQ: Perceived Quality

RP: Revealed-preference

SKL: Swedish Association of Local Authorities and regions

SKT: Association of Swedish Public Transport

SL: The Stockholm County Public Transport Authority

SP: Stated-preference

SQ: Service Quality

CLT: Central Limit Theorem

UL: The Uppsala County Public Transport Authority

List of Terminology

Access to PT:	Defines people's ability to easily reach opportunities such as goods, services and destinations by PT.
Access to PT tickets:	An integral part of the broader concept of accessible PT systems that focuses on the ease of obtaining PT tickets to give people the legal right and opportunity to use a PT service.
PT system integration:	The process of integrating all major parts of the PT service such as networks, fares and ticketing, information, modes and transfers with the aim of achieving synergy and removing barriers.
Seamless travel:	The product of a well-integrated PT system as experienced by users.
Price:	The exchange value of a good or a service
PT price:	The exchange value of a PT journey.
PT fare:	The out of pocket cost of a PT journey.
PT fare policy:	All the principles, goals and constraints that are considered by service providers in setting and collecting fares.
PT Fare structure:	The pricing structure that allows PT service providers to set and collect fares.

Ticketing system: A tool for putting a PT fare policy into action and basically consists of two major function - fare payment & fare verification functions.

Smart ticketing: Innovative solutions to old forms of PT ticketing mainly driven by technology and user needs.

Ticketing disutility: The generalised cost or full price of the PT ticketing process to users.

Ticketing improvement: Any measures taken by a PT service provider to reduce ticketing disutility to users.

Integrated Ticketing: An aspect of transport system integration and smart ticketing that makes multimodal passenger transport services accessible to users by combining the ticketing and fare systems of the different travel modes involved.

Multi-operator ticketing integration or seamless ticketing (the gift of Seamless connections across different PT modes): An arrangement among PT service providers that makes multimodal PT services accessible to users by permitting them to use the same ticket on every part of the same journey regardless of the ticketing media or geographic boundary.

Extent of Ticketing Integration: Defines the number of PT operators involved in a given multi-operator ticketing integration.

Level of Ticketing Integration: The geographical extent of a given ticketing integration.

Commuters: People such as workers and students who travel to the same destination on regular basis.

Commuter's ticketing attitude: The extent to which a commuter holds a favourable or unfavourable evaluation of a PT ticketing system. I.e. the perceived quality of a given ticketing system.

Part I: Introduction to the Thesis

Chapter 1
General Introduction

Public transport or mass transit (PT) fare policies are usually implemented by means of a ticketing system. The ticketing system, which then constitutes the interface between the user and the PT service demands some time and effort from users. This demand increases the generalised cost of the PT service (i.e. the full price of the PT service to the user). An extensive review of existing works on PT ticketing suggests that little is known about users' perceptions and attitudes to the PT ticketing system as well as their behavioural response to ticketing innovations. The overall aim of this doctoral research is therefore to empirically contribute to the state of knowledge on PT users' attitudes to fare payment and inspection systems as well as their behavioural response to integrated ticketing. This contribution provides novel information for both practitioners and researchers that are concerned with improving PT ticketing systems, cost-benefit-analysis of integrated ticketing schemes, and incorporating the effects of ticketing improvements in travel demand analysis.

This chapter provides a general introduction to the research and is organised as follows. Section 1.1 presents the background. Section 1.2 covers a general review of ticketing and its integration. Section 1.3 provides the research justification. Section 1.4 provides a literature review and explains the research gaps. Section 1.5 outlines the research objectives. Section 1.6 provides the scope of the research. Section 1.7 covers the study approach. Section 1.8 presents the outline of the thesis and the research contributions.

1.1 Background

The triple bottom line concept of environment, economy and society is the fundamental concept in the application of sustainability to transportation (Miller et al., 2016). The transport literature is well stocked with evidence confirming that PT plays a key sustainable transport role due to its significant economic, social and environmental contributions to society (Stjernborg and Mattisson, 2016; White, 2009; Kol-TRAST, 2012; FHWA, 2014; Miller et al., 2016; Enoch, 2012). Some of the economic benefits of PT include increased productivity, minimising the cost of urban traffic congestion, increased property values, and the provision of employment opportunities (Goldsmith, Killorin and Larson, 2006). Major social benefits of PT include social inclusion such as improved mobility for low-income groups, unemployed, elderly and people with disabilities, less traffic accidents, public health benefits, access to jobs, education, health care, and recreation (Kol-TRAST, 2012, Rye and Mykura, 2009, Markkovich and Lucas, 2011). PT is a key alternative mobility tool to the private automobile and thus has many environmental benefits such as less resource and energy intensiveness, less air pollution, reduced carbon emissions, reduced road traffic congestion and travel time in high population density areas (Farzaneh et al., 2019).

In Sweden, the focus geographic area of this doctoral research, a long-term sustainable transport system is the focus of the national transport policy goals (Prop. 2008/09:93). PT plays a significant role in among others providing accessibility for all, and hence a strategic tool for achieving these national transport policy objectives. Stjernborg and Mattisson (2016) investigated how local governments in Sweden see the role of PT by analysing steering documents from 15 regions and 27 municipalities. The findings confirmed that the Swedish society considers PT to be important for addressing many economic and environmental issues, and to a relatively lesser extent, social issues. The estimated annual wider benefits of PT to the Swedish society is well over 14 billion SEK (SKT, 2017). The elements in this estimation included PT service production, noise, air pollution and infrastructural cost, travel time, revenue, safety, health effects, congestion and positive effects on the labour market.

The extent of PT ridership is key to its benefits. Hence, attracting as many passengers as possible is the most dominant objective of most PT systems (Vuchic, 2005). Two major aspects of the PT service, fare and service quality, SQ, defined as the difference between customer expectation and his/her perception of service performance (Parasuraman et al.,1985), enable service providers to achieve ridership targets (Paulley et al., 2006, Redman et al, 2013). Consequently, sufficient resources are required in line with this most dominant objective to further develop and make PT more attractive relative to alternative travel modes, the automobile in particular. Commercial PT services make profit by depending exclusively on revenues generated by PT systems mostly by means of ticket sales. Alternatively, subsidies from governments (taxes) and revenues generated by PT systems themselves through ticket sales are the major sources of financing the operation and development of publicly own PT systems. PT ticketing, which is the focus of this research effort, is hence, a very important tool for both profit-making and non-profit-making PT service providers for implementing PT fare policies (Urban ITS Expert Group, 2013).

Ticketing constitutes the interface between the PT user and the PT service and improved ticketing contributes to the overall sustainable transport policy goal (Urban ITS Expert Group, 2013). Current ticketing approaches generally require the active participation of users, as users are required to allocate some time and effort to the processes of fare collection and fare verification. Users need to allocate time and effort, firstly, into the act of paying for a trip - fare collection, and secondly, into enabling the service provider to check that passengers have paid for the intended or completed journey - fare verification (BRT Planning Guide, 2007). This implies that PT ticketing is instrumental in nature, i.e. not an end by itself but a means of accessing the PT service. It thus reduces PT SQ and adds to the generalised cost of the PT service compared to, for instance, the private automobile. That is, car drivers have a relatively easy choice as they are mostly faced with relatively similar payment options, whilst PT users are face with different pricing, different ticketing systems as well as different payment options and sales outlets.

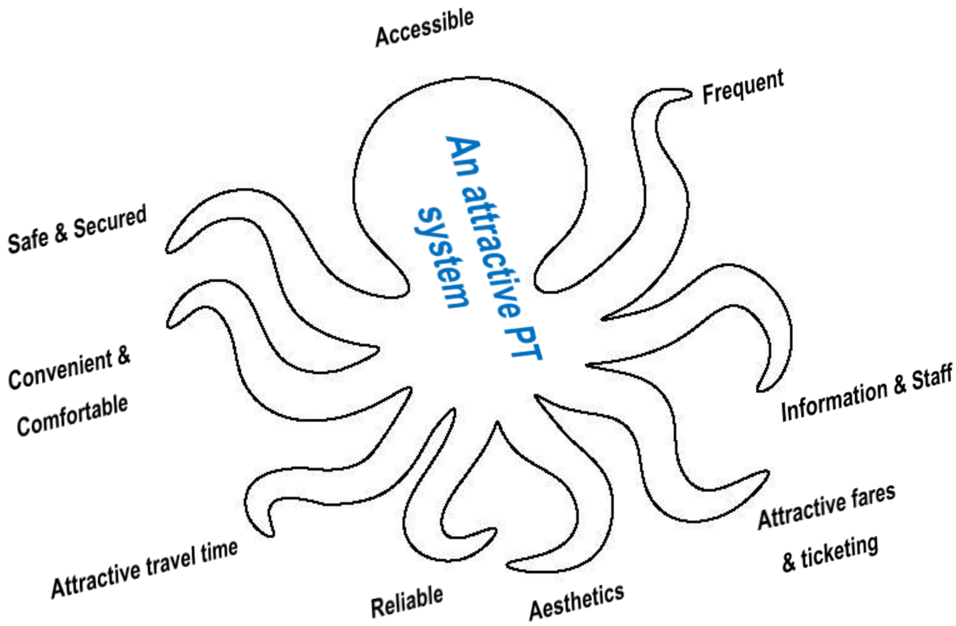

Figure 1-1: A proposed model of an attractive PT system

The demand for improved ticketing is thus currently very high due to the high need for improved PT SQ (Mass Transit, 2016). Figure 1-1 shows a model of an attractive PT system that is proposed by this doctoral research. It is based on the service quality dimensions considered in recent PT service quality research from 2007 – 2018, presented in Table 2-1. Accessibility is argued to be the most critical component of an attractive PT service, i.e. the head of the octopus, because if the

PT service is not accessible, then travel time, fare and other PT service quality dimensions would be meaningless for users.

Both users' and potential users' ticketing needs and expectations need to be well understood by measuring their behavioural response to ticketing improvements such as integrated ticketing, as PT does not only contribute to citizens' mobility within the borders of cities, regions and nations but increasingly beyond these borders (UITP, 2007). The PT ticketing system as an integral part of PT accessibility has a pervasive effect on all the major elements a quality PT system as illustrated in Figure 1-1 (Kol-TRAST, 2012; Puhe, 2014; White, 2009; and Vuchic, 2005). That is, while the main purpose of PT ticketing is to collect revenue, it affects PT service quality and remains one of the most important aspects of access to the PT service, customer satisfaction and the PT system's operational efficiency (Blythe, 2004). Making PT services more attractive and effective therefore require smart ticketing. This is only possible through a clear understanding of user behaviour, needs and expectations (Anderson et al., 2013; Schiefelbusch, 2009).

1.2 The PT ticketing system and its integration across operators

1.2.1 The PT Ticketing system and its main actors

The PT ticketing system is a central component of a PT fare policy and SQ. Price is a major determinant of the demand for a good or service as people respond to price changes by adjusting the quantity they consume. Fares are thus central to PT operation and development as they form a major part of service providers' income (Balcombe et al, 2004). PT fares are usually managed by a fare policy. Vuchic (2005) grouped the main objects of a PT fare policy into three - Passenger attraction, revenue generation and achieving some specific goals such as enhanced mobility for certain groups of people. Considering these objectives, the main actors of PT ticketing are passengers, service providers (companies and regulatory bodies) and policy makers. Hence, PT ticketing improvements are most likely to impact the specific goals of these actors.

Fare structure and ticketing are the two main components of a PT fare policy. Fare structure allows PT service providers to set PT fares using two fundamental pricing strategies - identical fares for all passengers or price discrimination, where fares are set to reflect the willingness of different users to use the PT service. Price discrimination strategies may be journey-based or passenger-based. Journey-based price discrimination which may be considered as a cost-effective approach determines fares based on the characteristics of the journey such as journey distance, mode, time of travel, etc. Different forms of journey-based price discrimination include flat fares, zonal fares, route fares, and distance-based fares (where the price per kilometre is applied). Passenger-based price discrimination considers the socio-economic characteristics of the user such as income, age, social status etc.

The ticketing system helps put a PT fare policy into action by allowing users to pay for their journeys and at the same time allowing service providers to ensure that users pay for their journeys. The PT ticketing system thus generally has two main functions, fare payment and fare verification functions.

Users normally buy tickets from various sales channels with the possibility to choose among ticket media/carriers. Ticket media/carrier technologies have evolved tremendously from cash, tokens, paper tickets through magnetic stripe tickets to contact-based smart cards, contactless smart cards and mobile devices, usually available to passengers from various sales channels. These media carry at least one ticket type such as single ticket and its variants, multi-journey tickets, season ticket, value ticket or pay-as-you-go, off-peak ticket, group or family ticket, special event tickets, combined ticket (e.g. with parking, events), etc. This payment process is associated with user-disutilities such as:

- queuing to buy a ticket and to board the PT vehicle
- buying the wrong ticket due to lack of information
- difficulties in claiming refunds
- complex fare zone structures
- problems with ticket vending machines
- mobile application system failures
- the need to make transfers among different operators
- the inability to buy a ticket on-board and penalties for buying the ticket on-board in some cases
- some vending machines accept cash only but not bank cards, etc.

Also, the ticketing inspection process, which does not currently leave room for passengers to choose how they want their tickets to be inspected, is usually done manually or automatically on-board PT vehicle and/or off-board. It is associated with user-disutilities such as:

- ticket inspectors invading passenger privacy
- the barrier effects of turnstiles
- lack of the freedom for users to choose fare inspection option
- violence etc.

1.2.2 The integration of ticketing systems across operators

The demand for integrated mobility platforms, promoted by user needs and developments in information and communication technologies (ICT), has been increasing over the last decade. One form of integrated mobility platform is the one that is popular among conventional PT operators, where PT operators make multimodal PT services available to users via integrated and smart ticketing. The other form, known as Mobility-as-a-service (MaaS), is essentially an extension of the one provided by conventional PT operators to include more personalised services and travel modes such as car rental, car sharing, taxi and bicycles. Users buy mobility services instead of buying means of transport in both forms of integrated platforms, and integrated and seamless mobility is the central idea behind both forms (Kamargianni et al. 2016; Pangbourne et al., 2020). Stakeholders around the world are heavily investing into these integrated and smart ticketing platforms considering current wide-spread multimodal and deregulated PT markets (Elliott et al., 2019). Ticketing integration helps PT users to remove or reduce interservice-provider ticketing barriers and to select the best combination of the PT service attributes from among the participating PT operators that matches their travel needs. The UK Department for Transport (2009) estimated the net benefits of national level integrated smart ticketing to be over £1bn per year. Synergy and removal of barriers are two major values of transport system integration (May et al, 2006), and the main aim of integrated ticketing is to provide PT users with a broad set of destination and mode choices in a convenient, accessible, comfortable, safe, fast and affordable manner (Ibrahim, 2003). Chowdhury and Ceder (2016) specifically decomposed PT integration into five dimensions:

- Network integration
- Fare and ticketing integration
- Information integration
- Physical integration of stations and
- Integrated timed-transfers.

Modal integration, the integration of PT and other travel modes, should actually also be considered an important dimension of PT integration as this is generally on the increase.

From these PT system integration perspectives, the product of a well-integrated PT system, as perceived by users, may be referred to as seamless travel. Integrated ticketing as an aspect of seamless travel may thus be referred to as seamless ticketing as it provides seamless transfers across different modes. Thus, from a user perspective, ticketing integration makes it easy for PT users to use one ticket on every part of the same journey regardless of the ticketing media or whether the journey requires multimode or transcends geographic boundaries. This view point consequently covers the vision of the International Association of Public Transport of enabling people “to travel within, between and through cities, regions and borders without the need to change the ticketing media they use” (UITP, 2007). It also mirrors the need raised by the former vice president of the European Union Commission responsible for transport, SiimKallas, as cited by Verity (2012), “Why can’t I yet plan or book my journey through Europe – switching from air to rail or sea, to urban or road transport – in one single go and online?”

Based on this spatial perspective of integrated ticketing, five levels of ticketing integration may be identified:

- Level 1: Same ticket can be used to conveniently travel across service providers within a city’s or county's PT system.
- Level 2: Same ticket can be used to conveniently travel across service providers within neighbouring counties.
- Level 3: Same ticket can be used to conveniently travel across service providers within a state.
- Level 4: Continental - Same ticket can be used to conveniently travel across service providers within and across different states in a region such as within the EU.
- Level 5: Intercontinental/global - Same ticket can be used to conveniently travel across service providers within and across continents such as Europe and North America.

Some major documented benefits of integrated and smart ticketing to both users and service providers include: increased PT usage, improved passenger satisfaction, modal shift, increased revenue, decreased transaction and administration costs, social benefits, reduced fraud, contribution to city life and identity, enhanced data acquisition, reduced boarding and dwell times, improved access to non-transport related services, etc. (White, 2009; PTEG, 2009; Abrate et al, 2009; Bagchi, 2003; Sharaby and Shiftan, 2012; STOA, 2014; Puhe 2014).

1.3 Justification of the research

There is a clear need for new empirical research on the user perspective of the PT ticketing system. Unquestionably, ticketing is an integral part of accessibility to the PT service. The need for ticketing improvements was, for instance, ranked fourth among thirty PT issues by over 3800 passengers in England (Passenger Focus, 2010). Even though, the growing need for improved PT ticketing motivated growing investments and research work in this field (Figure 1-2), very little, as pointed out by Chowdhury and Ceder (2016) in their review paper, is known about the behavioural perspective of PT ticketing. Yet, ticketing improvements such as integrated and smart ticketing is a current PT policy focus area across the world, due to increasing deregulated markets, multimodalism, fast urbanisation and regionalisation of PT systems. That is, while the analysis of user attitudes is central to understanding user ticketing needs, it is still difficult to find literature on users attitudes towards fare payment and inspection and the factors influencing these attitudes. Similarly, whilst understanding users' season ticket choice behaviour and preferences in integrated ticketing environments is useful for justifying economic investments into integrated ticketing, previous studies focused on analysing city/regional level ticketing integration even though the geographic coverage of ticketing integration is increasingly extending beyond local and regional boundaries (UITP, 2007). Hence, the existing knowledge does not sufficiently enhance our understanding on the extent to which intercounty level ticketing integration affect the decisions of both PT and car users.

In addition, even though there is a growing need to understand and to forecast the effects of ticketing integration schemes on modal shift, prior studies failed to quantitatively analyse the link between ticketing integration and the extent to which that makes PT appear attractive to car users (PTEG, 2009).

This doctoral research therefore identified and contributed to the following six major knowledge gaps in PT ticketing:

- theoretical models for analysing the behavioural aspect of PT ticketing systems
- users' attitudes to PT fare collection and inspection
- users' reaction to a next generation PT ticket inspection solution
- the effect of integrated ticketing on modal shift
- users' willingness-to-pay (WTP) for integrated ticketing, and finally,
- the impact of integrated ticketing on PT ridership, user satisfaction and the perceived quality of ticketing.

The next section discusses these research gaps in detail.

1.4 Critical assessment of previous research in relation to the observed research gaps

As summarised in this section, so far, many research works have looked into technological, policy, operational and behavioural perspectives of PT ticketing. The growing need for improved PT ticketing is reflected by the fast-growing research work in this field since 1990 (Figure 1-2). A total of 289 published works that captured the terms public transport/transit and ticketing for the period 1990-2019 were returned by Scopus with, UK having the most counts (Figure 1-3).

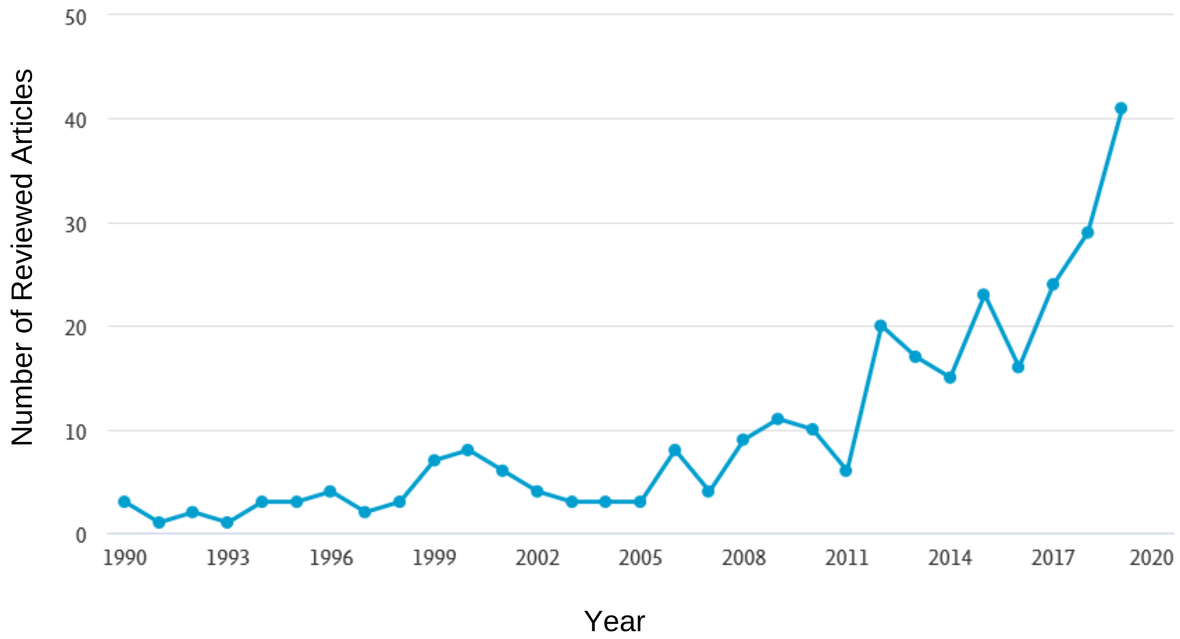

Figure 1-2: Number of Reviewed Articles by Year (1990-2019)

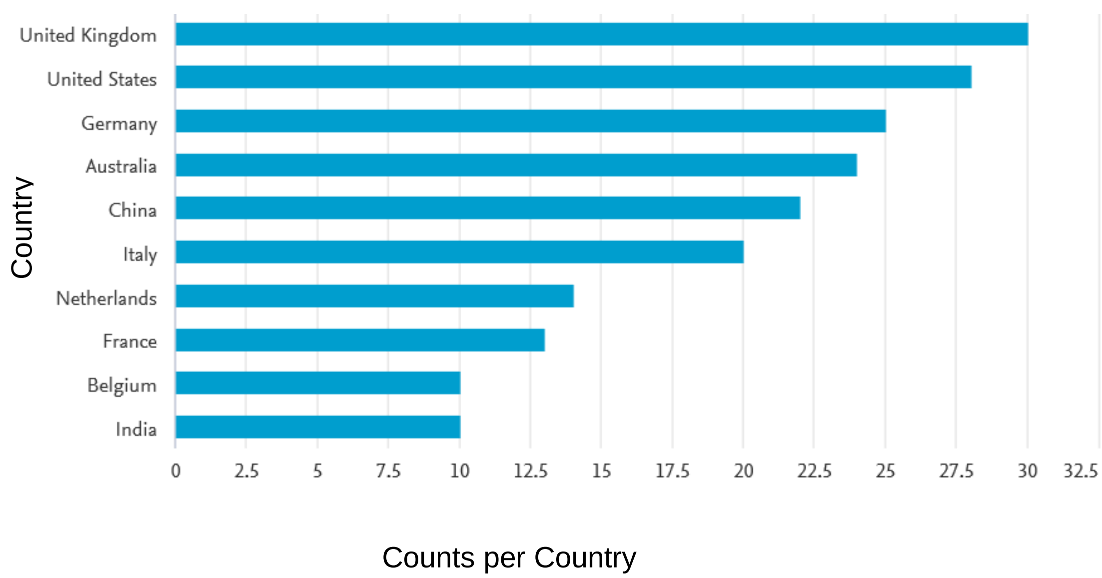

Figure 1-3: Number of Reviewed Articles by Country, top ten, (1990-2019)

1.4.1 Technological perspectives

Solutions to the problems associated with traditional forms of ticketing are largely technology driven and broadly fall under two groups:

- automation and digitalisation of fare payment and payment verification functions (Pelletier et al, 2011; Brakewood et al, 2014; Giuliano et al, 2000; Cheung, 2004)
- multi-operator ticketing integration, aided by automation and digitalisation (Welde, 2012; Turner and Wilson, 2010; Sharaby and Shiftan, 2012).

These technological and user driven solutions have led to the emergence of the concept of smart ticketing in the PT industry. While PT service providers tend to interpret this term differently in practice, the eleven most common aspects of smart ticketing (with old forms of ticketing as a benchmark) are:

- enhanced user convenience
- simplicity and easy to use
- flexibility
- seamless transfers across different modes
- time savings through reduced queues at ticket sale's points, during boarding and at stations
- decreased transaction and administration costs
- reduced fraud
- multi-functional cards
- enhanced data acquisition
- implementation of complex fares in PT fare structures etc.

So, smart ticketing in substance, is concerned with innovative solutions to old forms of ticketing, mainly driven by technology and user needs. Integrated ticketing can then be seen an aspect of transport system integration and smart ticketing that makes multimodal passenger transport services accessible to users, by combining the ticketing and fare systems of the different travel modes involved.

Obviously, these technological advances in PT ticketing tend to focus on improving fare payment than fare inspection. This thesis thus argued the need for technological advancement in fare inspection systems considering the growing digitalisation and automation of PT systems.

1.4.2 Policy and operational perspectives

Iseki et al (2007) surveyed PT agencies in the USA to examine their knowledge and perceptions about the cost, benefits and risks of adopting smart cards. They concluded that managers were often uncertain about the benefits and that they also found variations in the adoption of smart technologies and interoperable systems due to funding availability and the degree of partnership with other service providers on Intelligent Transport Systems (ITS) projects. Similarly, Yoh et al (2006) conducted in-depth interviews with transit industry experts to identify hindrances to the implementation of interoperability. Four hindrances were identified, namely: unwillingness to give up locally controlled fare policies, uncertainty in the future of smart card technology, decentralised decision systems and lack of institutional capacity. Furthermore, in the municipality of Groningen, the Netherlands, Cheung (2004) evaluated the effectiveness of the Tripperpas smart card technology using a survey. He pointed out that technical reliability was relevant in winning user confidence, the group use provision of the card was favourable to users and that although the check-in-check-out could generate useful travel data to service providers, it was a drawback for users. Similarly, Shon (1989) investigated PT fare integration in London using revealed-preference analysis and elasticity models. He concluded that although there was some revenue lost to the service provider, PT ticketing integration was beneficial to both users and society. In addition, Oporum (2005) analysed the effect of AFC on rail rapid transit in New York City and confirmed that, AFC was economically beneficial to society. He also found that, AFC was preferred by users over the traditional fare collection, free transfer and fare discount elements of the AFC had encouraged ridership on PT. Furthermore, using the principles of cost-benefit analysis, Welde (2012) analysed the profitability of a fully-interoperable smart card ticketing system in Trondheim (Norway) and concluded that it gave a positive net present value. Reduced boarding and dwell times were the major benefits to the operator while increased reliability and reduced need of cash were the main benefits to the passenger.

While these previous works confirm the benefits of ticketing improvements to both users and PTSP, they also pointed out uncertainty about the benefits of ticketing improvements as an issue. This doctoral research contributes to this issue by evaluating the impacts of multi-region and multi-operator integrated ticketing on some major PT policy goals.

1.4.3 Behavioural perspectives

Chowdhury and Ceder (2016) conducted a qualitative systematic review focusing on factors influencing commuters' willingness to use an integrated PT system. The study focused on commuters' willingness to change mode to PT along routes with transfers and the object was to understand the travel behaviour of both users and potential users. They concluded that studies relating to PT transfers had focused on PT operational aspects with limited studies on psychological aspects and the effects of policy.

Brakewood et al (2014) used on-board stated preference survey to assess the potential of adopting mobile ticketing on two commuter rail lines Boston and about 26% of the commuter rail users showed the most interest in mobile ticketing. Furthermore, Graham and Mulley (2011) surveyed PT users to study their behaviour before and after the implementation of prepaid tickets in New South Wales (Australia). Significant differences were found in the characteristics of passengers using multimodal tickets and pay-as-you-go passengers, mainly influenced by age, income and whether the journey involved transfer or not. Likewise, Sharaby and Shiftan (2012) evaluated the effect of fare integration on ridership and travel behaviour in Haifa and concluded that the new fare policy reversed the downward trend in PT usage. The packet of measures implemented included fare zone restructuring, free transfer and fare reduction (which according to the study was the significant factor in attracting PT users). The contribution of each of the individual measures that were implemented to increased PT usage was not however explicitly presented by the study. On the other hand, Giuliano et al (2000) evaluated Ventura County’s smart car demonstration project and pointed out that smart card users were very satisfied with the new medium of payment. Similarly, Hao (2007) used RP, SP, elasticity models, fuzzy logic and artificial neural network to evaluate the benefits and effectiveness of smart card usage as well as users’ preferences for payment options in Dalian, China. Similar to Pelletier et al (2011), the results confirmed an increasing trend in smart card usage. He suggested the need for further research on a combined smart card for PT and other public services and the need to explore non-PT user perceptions of smart card in PT systems and if that could attract them to PT.

In the case of PT non-users, Beecroft and Pangbourne (2015) confirmed that PT operators have very little amount of knowledge about non-users (mostly car drivers). Within the EU, private car journeys constitute about 80% of passenger kilometres travelled while PT account for only around 17% (Commission of the European Communities, 2012). Improve PT ticketing could contribute to making PT more attractive to car users as Scott and Axhausen (2006) argued that there is a strong substitution effect between season ticket ownership and car ownership. A survey conducted by Flash Eurobarometer (2011) confirmed that about 71 % of car users perceived PT to be inconvenient and 72 % of them pointed out lack of connectivity as the problem. Ticketing integration enhances seamless travel and multimodal mobility and this may thus make PT appear attractive to these group of non-users.

There are several research gaps in the behavioural perspective of PT ticketing. As described in the preceding sections, many research works have looked into technological, policy, operational and behavioural perspectives of PT ticketing. One major characteristic of these previous works is that, they often analysed fare and ticketing jointly, but usually focusing more on the effects of fare, as the fare is of the highest interest to PT service providers. PT user challenges such as the ease of purchase, the speed of purchase, barrier effects of turnstiles, the ease of use of ticket vending machines, accessibility to tickets and inter-transit systems transfer challenges are some major problems associated with ticketing. While these issues may relate to fare, and fare is clearly a very important determinant of PT demand, the effects of perceived quality of PT ticketing on user experience are clearly not the same as that of fare. This, thus motivates this doctoral work to empirically address the following highlighted five knowledge gaps in the literature of PT ticketing, focusing more on users' and non-users' reactions to ticketing aspects rather than their reactions to fare changes.

Research Gap1: Users attitudes to fare collection and inspection

There is lack of knowledge on users' attitudes to PT fare collection and inspection systems. PT SQ is central to retaining current users and attracting new users. Its measurement is hence of high importance for PT operators. Consequently, many studies on PT service quality and satisfaction have been conducted based on data collected from user surveys (De Oña and De Oña, 2014). The measurements of service quality and user satisfaction are mostly either based on user experience (perceived quality) or based on users' expectation (expected quality). Perceived quality is more common in PT service quality research (Allen et al, 2018) and is predominantly measured as an attitude (De Oña and De Oña, 2014). The assessment of the quality of PT ticketing systems and attitudes to ticketing have received limited consideration in PT research. Many of the studies that included fare in the evaluation of the perceived service quality of PT systems overlooked ticketing aspects (Mahmoud and Hine, 2016; De Oña and De Oña, 2015; De Oña et al., 2013; Eboli and Mazzulla, 2010). Very few studies included some aspects of ticketing inconveniences as a relevant factor in PT SQ evaluation, and these were often limited to aspects of fare collection, with almost no consideration of fare verification aspects. For instance, Carreira et al (2013) included only ticket line service, measured as empathy at the ticket line and not having to wait to buy a ticket. Also, Abenoza et al. (2016) included ease of purchasing tickets as an attribute in their analysis of travel satisfaction with PT in Sweden from 2001 to 2014 and reported that it generally followed a negative trend. One focused area of this thesis was therefore to contribute to users' attitudes to PT fare collection and inspection systems.

Research Gap2: Fare collection and inspection improvements

Very limited research has investigated the user convenience and satisfaction perspectives of ticket inspection. Both research and technological advances in PT ticketing tend to focus on improving fare payment than fare inspection. This generally makes it more convenient for PT users to choose among different payment options and to seamlessly travel across different service providers. On the other hand, PT users currently lack the opportunity to choose how they want their tickets to be inspected. Even if the opportunity to choose their preferred ticket inspection approach were to be given to PT users, the choice set would be limited to ticket inspection by personnel and/or turnstiles. Meanwhile, combating fare evasion is a major concern PTSP, particularly, those using proof-of-payment ticketing systems. The shift in global fare evasion research is grouped into three perspectives by (Delbosc and Currie, 2019): conventional PT system, the customer profiling, and the customer motivation. Similarly, Barabino et al. (2020) categorised fare evasion research into five broader areas: fare evader-oriented, criminological, economic, technological and operational. In terms of fare evasion measures, ticket inspection by staff, investing more power in inspectors, partnership with the police, communication, on-board technologies such as video surveillance, and access control by the use of turnstile are identified by Public Transport International, Bonfanti and Wagenknecht (2010). Also, the EU Commission's Urban ITS Expert Group's (2013) guidelines on smart ticketing recommends efficient inspection at turnstiles and within PT networks for combating fare evasion. While, fare evasion and user satisfaction are two of the top three challenges that new ticketing technologies need to address (Mass Transit, 2016), very limited research investigated the user convenience and satisfaction perspectives of ticket inspection, such as users' preferences and satisfaction with current ticket inspection options. Seamless ticketing has mainly focused on seamless ticket payment issues and to the best of my knowledge, previous research work has not investigated seamless ticket inspection. Hence, this doctoral research also explored users' preferences for ticket inspection options and the associated factors that influence their likelihood of accepting seamless ticket inspection.

Research Gap3: Impacts of integrated ticketing

There is a general lack of practical evidence on the achievements of integrated transport policies Preston (2012). Deregulated PT markets are wide spread and the need to travel across PTSP has made integrated ticketing an important component of both national and international integrated transport policies (Puhe, 2014; Turner and Wilson, 2010). The benefits of integrated ticketing are yet often promoted based on expected benefits and the actual post implementation benefits are not often captured or reported to the public (PTEG, 2009). In addition, even though the geographic coverage of integrated ticketing is increasingly extending beyond local boundaries, previous studies on integrated ticketing tend to focus on those at city/town level (Welde, 2012; Shon, 1989; Oporum, 2005). Given this research gap, one of the objects of this doctoral research was to evaluate the impacts multi-region and multi-operator integrated ticketing has on some major PT policy goals - patronage, user satisfaction and the perceived quality of ticketing.

Research Gap 4: The value of integrated ticketing to users

Like many PT improvements, knowledge of the monetary value of integrated ticketing to users is very useful for the economic appraisal of investment decisions linked to integrated ticketing. For instance, to assess the importance of integrated ticketing among EU citizens, an opinion survey was conducted by Flash Eurobarometer's (2011). While study approaches like this have the potential to highlight the importance of integrated ticketing, they lack the ability to provide information on its monetary value as input for the economic appraisal of investments into these schemes. This doctoral research attempted to address this general lack of evidence in transportation research on users willingness-to-pay (WTP) for integrated ticketing by analysing PT users' WTP for multi-region and multi-operator integrated ticketing as well as the variation in taste among PT user segments.

Research Gap 5: Integrated ticketing and modal shift

Positive effects on PT patronage are normally expected following PT service quality improvements (Paulley et al. 2006). Interestingly, the effects of many PT service improvements such as integrated ticketing on particularly future travel demand are often overlooked in mode choice analysis. For instance, the Swedish National Railways reported about 24% increase in ticket sales after the implementation of the Movingo integrated season ticket in Mälardalen region, which constitute about 40% of the total population of Sweden (SCB, 2020), yet, the effect of Movingo on increased rail commuting was not captured by the recent Swedish Transport Department travel demand forecast. Similarly, evidence on the correlation between integrated ticketing and modal shift around the world could not be found by the Public Transport Executive Group (2009) in the UK. At the same time, both the PTEG (2009) and the EU Commission's Urban ITS Expert Group's (2013) confirmed that integrated ticketing increases PT usage, though the extent to which it does so is unclear. Considering this knowledge gap, the proliferation of integrated ticketing schemes around the world and the existing evidence confirming positive substitution effects between car ownership and season ticket ownership (Scott and Axhuasen, 2010), one aspect of ticketing that this doctoral work examined was the correlation between mode choice for commuting and integrated ticketing.

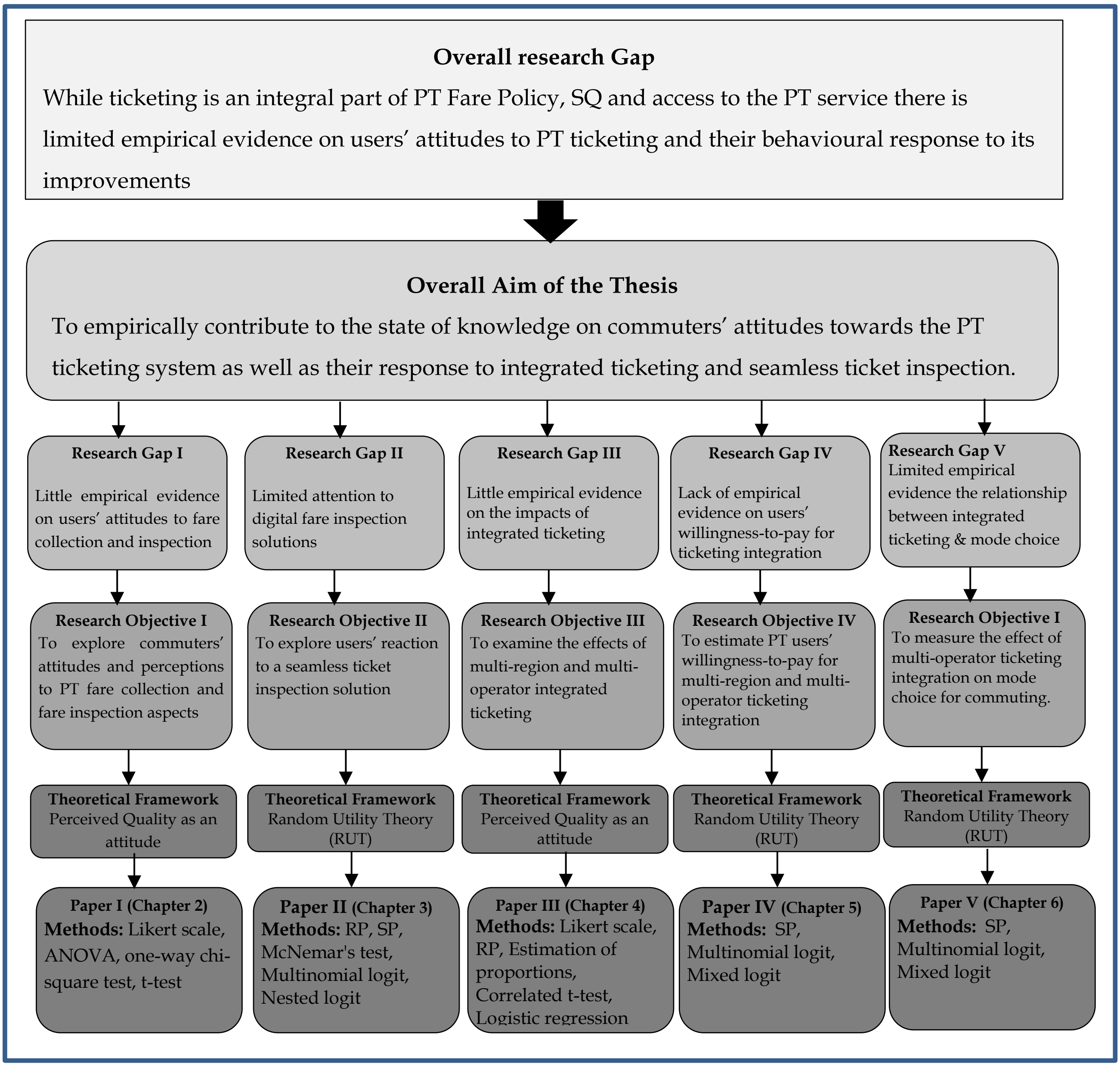

Figure 1-4: Research framework - The relationship between the research gaps, overall research aim (thesis level), specific research objectives (paper level), theoretical models, the attached papers & research methods

1.5 Research objectives

The relationship between the research gaps, overall research aim (thesis level), specific research objectives (paper level), the applied theoretical models, the attached papers and research methods is summarised in Figure 1-4.

That is, following the knowledge gaps identified in the preceding section and, the fact that commuting forms a substantial portion of global daily trips, the overall aim of the research was to contribute to our knowledge on commuters' attitudes towards the PT ticketing system as well as their response to multi-region and multi-operator ticketing integration. The following five specific and related research objectives were set and addressed by the research through the five manuscripts presented in the thesis.

- To explore commuters' attitudes and perceptions to PT fare collection and fare inspection aspects
- To explore users' reaction to a seamless ticket inspection solution
- To examine the effects of multi-region and multi-operator integrated ticketing on PT ridership, user satisfaction and the perceived quality of ticketing
- To estimate PT users' willingness-to-pay for multi-region and multi-operator ticketing integration
- To measure the effect of multi-operator ticketing integration on mode choice for commuting.

1.6 Scope of the research

Investigating PT users and non-users attitudes and behavioural response to ticketing and its integration obviously covers a potentially wide field of research. To make this doctoral research effort more focused and manageable, the research was scoped based on the five main dimensions presented in this section, namely: geographic or spatial coverage, handling of time (or temporal variations), unit of analysis, behavioural responses (or social), and finally the level and extent of integrated ticketing.

Geographic coverage

As presented in section 1.1, the Swedish society considers PT to be an important tool for addressing economic, social and environmental transport policy objectives. Consequently, the 2012 Swedish PT act (Prop. 2009/10:200), vested the right of PT operation and development in the country's 21 county councils, with each forming a regional PT authority (PTA), and all the regional PTAs are required to strategically develop regular regional PT supply plans (Rye and Wretstrand, 2014).

With an average trip length of 10.6 Km, a total of about 1.5 billion PT trips are performed annually in Sweden as of the year 2017 (SKT, 2017). The number of PT trips per citizen has increased by 28% between the year 2000 and 2016 (Sveriges Bussföretag, 2018). That is, more than half of the Swedish population currently travels regularly (i.e. from 1-3 days/month to 5-7 days/week) with PT and females travel with PT more frequently compared to males. Explicitly, 31% of all motorized trips in Sweden are made with PT in 2018 compared to 27% in 2017. 51% of these PT trips are made with the bus while 35% are made with the light rail/underground train. Also, about 79% of PT users in Sweden express satisfaction with PT in 2018 compared 76% in 2017 (SKT, 2018). PT usage in Sweden has increased from about 18% to 31% between 2006 and 2018 (SKT, 2016; SKT, 2018). Making Sweden one of the seven countries in the European Union with sustained growth of PT usage (UITP, 2016).

Commuting in Sweden has been increasing annually since 1993 and 31% of the working population commuted beyond municipal boundaries in 2006 (SKL, 2008). The proportion of commuting trips in Sweden is therefore comparatively high as Beck and Hess (2016) reported that 23.3% of all trips made in Sydney were commuting or work trips, 16% of all person trips in the United States in 2013 were work related commuting trips which is similar to that of the United Kingdom in 2014. They also confirm that the decision to commute is less uniform for males and female and that they differ in their preferences for commuting. Stockholm county reported in 2015 that woman commuters in 9 out of the 26 municipalities in the county have longer commuting distances compared with men (Stockholm’s county board, 2015).

PTAs in Sweden function as separate decentralised organisations focusing on their areas of jurisdiction. This decentralised decision making resulted in some regional differences in regulations, pricing and ticketing systems.

Consequently, to ease citizens’ mobility beyond city and county borders, integrated ticketing is of national interest in Sweden. The Swedish PT act allows commercial PT companies to provide PT services anywhere in the country alongside the PTAs, yet the PTAs practically dominate the PT market due, probably to the subsidised services they offer to users. This dominance somehow simplified integrated ticketing at city and county levels. Intercounty and national levels’ ticketing integration however remains an issue, as passengers need at least two different tickets to travel across county borders (Gunnäs, 2014).

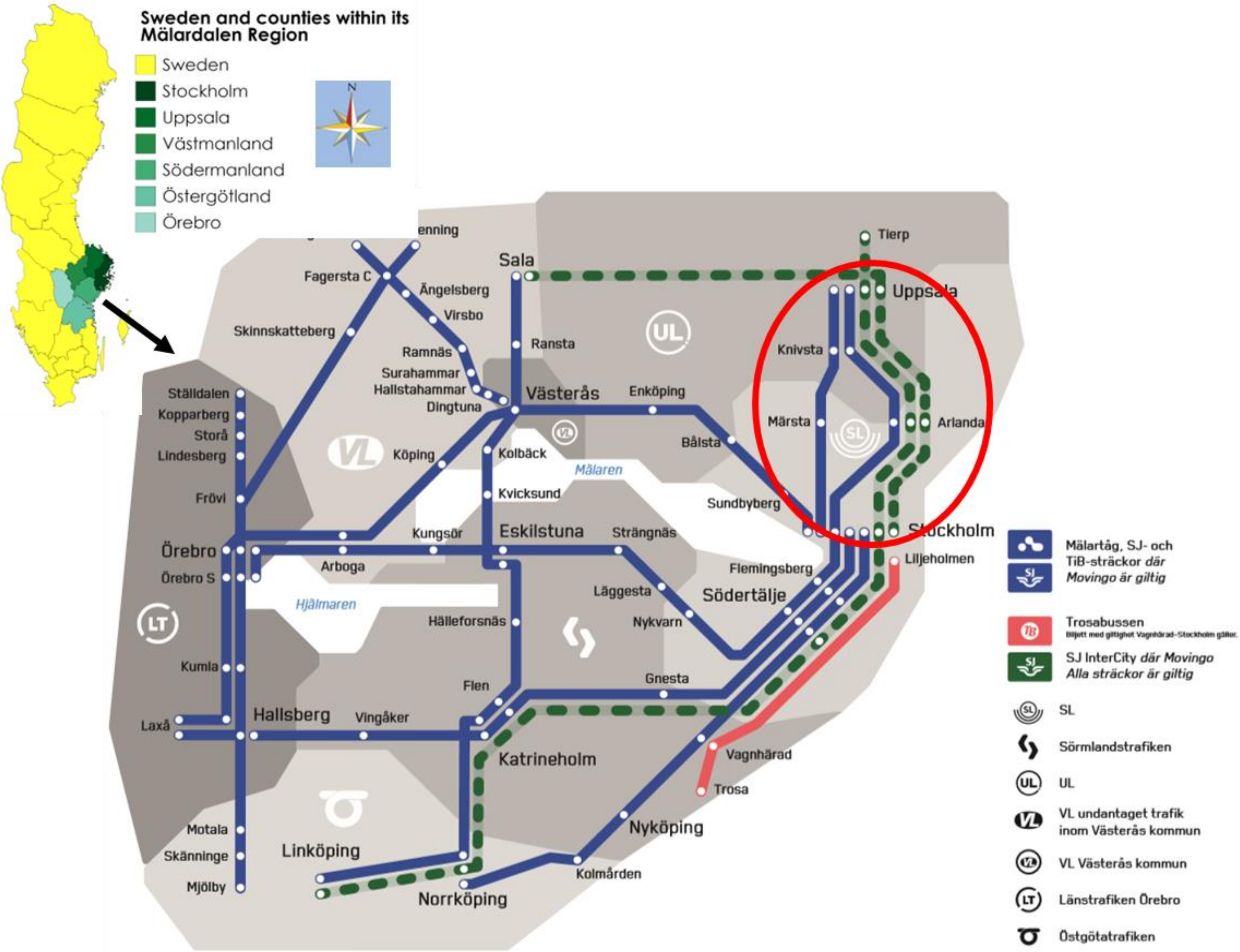

Figure 1-5: Cities, rail network, operators & tariff zones in Mälardalen (studied corridor red-circled) (Mälardalstrafik MÄLAB AB, 2020, modified)

This problem motivated the Movingo intercounty integrated ticketing scheme in the Mälardalen region of Sweden (Figure 1-5), which provides a good case for collecting data for an analysis where wider academic and policy lessons can be drawn.

Movingo, launched in October 2017 with the object of encouraging commuting by PT within the entire Mälardalen region, is a smartcard and mobile phone based multiple-county commuting ticket that applies to both intercity and intracity bus and train services. The commercial rail service provider (the Swedish Railways, SJ) and the six adjoining PTAs in the Mälardalen region are the implementing organisations. The three season ticket options are 30 days, 90 days and 365 days. A user can buy a season ticket that is valid for at least two regional nodes and at least a county. The pricing structure is hybrid - flat within county and differentiated based on distances between regional nodes.

Even though the scheme, covered the entire Mälardalen region, the study focused on the Stockholm – Uppsala corridor because it:

- has the largest share of the cross-county commuting journeys in Mälardalen and in Sweden as a whole (As evidenced in figure 2-2).
- is considered commercially attractive and prioritised in the Movingo scheme
- shares some similarities with many corridors in Mälardalen, Sweden and beyond, making the results of the study possibly transferrable. Sweden's biggest internal airport, Arlanda, which has about forty-one direct flights and is among the biggest fifty airports in Europe is located along this corridor at the boundary of the two counties. The major four travel relations along the corridor are Stockholm ↔ Uppsala, Stockholm ↔ Knivsta, Stockholm ↔ Märsta and Uppsala ↔ Märsta. Even though the Stockholm ↔ Arlanda and Uppsala ↔ Arlanda travel market is important, it has other characteristic such as payment of additional fees at the Arlanda train station, competition with other operators such as Swebus, A-train, taxi etc., which are not part of the Movingo scheme. This airport travel market thus needs a detail and separate study.

Unit of analysis

The unit of analysis were travellers along the Stockholm – Uppsala corridor particularly car and train commuters as the Movingo scheme focuses on commuters. Bus, walking and cycling modes are not currently attractive for commuting along the corridor due to distance. These modes were therefore treated only as access and egress modes in the research. As commuting trips are basically made up of work and education trips, the target age group was 16 to 65+ years old.

Behavioural responses

The two main purposes for studying choice behaviour are the relative valuation of attributes and demand forecasting. The former is of more interest to the research objective. Since most of the respondents are commuters, they have a good knowledge of the corridor and this made it easy to place in the context of the SP experiment. This was useful in helping them to assess the choice situation before them with a good level of awareness.

Furthermore, fare and ticketing are often studied jointly in previous works as ticketing tends to be largely perceived by many PT service providers as a means of implementing PT fare policy and not an end in its own right. This joint treatment tends to focus more on PT operational and economic efficiency even though the ticketing process itself has factors that affect PT users diversely. This motivated the study to focus more on the users' and non-users' reactions to ticketing aspects rather than their reaction to the fares.

Handling of time

Attitudes and preferences and for that matter demand change over time. Hence, both cross-sectional and a two-wave panel dataset were used to address the research questions in the study. That is, a survey was conducted before the implementation of the Movingo and the second was conducted to the same respondents one year after the implementation.

The level and extent of ticketing integration

Considering the five levels of ticketing integration defined in section 1.2, county and city level ticketing integration (the first level) is not much of a problem in the study area (Gunnäs, 2014), as the two PTAs involved in this study are the main providers of line PT services within the counties. The study hence focused on examining integrated ticketing at the regional level (where the same ticket can be used across PT service providers within and across counties). The Movingo integrated season has three options – 30-days, 90-days and one-year season tickets. The most common of these three is the 30-day season since over 80% of commuters used this ticket. Consequently, in order to reduce the complexity of the survey and for that matter reduce the respondents' burden, which can otherwise negatively affect the survey response rate, the choice analysis focused on the choice among the 30-days ticket options.

1.7 Research Approach

A brief theoretical overview

The individual's attitudinal and behavioural response to transport system improvements are influenced by both objective factors - such as travel time, speed, reliability, service frequency, etc., and subjective factors - such as comfort, convenience, ease of use etc., (Redman et al, 2013). An inter-disciplinary psychological and economic approach was hence, adopted in addressing the research gaps identified in this study.

Models used in explaining, predicting and understanding this behavioural response generally need to be backed by some theory of travel behaviour to ensure consistency in the interpretation of their results and, to ensure that they will be valid in the future (Ortúzar and Willumsen, 2011).

Psychological and economic theories are predominantly used in travel behaviour studies (UK Department of Transport behavioural insights toolkit, 2011). This toolkit explains the theories of behaviour from three broad perspectives – economic, psychological and sociological theories.

The economic theory of human behaviour traditionally simplified human behaviour by assuming that it is largely a function of rational choices. Due to the inability of the traditional economic theory to explain irrational human behaviour, behavioural economics has emerged to capture the effects of systematically irrational behaviour. The idea of consumer preferences in microeconomic shows whether a consumer likes one good or set of goods more than another. This is useful in understanding how consumers compare/rank the desirability of different sets of goods based on the suppositions that their preferences are complete, transitive and that more is better. These three presumptions permit the mathematical or graphical representation of consumer preferences as utility functions.

The psychological theories of human behaviour consider behaviour to be driven by: internal and conscious thoughts; external environment; and sub-conscious influences such as habit and emotion. An example of a common psychological theory that is applied in transportation studies is the theory of planned behaviour, TPB (Ajzen, 1991; Fishbein and Ajzen, 1975). The TPB explains choice behaviour by assuming that behaviour is a function of the intention to do it and that behavioural intentions are in turn, determined by 1). Attitude (What I think) - the extent to which an individual holds a positive or negative evaluation about some person, object or issue 2). Subjective norms (What others think) - the perceived social pressure to execute or not to execute a given behaviour and 3). perceived behavioural control, PBC (Can I do it?) - the perceived ease or difficulty of executing a given behaviour. Other psychological theories include the ABC model, the Deficit model, Triandis' theory of interpersonal behaviour, Norm Activation Theory, Value Belief Norm Theory, etc.

The sociological theories of behaviour mainly consider human behaviour to consist of three components – things (objects, tools, and materials), skills and images. While the economic and psychological theories focus on the individual, sociological theories of behaviour view the individual behaviour as a function of factors bigger than the individual. Some examples are the social practice theory and the Transtheoretical Model of Health behaviour Change or Stages of Change Model.

1.7.1 Attitudinal and discrete choice theories

While the different theories of behaviour mentioned in the previous section may overlap, or build on the insights of each other, the two main theoretical concepts that are strongly related to the research objectives are the psychological concept of attitudes and the microeconomic concept of discrete choice. This is because the individual’s attitudinal and behavioural response to transport system improvements are influenced by both objective and subjective factors. That is, given the empirical nature of the research objectives, the attitudinal and discrete choice modelling theoretical frameworks that were used to guide the research design, data collection, analysis, interpretation of the findings and conclusions are presented in this section.

The theoretical models of attitudes and perceived service quality

In the literature, the social-psychological concept, attitude, has been used to conceptualise different life aspects including beliefs, values, perceptions, knowledge, awareness, opinions, and concerns (Anable et al., 2006). Attitude has hence, been described as the most important social-psychological concept. The three most fundamental constructs of attitudes in social-psychology are one-component, two-component, and three-component models (Hogg and Vaughan, 2011). The one-component attitude model view attitude as “the affect for or against a psychological object” (Thurstone, 1931). That is, the extent of positive or negative affect towards some psychological object. The two-component attitude model considers an attitude to be made up of the affect for or against a given psychological object as well as the metal readiness to act. In the three-component model, an attitude is considered to be made up of cognitive, affective and behavioural components (Hogg and Vaughan, 2011).

Consequently, five psychological properties of attitudes form the basis for using attitude measurements to empirically evaluate specific interventions, such as rail commuters' perceived quality of PT ticketing before and after integrated ticketing as demonstrated in this study. That is an attitude is an evaluation on whether the attitude object is good or bad; it is affective, behavioural and cognitive nature; it has a knowledge, utilitarian, ego defence and value expressive functions; it is measurable; and finally, it can be influenced by the way questions are asked (Richardson, 2014).

Parasuraman et al. (1985) considered perceived service quality to be a form of attitude relating to the satisfaction that comes from a customer’s comparison of her expectation with her perception of service performance. Moreover, Cronin and Taylor (1992) argued that perceived service quality is best conceptualized as an attitude, based on only the evaluation of service performance. These two definitions provided two main streams in the development of service quality models. For instance, in the Nordic (European model), perceived service quality is based on a comparison between expected service and perceived service in relation to two quality dimensions

- technical quality (what customers received due to interaction with service organisation) and functional quality (how customers receive services). Similarly, the American model (SERVQUAL) considers SQ as the difference between the expected level of service and customer perceptions of the level received. The Nordic model prompted the need for the three-component model by Rust and Oliver (1994), that models SQ as mainly a function of service product, service delivery and service environments. Also, since customer expectations were found to be consistently high, Cronin and Taylor (1992) proposed the SERVPERF service performance only model in a critique of the American model.

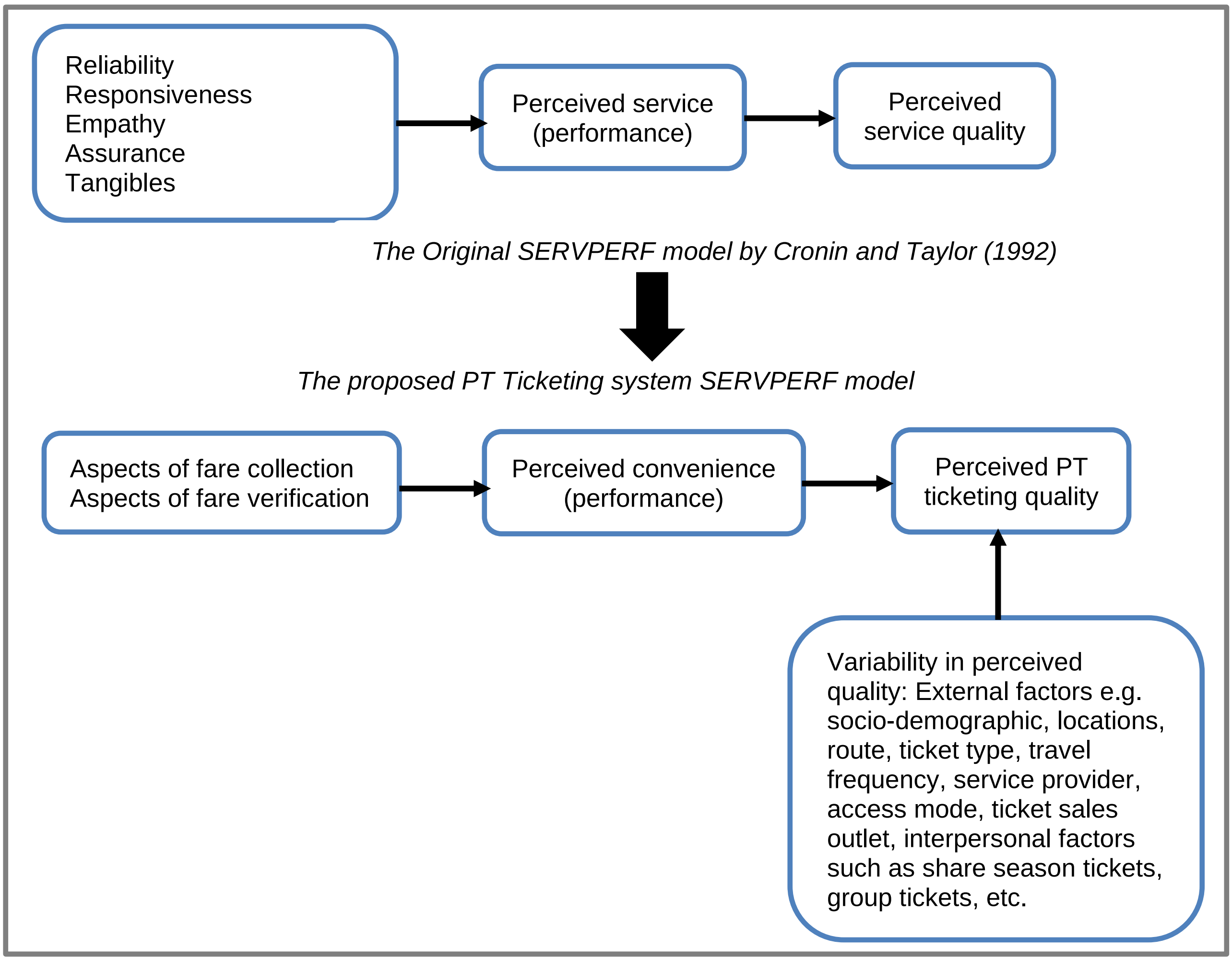

Figure 1-6: The SERVPERF model and the proposed PT Ticketing System SERVPERF model

In the case of PT service quality studies, De Oña and De Oña's (2014) provides a representative list of research works that used attitudinal surveys to measure PT service quality. Even though attitudes towards PT ticketing are central to measuring and understanding the perceived quality of ticketing, to the best of the author's knowledge, previous research works have not analysed PT ticketing aspects based on users' attitudes. Since PT ticketing is a secondary service towards accessing the primary PT service, Cronin and Taylor's (1992) SERVPERF model is considered simple but adequately robust for investigating the perceived quality (PQ) of a PT ticketing system. That is, the performance only model, SERVPERF, explains more variance in overall SQ compared to the difference between expectation and performance model, SERVQUAL, (Lee et al., 2000; Babakus and Boller, 1992; Boulding et al., 1993, Cronin and Taylor, 1992). It is also relatively less resource-intensive in terms of data requirements and computation and is easier to interpret. Interestingly, like the other models, the SERVPERF rarely considers external factors that may influence perceived quality. As shown in Figure 1-6, with the PT ticketing system as the attitude object, the original SERVPERF model has hence been extended to a "PT Ticketing System SERVPERF", thus including the analysis of the sources of variability in the perceived quality of a ticketing system. As empirically demonstrated in chapter 2, the "PT Ticketing System SERVPERF" is a 17-item Likert scale measuring PT users' attitudes or PQ towards seventeen ticketing attributes. The mean attitudinal scores across the surveyed PT users can then be used to estimated dimensional mean scores for fare collection, fare verification and the overall service quality of a given ticketing system. Besides using the mean attitudinal scores to establish the PQ of a specific ticketing system, these mean scores also serve as the dependent variable in analysing the external factors that may have an association with the perceived quality of ticketing.

The discrete choice modelling theoretical framework

As covered previously, both psychological and economic perspectives are widely used to analyse factors which determine the individual's travel behaviour. Transport economics is much founded on the argument that transport is essentially a derived demand (Button, 1982). Hence, decisions on whether to travel and how to travel are largely treated as rational attempts to maximise utility associated with accessing places and facilities whilst minimising the disutility associated with travelling. This economic perspective is sometimes considered as an oversimplification since human behaviour is sometimes systematically irrational. For instance, individuals sometimes undertake actions that are harmful to their wellbeing such as overconsumption of alcohol or cigarettes, while knowing the negative effects on their wellbeing. At the same time, previous research confirmed that people rationally accept longer commutes for better work incentives such as higher salaries (Beck and Hess, 2016). Hence, considering the fact that ticketing system improvements such as integrated ticketing constitute economic investments, an economic evaluation of these investments is central for providing information on whether the benefits of the investments outweigh the cost, justifying expenditure to funders and taxpayers and evidence for cost-effective solutions for future considerations.

The economic approach of rational choice is therefore considered more appropriate than psychological approach of human behaviour in analysing users behavioural response to integrated ticketing improvements based on the following three propositions:

- Commuting is primarily a derived demand emanating from the need to satisfy some regular commitments made by the individual
- The decision to commute and the choice of the means of commuting are rational decisions made by the individual as this is often a well-planned decision by the individual
- That PT ticketing constitutes some form of disutility for the individual commuter as it is not an end by itself, but a means of accessing the PT service.

The two main approaches to modelling travel behaviour in transportation economics are the aggregate modelling methodology (first-generation models), where individual travellers' decisions are grouped in the analysis (based on for instance traffic analysis zones) and the discrete choice modelling methodology (disaggregate or second-generation models), where individual travellers' choice behaviours are observed, modelled and analysed, based on a finite set of alternatives that are available to the individual decision-makers to choose from.

The disaggregate approach, especially the random utility model (RUM), has been extensively used in transportation research for more than 30 years for analysing and predicting traveller's choice behaviour (Train, 2009; Koppelman and Bhat, 2006). The discrete choice modelling theoretical frame has four main components – the individual decision-maker, a finite choice set of alternatives, attributes of the alternatives in the given choice set, and a choice rule that enables the individual to choose one of the available alternatives. The RUT was proposed by Thurstone (1927) as cited by Louviere (2010) and extended by McFadden (e.g. 1980, 1997, etc.) and others. The theoretical basis and derivation of these models are provided by (Luce, 1959; McFadden, 1980; Hensher and Johnson, 1981; Ben-Akiva and Lerman, 1985; Anderson et al., 1992; Koppelman and Bhat, 2006; Bierlaire, 1998).

The random utility theory (RUT) is the most common theoretical basis for discrete choice models. As illustrated in Figure 1-7, it assumes that the individual preferences are observable, latent and unobservable. That is, the utility can be represented by observable and unobservable parts. Figure 1-7 showed the RUT framework and the modified RUT framework for the analysis of users responses to integrated ticketing.

This modified RUT framework has been used to empirically analyse users' WTP for integrated ticketing in chapter 5, as well as the association between integrated ticketing and mode choice in chapter 6.

The assumption made about the distribution of unobservable error term defines the mathematical forms of probabilistic choice models such as the logit and probit classes of models. Bliemer and Rose (2011) review of 64 discrete studies conducted within the period 2000 to 2009 suggested that 59 (92%) of the studies used the logit class of models, only 3 (5%) used probit models, and 2 (3%) used the regression model.

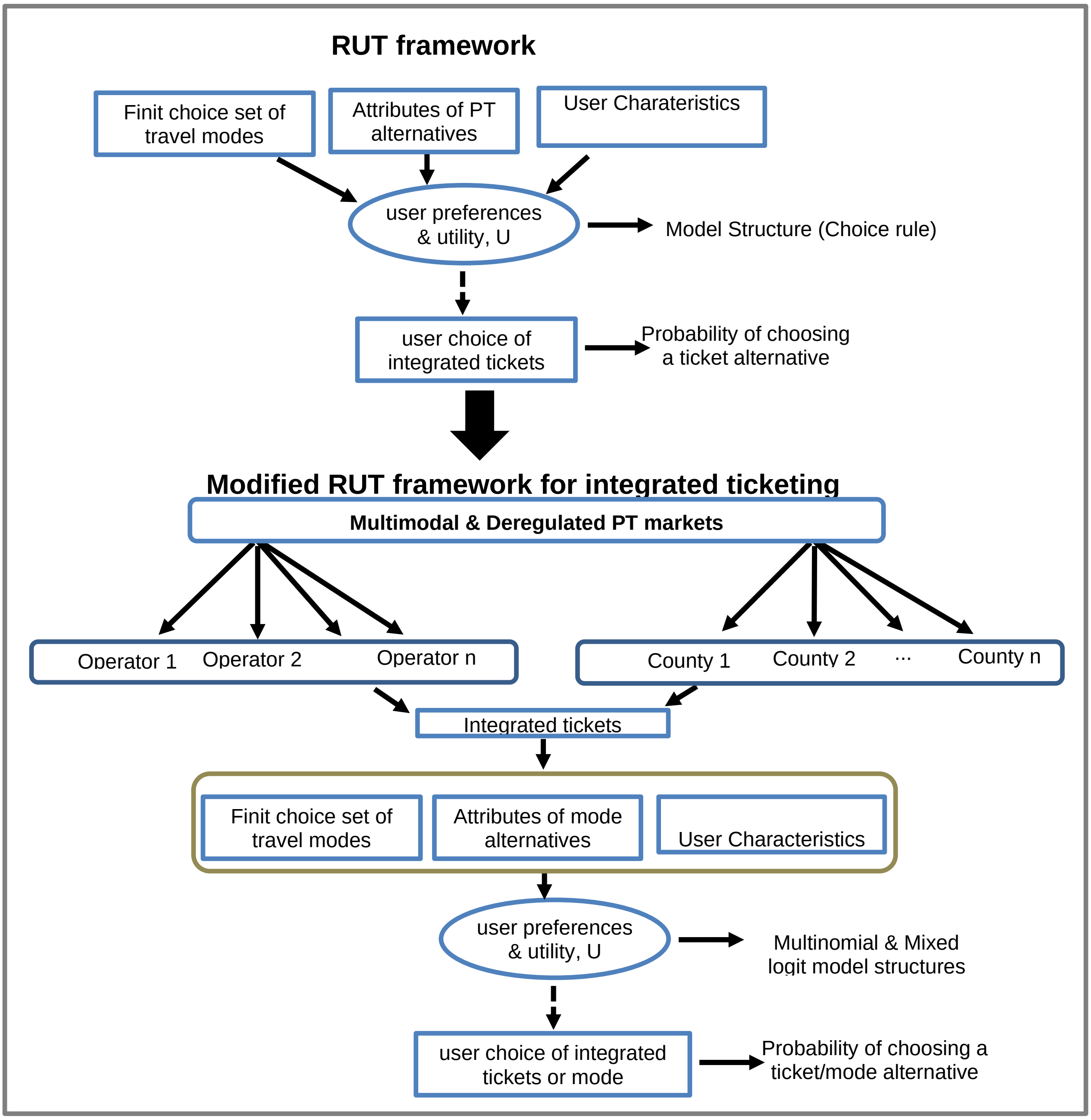

Figure 1-7: RUT Framework and Modified RUT Framework for Integrated Ticketing

Similarly, PT ticketing-related works that applied discrete choice analysis are largely base on the standard multinomial logit model (MNL). Yet, the MNL is based on the I.I.D assumptions. That is, it has a restricted substitution pattern, does not allow for random taste variation and does not account for correlation in unobserved factors over time (Train, 2009). The Multinomial Mixed Logit (MNML) is a very flexible model that can approximate any random utility model (Train, 2009). The MNML, which is the state-of-the-art analysis method in discrete choice modelling (Ortúzar and Willumsen, 2011), can handle all the limitations of the standard MNL model and was hence, used to make the analysis more robust.

Hence, considering commuters as the unit of analysis in this study and the above three propositions, the value that a commuter c assigns to a given ticket alternative i for commuting between origin p and destination q given a choice set of ticket alternatives C_j is given by the utility function U_{cipq}, in equation (1-1)

$$U_{cipq} = V_{cipq} + \varepsilon_{cipq} \qquad (1\text{-}1)$$

Where V_{cipq} is the deterministic part of the utility, and the ε_{cipq} is the random part.

Equation (1-1) is further expressed as:

$$U_{cipq} = \beta_y APT + \beta_z X_{cz} + \alpha_k \qquad (1\text{-}2)$$

Where; *APT* = attributes of the PT service, X_{cz} = a socioeconomic characteristic, z, of an individual commuter, c, β_y and β_z are vector of parameters indicating the marginal effects of each specified attribute of the PT service and socioeconomic characteristic on travel utility, and α_k = a parameter representing unobserved part of the utility.

The market share of each ticket alternative will be given by the probability that an individual commuter c chooses ticket alternative i from the given choice set of season ticket alternatives C for commuting between origin p and destination q can be computed using equation (1-3) (Train, 2009).

$$\mathrm{P}(\mathrm{i} \mid C) = \mathrm{P}\,(U_{cipq} \geq U_{cjpq}, \forall \mathrm{j} \in \mathrm{C}, \mathrm{j} \neq \mathrm{i}) = \frac{\mathrm{e}^{U_{cipq}}}{\sum_j \mathrm{e}^{U_{cjpq}}} \qquad (1\text{-}3)$$

The probabilities of the MNML are then the integrals of the standard logit model (in equation 1-3) over a density, i.e.

$$\mathrm{P}(\mathrm{i} \mid C) = \mathrm{P}\,(U_{cipq} \geq U_{cjpq}, \forall \mathrm{j} \in \mathrm{C}, \mathrm{j} \neq \mathrm{i}) = \int \left(\frac{\mathrm{e}^{U_{cipq}}}{\sum_j \mathrm{e}^{U_{cjpq}}}\right) f(\beta \mid \theta) d\beta \qquad (1\text{-}4)$$

Where $f(\beta \mid \theta)d\beta$ is the density function of β with θ being the vector of parameters of the density function, specified mean and variance if normal distribution is assumed.

Consequently, by using this state-of-the-art method in discrete choice modelling to analyse users' WTP for integrated ticketing as well as the association between integrated ticketing and mode choice for commuting, this study made a methodological contribution to the application of discrete choice analysis in PT ticketing research.

1.7.2 Survey design and data collection

Participatory methods are the best ways to get good understanding of behaviour knowledge (Anable et al., 2006). Hence, three travel surveys were conducted in this study (See the appendix section for the survey questionnaires, ethical assessment and approval).

Primary data for transportation research are often collected through automatic data collection, observational traffic survey or participatory transport survey techniques. While participatory transport surveys require the active participation of the survey respondents, the automatic and observational techniques do not, rendering these latter two techniques inappropriate for addressing the research objectives.

Participatory transport surveys may take the form of focus groups, household travel surveys (such as conventional household surveys, telephone surveys, etc.), trip end surveys (workplace, shopping centre, recreation facility etc.), online surveys, en-route surveys (road side interviews, questionnaire surveys, and license plate survey), and PT user surveys .

A review work by De Oña and De Oña (2014) confirmed that most previous works in PT SQ research used attitudinal surveys for gathering information from a sample of individuals. Since commuters were the interest group in this study, a combination online and participatory-intercept (or en-route) surveys on-board trains, at train stations and at the E4 motorway along the corridor was used. This is the most efficient way of collecting information from people making a given journey (Bonsall and O´Flaherty, 1997). Even though home interviews or household surveys have the potential to provide rich and useful dataset and help include potential commuters, it is the most difficult and expensive type of survey (Stopher, 2000). Thus, en-route and online survey provided cost-effective, direct and easy access to the commuters. In addition, Ortúzar and Willumsen (2011) pointed out that household surveys tend to generally give poor estimation of quality of service by respondents.

Also, participatory-intercept may take an interview or questionnaire format. En-route interview survey has a requirement for brevity due to the short contact time between data collectors and respondents. However considering the quantitative nature of the research objectives, the respondents were required to answer a relatively large set of questions so as to generate enough survey data. This made en-route questionnaire survey most suitable for the study compared to en-route interview survey.

Specific methods for collecting attitudinal and behavioural data include protocol analysis and keyword analysis, ranking exercises, rating and scaling exercises, RP, SP experiments, etc.

Survey based ratings have proven to be relatively efficient for the measurement of convenience and comfort factors in PT (Wardman, 2014; Douglas and Karpouzis, 2006), making rating the suitable technique for analysing the commuters attitudes to ticketing. These surveys often generate cross-sectional or time series data. Since the study covered pre-and-post implementation analysis of the ticketing improvement, two waves of cross-sectional data were administered to form panel data. While this data collection approach has a theoretical merit of reducing or removing unwanted statistical variations, and any differences detected in the waves could be attributed to an underlying change, they are often affected by sample attrition and this study was not an exception.

On the other hand, RP and SP methods are suitable for analysing discrete choice behaviour (Ortúzar and Willumsen, 2011). Thus, SP and/or revealed preference (RP) data are the standard methods for empirically estimating the monetary value of non-market goods like seamless transfer. The two-wave survey in this research, therefore, provided data on both the users' RP and SP. The RP data was collected in the second wave as the Movingo scheme was then implemented.

Both RP and SP are useful and well-established data collection methods in transportation research. A major advantage of RP over SP is that it deals with actual choices and measurement biases relating to SP are hence avoided. At the same time, a condition for using RP is that there is a market demand curve for the product in question and economic evaluation is usually more complex than this. Thus, RP merely captures "use value" while SP can capture total economic value (Kjær, 2005). Ortúzar and Willumsen (2011) also pointed out that RP has some practical weaknesses relating to survey costs and the difficulty of discerning the independent effects of attributes that are not easily observed such as quality, convenience and comfort. Consequently, the SP or pseudo panel dataset (described in chapter 5) was used in the trade-off analysis while the RP dataset (described in chapter 4) was used to evaluate the impacts of the Movingo scheme.

To make the travel survey process effective, efficient and to reduce sampling biases, the process for planning and conducting travel surveys suggested by (National

Centre for Transit research, NCTR, 2002; Bonsall and O´Flaherty, 1997; Richardson et al, 1995) was adopted. The steps followed included:

- definition and clarification of the survey objectives
- identification of the population and sample
- identification of the appropriate survey methods
- estimation of the survey cost
- development of a survey plan
- questionnaire design
- recruitment and training of surveyors
- conducting pre-test of questionnaires
- conducting the survey
- processing the data and, finally
- reporting the results

1.7.3 Sampling and characteristics of the observed samples

This section discusses survey sampling and the collected survey samples in terms of sample size and representativeness of the study area population.

Survey Sampling

As explained in section 1.6, the scope of the research, the target population was commuters along the Stockholm – Uppsala corridor. Nevertheless, a complete survey (census) of all these commuters is impracticable and beyond this study's scope. Hence, a random sampling of the commuters was required to obtain results accurate enough to be projected to the whole commuter population.

The apparent trade-off between sampling and census is that some level of error is introduced into the results since the entire population is not surveyed. This means that no matter how carefully the sample survey is designed and implemented, parameters estimated from the sample will be associated with some errors. The two main types of errors in survey samples are sampling error and sampling bias (Richardson et al.,1995).

Sampling bias arises from mistakes in some aspects of the sample survey such as sampling frame, sampling technique etc. and can therefore be eliminated. The approach and measures that were taken to manage sampling biases in the survey are explained in section 1.7.2.

On the other hand, sampling error can only be minimised since it is mainly a function of the sample size and the inherent variability of the parameter to be estimated. Thus, sampling error, the difference between the sample characteristics and the characteristics of the population from which the sample is drawn, expresses the lack of fit between the sample and the population.

The uncertainty in the error level is often handled with the Central Limit Theorem (CLT). It enables the uncertainty to be captured using the concept of confidence level. The CLT, the heart of sample size estimation, states that if a sufficiently large sample is randomly selected from any population with a population mean μ and population standard deviation, σ, the sample mean is approximately normally distributed with mean μ and standard deviation $\sigma/\sqrt{\boldsymbol{n}}$ (Washington et al., 2010). Thus, the mean of a sample approaches a normal distribution as the sample size increases to a reasonable size (> 30). The theorem still covers small sample sizes only if the original distribution is bell-shaped. The sample size is, therefore, an important factor of any empirical study in which the goal is to make inferences about a population from a sample.

For continuous variables, the sampling error in a random sample (i.e. the standard deviation of the distribution of the samples means), $\boldsymbol{se}$, is then given by equation (1-5)

$$\boldsymbol{se} = {}^{\boldsymbol{s}}/_{\sqrt{\boldsymbol{n}}} \qquad (1\text{-}5)$$

Where s is the sample standard deviation of the measure of interest and n is the sample size. This expression implies that the sampling error in a random sample is a function of only the variance of the measure of interest and the sample size. Hence the sampling error can only be reduced by increasing the sample size. Yet increasing the sample size can increase the survey cost with only small reduction in the error in comparison to the cost. Sampling may be done with or without replacement. The sampling in this study was done without replacement as sampling with replacement is not suitable for a survey of human-subjects (Stopher, 2000). This is mainly because most individuals will object to completing the same survey or interview twice.

From the above expression, the sample size or number of sampling units, n, required for a point estimate, say the population mean, $\bar{\mathbf{x}}$, for a large population can be computed using equation (1-6)

$$\boldsymbol{n} = \frac{\boldsymbol{s}^2}{\boldsymbol{se}(\bar{\boldsymbol{x}})^2} \ \boldsymbol{or}\ \boldsymbol{n} = \frac{\boldsymbol{s}^2}{\boldsymbol{se}(\bar{\boldsymbol{x}})^2}/(\mathbf{1} + (\frac{\boldsymbol{s}^2}{\boldsymbol{se}(\bar{\boldsymbol{x}})^2}/\boldsymbol{N})), \text{for a finite population size N} \qquad (1\text{-}6)$$

For discrete variables such as a commuter owns a car or not, the CLT applies to the proportion of a sample possessing a certain characteristic, for example, the percentage of people commuting by car. The standard error for the estimation of a proportion p is given by equation (1-7)

$$se(\boldsymbol{p}) = \sqrt{\frac{\boldsymbol{N}-\boldsymbol{n}}{\boldsymbol{N}} * \frac{\boldsymbol{p}(\mathbf{1}-\boldsymbol{p})}{\boldsymbol{n}}}, \qquad \boldsymbol{Hence}, \qquad \boldsymbol{n} = \frac{\boldsymbol{p}(\mathbf{1}-\boldsymbol{p})}{\boldsymbol{se}(\boldsymbol{p})^{2}} / (\mathbf{1} + (\frac{\boldsymbol{p}(\mathbf{1}-\boldsymbol{p})}{\boldsymbol{se}(\boldsymbol{p})^{2}} / \boldsymbol{N}) \qquad (1\text{-}7)$$

Sampling methods may generally be grouped into probability and non-probability. The eight major ones used in transportation surveys, according to Stopher (2000), are simple random sampling, stratified random sampling with uniform sampling fraction (proportionate sampling), stratified random sampling with variable sampling fraction (optimal or disproportionate sampling), cluster sampling, systematic sampling, choice-based sampling, multistage sampling and overlapping sampling. Detailed descriptions of these sampling strategies are provided by (Stopher, 2000; Ortúzar and Willumsen, 2011; Bonsall and O´Flaherty, 1997).

While simple random sampling was considered appropriated for surveying car commuters along the E4 motorway, stratified random sampling with uniform sampling fraction was considered most appropriate for surveying the PT commuters. It allowed the collection of the same amount of information as simple random sampling with a smaller number of respondents. The corridor PT travel market was stratified based on the three separate train lines (SL/UL, SL and SJ) serving the corridor, with commuters on each line constituting a stratum. Applying proportionate sampling ensured adequate representation of each stratum, and it reduces the sampling error compared to simple random sampling. This is because only the part of the variance that is within the strata counts in the estimation of the sampling error, and the remaining variance between the strata does not add to the sampling error (Stopher, 2000).

Accepting a 5% margin of error, for a 95% confidence level, the minimum sample sizes for the identified strata were computed using the equation (1-8). 95% level of certainty implies that in 95 out of 100 times, the result will be within the range of the margin error. That is, there is a 95% probability that the error of the mean estimate is not more than 1.96 times the standard error. There is, however, a 5% chance that the true value will be outside of the range.

$$\boldsymbol{n} \geq \frac{\boldsymbol{p}(\mathbf{1}-\boldsymbol{p})}{\left(\frac{\boldsymbol{e}}{\boldsymbol{z}}\right)^{\mathbf{2}} + \frac{\boldsymbol{p}(\mathbf{1}-\boldsymbol{p})}{\boldsymbol{N}}} \qquad (1\text{-}8)$$

Where: p = the proportion of regular daily commuting trips = 0.5, n = the sample size, N = the population size (observed average daily commuting trips), e = the expected error = 0.05, and z = z-score, the standard normal variate value for the chosen 95% confidence level = 1.96.

Public transport commuter surveys

An overview of the travel surveys is presented in Table 1-1, with the detailed descriptions provided in Chapter 2 through to chapter 6.

Table 1-1: An overview of the travel surveys

Survey	Date	Sample size (Response rate)	Survey Description
Onboard PT survey, wave 1	Sep. 2017 (Pre-Movingo)	n = 1320 (63 %)	Behaviour, attitudinal & SP
Web PT survey, wave 2	Sep 2018 (Post-Movingo)	n = 165 (36.7 %)	Behaviour & attitudinal survey
Car commuter survey	April 2018 (Post-Movingo)	n = 96 (20 %)	Behaviour & SP survey

The sample size is generally a significant factor in empirical studies where the goal is to make inferences about a population from a sample. Yet, it is impossible to select a sample from a population that represents the population perfectly (Salkind, 2009). A conventional approach to analysing post-survey non-response bias is to compare the sample estimates with estimates from a more reliable source such as government surveys (Groves, 2006). Statistics Sweden mobility data and data from the Swedish PT barometer were used for this comparison in this research.

Statistics Sweden reported in 2018 that about 23297 workers commute between Stockholm county (all municipalities) and the Uppsala municipality. This actual target population is slightly higher than this figure as it includes a relatively small proportion of student commuters. The Swedish PT barometer classified citizens into four traveller groups based on their frequency used mode of travel – Frequent car users, frequent PT users, those who frequently alternate between car and PT and those who choose car or PT once in a while. The proportions of these groups in the 2018 PT barometer report were 44%, 14%, 38% and 3%, respectively. Applying these proportions to the target population of 23297 commuters provides an estimate of the target population per mode. That is 12114 PT commuters and 11183 car commuters.

The first PT survey wave has more than the minimum required sample size of 384 at a 5% margin of error. Concerning the representativeness of this first PT survey wave, the distributions of gender, age and income in the sample is compared with Statistics Sweden data for Stockholm and Uppsala.

The gender distribution in these two geographic areas is the same. 49.5% men and 50.5% women (SCB, 2020). The gender distribution in the sample (Table 2-2) is 57% women and 43% men. This gender variability in the sample is a characteristic of the studied PT commuter population as more women patronise the PT service than men (SKT PT Barometer, 2018).

The national age distribution (SCB, 2018 – Uppsala kommunfakta) and that of the sampled PT commuters are provided in Table 1-2. These two age distributions are not directly comparable as it is just a proportion of the citizens that commute by PT. The sample distribution, however, tends to highly represent active commuting age groups.

Table 1-2 Swedish national and sample age distribution

Age group	National (%)	PT sample (%)
0 – 15	18	-
16 – 24	10	18
25 – 44	26	51
45 – 64	25	29
65+	20	2

The average monthly income (before tax) for the subpopulation 20 years and above in the Uppsala municipality 27200 SEK/Month, and that of Stockholm is 33500 SEK/Month (SCB, 2020). As summarised in Table 2-2, slightly less than 25% of the sample respondents fall within these two averages, 28% below and, 40% above. That is, most commuters of this corridor have higher than average level income.

Typical of panel surveys, there was a significant reduction in the sample size in the second PT survey wave due to attrition (Table 1-1). While this sample is still considered statistically large enough for the analysis, it has a larger margin of error than the sample in the first wave. For a 10% margin of error, a minimum sample size of 95 respondents would be required. The observed sample size of 165 respondents is significantly higher than this minimum.

The representativeness of the second PT survey wave is established by pairwise comparison of the proportions of key variables such as gender, age, income and commuting frequency in the two survey waves. The results of the test of equal proportions (with H_0: $P_1 = P_2$, and H_a: $P_1 \neq P_2$) for the two survey samples are summarised in Table 1-3.

The proportion of women and men in the two survey waves is not different. Regarding age, the two samples differ in proportion for the age groups 16-24, 45-54 and 55-64. Yet, only the age group 16-24 seemed underrepresented in wave 2. The proportion of income groups for the two samples is largely equal except for 35001–50000 and over 50000. The income group 15 001–25 000, however, seems underrepresented. The two samples generally have a good representation of commuting frequency even though there exists a difference in the proportions for people commuting at least five days per week.

Table 1-3: Test of equality of proportions for wave 1 and wave 2

Variable	Wave 1 (%), n =1320	Wave 2 (%), n =165	Test of equal proportions
Gender			
Female	56.9	54.5	χ^2 = 0.240, df = 1, p-value = 0.623
Male	42.6	44.8	χ^2 = 0.223, df = 1, p-value = 0.636
Age (Years)			
16 – 24	17.8	4.8	χ^2 = 17.05, df = 1, p-value = 000
25 – 34	29.7	24.8	χ^2 = 1.443, df = 1, p-value = 0.230
35 – 44	20.8	18.8	χ^2 = 0.260, df = 1, p-value = 0.610
45 – 54	18	28.5	χ^2 = 9.673, df = 1, p-value = 0.002
55 – 64	11.3	20.6	χ^2 = 10.94, df = 1, p-value = 0.001
65+	2.4	2.4	χ^2 = 0.042, df = 1, p-value = 0.837
Monthly gross income in SEK			
0–15 000	21	11.6	χ^2 = 3.027, df = 1, p-value = 0.082
15 001–25 000	7	3.6	χ^2 = 2.131, df = 1, p-value = 0.144
25 001–35 000	25	20.6	χ^2 = 1.302, df = 1, p-value = 0.254
35 001–50 000	25	33.9	χ^2 = 5.637, df = 1, p-value = 0.018
Over 50 000	15	24.8	χ^2 = 9.818, df = 1, p-value = 0.0017
Will not disclose	7	5.5	χ^2 = 0.319, df = 1, p-value = 0.572
Commuting frequency by train (days/week)			
1 – 2	7.4	6.1	χ^2 = 0.227, df = 1, p-value = 0.633
3 – 4	25.4	20.6	χ^2 = 1.543, df = 1, p-value = 0.214
≥ 5	58.1	67.3	χ^2 = 4.727, df = 1, p-value = 0.0297
Rarely	5.7	4.2	χ^2 = 0.339, df = 1, p-value = 0.560
Never	3.4	1.8	χ^2 = 0.733, df = 1, p-value = 0.392

Car commuter survey

The target population of this crossectional car travel survey was car commuters along the Stockholm – Uppsala section of the E4 motorway. The estimated population size is 11183, and the minimum required sample size at 5% margin of error is 370 respondents or 95 respondents at 10% margin of error. As shown in Table 1-1, the observed sample size was relatively small. It is yet still considered statistically large enough for the analysis with a likely increased margin of error. The user characteristics used in the model estimation (Table 6-3) are income, gender, commuting frequency by car, and company car use for commuting trips. All these groups have a good representation in the sample. In terms of representativeness, there were more males (68%) than women (32%) in this sample. This is a characteristic of the studied population as men tend to patronise the automobile more than women in the study area and in Sweden as a whole (SKT PT Barometer, 2018). Regarding income, most of the respondents (88%) have monthly income above the average income level.

1.8 Thesis Outline and Contributions of the Research

Considering the Faculty of Environment's protocol for the format and presentation of an alternative style of a doctoral thesis including published material (Version 4, updated March 2019), this section provides an outline of the thesis. It has three (3) major parts. Part I provides a more general introduction to the research (chapter 1). Part II contains five chapters (chapter 2 through to chapter 6), whereby each of the five papers that were written during the research forms a chapter. Part III provides a final discussion, some methodological reflections, conclusions and recommendations for future work (chapter 7).

Figure 1-4 summarises the relationship between the research gaps, overall research aim (thesis level), specific research objectives (paper level), the attached papers & research methods.

Chapter 2 presents a paper entitled *"Revisiting public transport service delivery: exploring rail commuters' attitudes towards fare collection and verification systems"*. Given the need for knowledge concerning PT users' attitudes and perceptions towards fare payment and fare inspection (i.e. Research gap 1), the aim of this paper was to explore commuters' attitudes to fare collection and verification systems. The findings showed that PT commuters were showed variability their attitudes to ticketing with respect to the factors income, commuting route, ticket type and ticket purchase channel. They had a more positive attitude towards fare collection compared to fare verification and showed preference for automatic fare inspection compared to manual fare inspection by staff. They were also neutral to the policy of "No-ticket-purchase on-board". This paper contributes to both the literature and policy by identifying some variables that can influence commuters' assessment of the quality of fare collection and verification systems, pointing out future directions for enhancing fare inspection, and providing information on users' acceptance of the "No-ticket-Purchase onboard PT vehicle" policy.

Chapter 3 presents a paper entitled *"Seamless ticket inspection: Proposing and exploring users' reaction to a next generation public transport ticket inspection solution"*. Considering the general lack of knowledge on PT users' preference and satisfaction with ticket inspection, and the need to apply new technologies in the development of smarter and seamless ticket inspection solutions (i.e. Research gap 2), the aim of this paper was to investigate PT users' preferences for ticket inspection options and the factors that correlate with their likelihood of accepting a seamless ticket inspection solution. The results showed that the majority of the respondents opted for seamless fare inspection and major PT user groups such as females and young people have a high tendency to accept seamless fare inspection. This paper contributes to the field by giving new information on how PT user characteristics may influence their preferences for ticket inspection alternatives and this information is relevant for both researchers and practitioners that are concerned with improving PT ticket inspection systems.

Chapter 4 presents a paper entitled *"The Movingo integrated ticket: Seamless connections across the Mälardalen region of Sweden".* Given limited evidence on the benefits of regional integrated ticketing (i.e. Research gap 3), the object of this paper was to analyse the effects of the Movingo integrated season ticket scheme in the Mälardalen region of Sweden on ridership, user satisfaction and on the perceived quality of ticketing. The study revealed that while this regional integrated ticketing did not enhance the perceived quality of the ticketing due to interoperability challenges, it made PT commuting attractive and increased user satisfaction due the many synergistic effects of the integration that reduced the generalised cost of PT commuting. This work contributed to the literature on the benefits of integrated ticketing, it identifies areas for improving the Movingo scheme and provided the project stakeholders with information on how the scheme contributed to their strategic goals. It also provide important lessons for other authorities and stakeholders looking to introduce or improve integrated ticketing.

Chapter 5 presents a paper entitled *"Public Transport Users' Valuation and Willingness-to-pay for a Multi-region and Multi-operator Integrated Ticketing System".*

Mindful of wide spread investments into integrated ticketing due to barriers resulting from multimodal and deregulated PT markets and the lack of knowledge of PT users' preferences and willingness-to-pay for integrated ticketing systems (i.e. Research gap 4), the objective of this paper was to estimate users' willingness-to-pay for a regional integrated ticketing system. The findings suggest strong evidence of heterogeneity in users' willingness-to-pay for the benefits associated with integrated ticketing. Methodologically, the application of discrete choice modelling in PT ticketing research has been dominated by the use of the multinomial logit model, however, by applying the multinomial mixed logit (MNML) model in this work, it was demonstrated that the MNML greatly improves the model estimation results. In terms of policy, the estimated range of willingness-to-pay values can be used in cost-benefit-analysis to estimate the value of integrated ticketing for PT users and society.

Chapter 6 presents a paper entitled *"Examining the effect of multi-regional and multi-*service provider integrated ticketing system on mode choice for commuting". The effects of some PT service improvements such as integrated ticketing, are not often considered in travel demand forecasting (i.e. Research gap 5). The aim of this paper was to investigate the correlation between multi-regional integrated ticketing and mode choice for commuting. The findings showed a positive effect of integrated ticketing on mode choice for commuting. Income, frequency of commuting, gender and the use of employer's car for work trips were some of the factors that explained the choice behaviour. The policy implication of this work is that it provides evidence for including the effects of integrated ticketing in travel demand analysis. The work thus made an original contribution to the improvement of travel demand forecasting at regional and national levels.

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Part II: The Attached Papers

Chapter 2

Revisiting public transport service delivery: exploring rail commuters' attitudes towards fare collection and verification systems

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Abstract

Making Public Transport services more attractive and effective requires attractive and effective ticketing. This requires a clear understanding of user attitudes, needs and expectations. This study explored commuters' attitudes to fare collection and verification and the underlying factors, their acceptance of the policy of "No-ticket-purchase on-board" and their preferences for fare verification options. Commuters rated their agreement with 17 ticketing related statements in a cross-sectional questionnaire survey conducted along the corridor with the largest proportion of cross-county commuting in Sweden, Stockholm – Uppsala. Four sets of hypotheses were then tested. The average scores were normally distributed and hence analysed using a two-way ANOVA. A One-way chi-square test was conducted to determine the commuters' preference for fare verification approach. A t-test was used to analyse the perceived quality of ticketing and the commuters' reaction to the policy of "No-ticket-purchase on-board PT vehicle". Whilst the results showed that the commuters were relatively uniform in their attitudes, income, commuting route, ticket type and ticket purchase channel affected their attitudes. They were neutral to the policy of "No-ticket-purchase on-board". Their attitude to fare collection was more positive than that of fare verification and they showed a preference for automatic fare verification. The study highlights a number of policy implications and recommends further research on the feasibility of passive fare verification and on commuters' preferred options for fare verification.

Keywords: *Attitudes, commuters, convenience, fare collection, fare verification, ticketing.*

2.1 Introduction

The fare is one of the main service aspects of public transport (PT) that enables service providers and stakeholders to achieve ridership targets (Paulley et al., 2006, Redman et al, 2013). Fare policies are generally implemented by means of ticketing, and this constitutes the interface between a PT user and the PT service. Hence, ticketing is an integral part of the PT system and one of the aspects of the PT service that affects user convenience and accessibility and, consequently, PT service quality (SQ).

PT ticketing requires the active participation of users. That is, users are required to allocate some time and effort to the processes of PT fare collection and fare verification. Users need to allocate time and effort, firstly, into the act of paying for a trip - fare collection, and secondly, into enabling the service provider to check that passengers have paid for the intended or completed journey - fare verification (BRT Planning Guide, 2007). Given that PT ticketing is not an end by itself but a means of accessing the PT service, it constitutes a source of inconvenience to users compared to, for instance, users of the private automobile. Yet, little is known about users' attitudes and perceptions towards these two main dimensions of ticketing.

Using Stockholm – Uppsala corridor in Sweden as a case study, this study contributes to the literature by exploring commuters' attitudes to fare collection and verification systems and the underlying factors, their perceived quality of these systems, their acceptance of the policy of "No-ticket-purchase on-board" as well as their preferences for fare verification options. Four research questions are addressed by the study:

- What factors influence PT commuters' attitudes to PT ticketing? (I.e. are there any differences between the average attitudinal scores of the different commuter segments?).
- What are PT commuters' attitudes towards PT fare collection and verification systems?
- Do PT commuters have preferences between the available fare verification options?
- Does familiarity with the policy of "No-ticket-purchase on-board PT vehicle" breed its acceptance amongst PT commuters?

Consequently, four sets of hypotheses were tested to address these questions. Given that all the independent variables were categorical and that the dependent variable (average scores) was normally distributed, a two-way Analysis of Variance

(ANOVA) was used to analyse heterogeneity in the mean attitudinal scores. A One-way chi-square test was conducted to determine the commuters' preference for fare verification approach and a t-test was used to analyse their perceived quality of ticketing and their reaction to the policy of "No ticket purchase on-board PT vehicle".

The four main contributions of the study are:

- It provides insight into the factors that affect commuters' evaluation of the quality of fare collection and verification
- It proposes a future direction for improving PT fare verification. Thus, by identifying the commuters' preferred choice of fare verification, Public Transport Authorities (PTA's) could use the results to support decisions on future fare verification systems.
- It provides rail service providers along the Stockholm-Uppsala corridor with information on the acceptance of the policy of "No-ticket-purchase on-board PT vehicle" by users. Other PTA's who intend to implement this kind of policy may draw on this example.
- It provides the service providers within the study area with up-to-date information on the quality status of fare collection and verification, thus providing some base data for evaluating the perceived quality of fare collection and verification both before and after the implementation of the Movingo integrated season ticket project. Movingo which is described in section 3 is an integrated ticketing scheme among six neighbouring PTA's and a commercial rail service provider (the Swedish national railways, SJ).

The rest of the paper is organised as follows. The next section provides a review of literature on PT SQ studies and ticketing. Section 2.3 describes the study area. Section 2.4 presents the theoretical framework, attitude measurements and how the data was collected and analysed. Section 2.5 focuses on the findings. Section 2.6 offers a discussion of the results and the final section provides some concluding remarks.

2.2 Literature review

PT SQ measurements is of high importance for both PT service providers and regulatory agencies as this is central to retaining current users and attracting new users. This motivates many studies on PT service quality and satisfaction using data often collected from user surveys (De Oña and De Oña, 2014). Two main perspectives on the measurement of service quality and user satisfaction exist. Based on user experience (perceived quality) or based on users' expectation (expected quality). The former is more common in PT service quality studies (Allen et al, 2018).

Table 2-1: Common PT service quality dimensions. Modified from an earlier review by Morton et al (2016)

Authors	Year	Service Quality Dimensions
Jaime Allena, Juan Carlos Muñoz, Juan de Dios Ortúzar.	2018	Service frequency, bus-stop, accessibility, busses and drivers, peripheral (image)
L. Eboli, C. Forciniti, G. Mazzulla.	2018	Safety, cleanliness, service, facilities for disabled people (additional services), information
Mahmoud & Hine	2016	Comfort, transfer requirement, stop location, park and ride, waiting time, reliability, service frequency, information, fare, discounts and safety
Rocio de Oña & Juan de Oña	2015	Accessibility, cleanliness, courtesy, fare, service frequency, information, proximity (stops), punctuality, safety, bus space, speed and temperature
Şimşekoglu, Nordfjærn, & Rundmo,	2015	Flexibility, convenience, safety
Chou, Lu and Chang	2014	Tangibles, convenience, employee interaction and reliability
Yaya, Fortià, Canals & Marimon	2014	Functional, physical and convenience
Carreira, Patrício, Jorge & Magee	2013	Individual space, information provision, staff skill, social environment, vehicle maintenance, off-board facilities, and ticket line service
Juan de Oña, Rocío de Oña, Laura Eboli, Gabriella Mazzulla.	2013	Accessibility, cleanliness, courtesy, fare, service frequency, information, proximity (stops), punctuality, safety, bus space, speed, temperature
Susnienė D.	2012	Tangibles, reliability, responsiveness, assurance, empathy
L. dell'Olio, A. Ibeas, P. Cecin.	2011	Waiting time, vehicle occupancy, cleanliness, journey time, driver kindness, comfort
Lai & Chen	2011	Core services and physical environment
Laura Eboli, Gabriella Mazzulla.	2010	Route characteristics, service characteristics, service reliability, comfort, cleanliness, fare, information, safety and security, personnel, customer services, environmental protection.
Laura Eboli, Gabriella Mazzulla.	2010	Walking distance to bus stop, service frequency, reliability, bus stop facilities, bus crowding, cleanliness, fare, information, transit personnel
Friman & Fellesson	2009	Frequency, seat and travel time
Pérez, Abad, Carrilo & Fernández	2007	Tangibles, reliability, responsiveness, assurance, empathy
Laura Eboli, Gabriella Mazzulla.	2007	Service planning and reliability, comfort and ancillary factors, network design
Stradling, Carreno, Rye & Noble	2007	Safety, service provision, unwanted arousal, cost, disability access, self-image

Perceived quality is commonly measured as an attitude in PT SQ studies (De Oña and De Oña, 2014). Perception refers to how something is viewed, understood or interpreted. An attitude, on the other hand, refers to the value an individual put on something (often known as the attitude object) and it may be negative, neutral or positive (Richardson, 2014).

A fundamental feature of PT SQ studies is that the overall perceived quality of a given PT system is measured by including relevant factors from different aspects of the PT service as experienced and reported by users. Identifying these relevant set of quality dimensions poses a challenge (Hensher et al., 2003) as no general standard currently exists. Many attributes have been proposed in different studies in efforts to correctly define PT service quality. Redman et al. (2013) grouped them into two. The first group attributes such as reliability, speed, travel time, etc. are those that can objectively or physically be measured without involving users. The second group are those perceived attributes such as comfort, convenience, ease of use, etc., which are measured by involving users through for instance user surveys. The quality dimensions commonly used in measuring PT service quality are presented in Table 2-1.

PT ticketing is a tool for implementing a PT fare policy and thus, an integral part of the PT system. Whilst its main aim is to collect revenue, it has been confirmed to be characterized by factors that affect passenger convenience and comfort, passenger information requirements, accessibility, vehicle dwell times (which affects travel time and service frequency), service reliability, passenger security, operator security, complexity of PT infrastructure and hence aesthetics, PT revenue collection cost and consequently PT demand (Puhe, 2014; White, 2009; and Vuchic, 2005). Thus, it remains an important aspect of PT SQ and operational efficiency (Blythe, 2004). Consequently, making PT services more attractive and effective requires attractive ticketing and this is only possible through a clear understanding of user attitudes, behaviour, needs and expectations (Anderson et al., 2013, Schiefelbusch, 2009).

Masabi (2016) reported customer satisfaction as one of the major benefits of mobile ticketing as users no longer need to wait in ticket lines. Similar benefits have been reported from implemented smart card technologies such as the Oyster in London, SL Access card in Stockholm, Combi-card in Tampare, Octopus in Hon Kong, Charlie card in Boston, Te´ce´ly card in Lyon, Myki card in Melboune, PASMO and Suica card in Tokyo (UK department for transport, 2009; Blythe, 2004). Obviously, the evolution from paper tickets and tokens to magnetic strips, smart cards and mobile devices as well as the volume of ongoing ticketing improvement interventions and investments globally confirms the magnitude of PT ticketing problems that service providers and other stakeholders are seeking to minimize or eliminate. For instance, making fare collection more convenient for users is a major recommendation in Northeast Florida's regional fare study (2018). The UK department for transport (2009) in its smart and integrated ticketing strategy also emphasised that ticketing should focus on the passenger. Transport for London having succeeded with the

Oyster card has set out a vision for improved and integrated electronic transport ticketing infrastructure for the whole of England by 2020 (Turner and Wilson, 2010). In Mass Transit survey (2016), over two hundred PT professionals were interviewed and most of them (at least 66%) agreed that fare evasion, cash handling and customer satisfaction are the three top challenges that new ticketing technologies need to solve. The survey cited available ticketing options, convenience of purchase, speed of purchase, and simplified fares as the ticketing attributes that need enhancement.

Yet, the assessment of the quality of PT ticketing systems and attitudes to ticketing have received limited consideration in published PT literature. As summarised in Table 2-1, even though PT SQ and satisfaction studies is a matured field of study, previous studies have tended to exclude the perceived quality of PT ticketing as a quality dimension of the PT service. PT user inconveniences such as ease of purchase, speed of purchase, barrier effects of turnstiles, ease of use of ticket vending machines, accessibility to tickets and inter-transit systems transfer challenges are some obvious issues associated with ticketing. While these issues may relate to fare, and fare is clearly a very important determinant of PT demand, the effects of perceived quality of PT ticketing on user experience are not the same as that of fare. Many of the studies that included fare in the evaluation of the perceived service quality of PT systems overlooked ticketing aspects (Mahmoud and Hine, 2016; De Oña and De Oña, 2015; De Oña et al., 2013; Eboli and Mazzulla, 2010). Very few studies included some aspects of ticketing inconveniences as a relevant factor in PT SQ evaluation, and these were often limited to aspects of fare collection, with almost no consideration of fare verification aspects. For instance, Carreira et al (2013) included only ticket line service, measured as empathy at the ticket line and not having to wait to buy a ticket. Also, Abenoza et al. (2016) included ease of purchasing tickets as an attribute in their analysis of travel satisfaction with PT in Sweden from 2001 to 2014 and reported that it generally followed a negative trend.

While the holistic analysis of PT service quality is undeniably valuable for improving its ability to compete favourably with alternative travel modes, looking into specific aspects of PT service quality provides in-depth understanding of how current PT users perceive these aspects. For instance, many studies have been conducted on users' perceptions of specific PT service aspects such as fares (Balcombe et al, 2004); travel time (Wardman, 2014); overcrowding (Batarce et al, 2016); free transfer (Chowdhury and Ceder, 2016); bus stop and station attributes; vehicle attributes; travel information; delay; rail service attributes (Douglas and Karpouzis, 2006) etc. Yet, little is known about attitudes and perceptions of PT users towards PT ticketing and its integration factors (Chowdhury and Ceder, 2016). Consequently, given the importance that attitudes and perceived quality play in understanding and improving PT systems, it is important that users' attitudes towards PT ticketing and their perceived quality of ticketing systems are explored.

Commuters are an important and well-defined group of users, and commuting constitutes a substantial portion of daily trips globally (SKL, 2008; Beck and Hess, 2016). Furthermore, where commuting involves crossing municipal boundaries or national borders there is the potential for PT ticketing issues to be heightened. In Sweden, 31% of the working population commuted beyond municipal boundaries in 2006 and the total number of commuters between Sweden and it's three neighbouring countries as at 2005 was 31865 (SKL, 2008).

The objectives of this paper are thus twofold. To investigate commuters' attitudes towards PT fare collection and fare verification systems, and their perceived quality of these systems using the corridor with the largest proportion of cross-county commuting in Sweden, Stockholm – Uppsala, as a case study.

2.3 Description of the case study area and the Movingo project

With increased PT usage from about 18% to 27% between 2006 and 2014 (Association of the Swedish Public Transport, SKT, 2016), Sweden is one of the seven countries in the European Union where the growth of PT usage has been sustained between 2010 and 2014 (UITP, 2016). This trend is expected to continue and, as efforts are made towards achieving the national goal of doubling PT usage and in line with the EU Interoperable Fare Management Project (EU IFM), more PT ticketing improvement schemes are being implemented in Sweden than ever before. Movingo is one such ticketing improvement initiative among six neighbouring Public Transport Authorities (PTAs) and a commercial rail service provider (the Swedish national railways, SJ). It is a smartcard and mobile phone based multi-operator season ticket that applies to both intercity and intracity bus and train services within and across the geographic boundaries of the cooperating six counties, called the Mälardalen region (Figure 2-3).

With the Movingo ticket, commuters have the option to buy a season ticket that is valid for at least two of the counties. Sales of Movingo started in October 2017 with commuters and other frequent travellers as the target group. It has options for only one month, three months and one year but no options for periods less than 30 days. With an average monthly sale of 13400, a total of 53700 Movingo tickets were sold within the first four months of Movingo (Figure 2-2). The Stockholm – Uppsala route section has the largest share, and 90% of the tickets sold were 30 days tickets. Tickets bought are non-refundable and season tickets for periods less than 30 days are still available from the individual service providers.

The main smart aspects of Movingo are: seamless transfers across different PT modes within the entire region, improved convenience for users (as they no longer need to hold more than one season ticket), simplified fare and zone structure, improved ease of commuting by PT, flexibility to buy the ticket anytime and anywhere, time savings through reduced queues at ticket sale's points, discounts for students, reduced transaction and administration costs, reduced fraud and enhanced data acquisition.

The Stockholm – Uppsala corridor (marked by the red ring line in Figure 2-3), which has the largest proportion of cross-county commuting trips in Sweden, was the area of focus for this investigation. Both PTAs in the study area use a hybrid fare structure that combines both flat fare and zonal graduated fare structures. The flat fare applies to season tickets while the zonal graduated fare applies to single-journey tickets. The Swedish national railways, SJ, however has a distanced-based fare structure, largely between intercity train stations. The pricing strategy for Movingo is thus both flat and distance based.

Figure 2-1 presents the demand growth for Movingo within the first one year of its implementation. There was 1.2% increase in sales in October 2018 compared to October 2017 (the launch month). Demand is lower in December and lowest in July since these are normally holiday months.

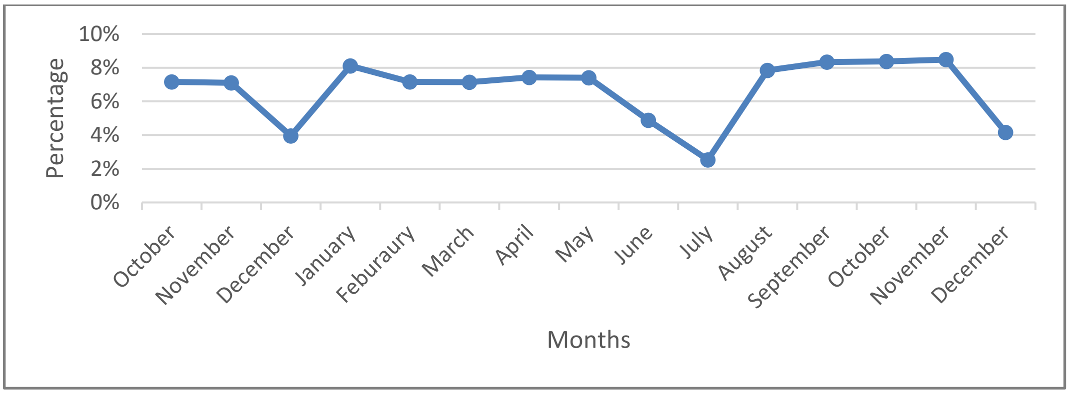

Figure 2-1: Monthly sale proportions of Movingo from October 2017 to December 2018. Source: MÄLAB, 2018

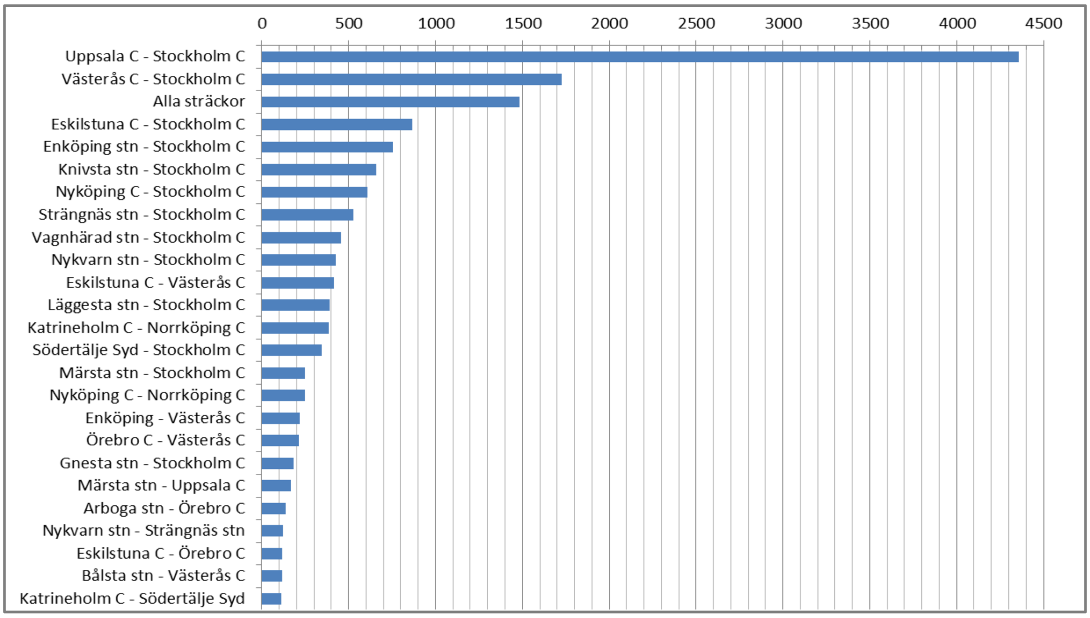

Figure 2-2: Average number of tickets sold per major commuting route in the first four months. Source: MÄLAB, 2018

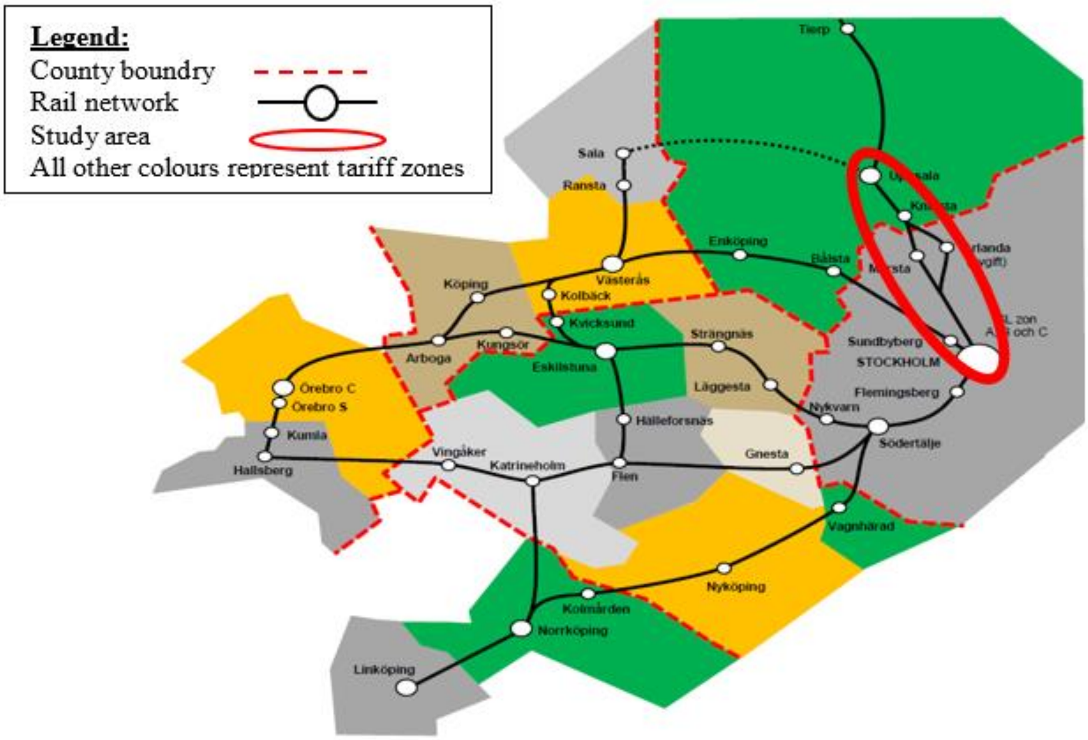

Figure 2-3: Tariff zones and county boundaries for the Movingo season ticket. Source: Movingo Project

2.4 Methods

2.4.1 Theoretical framework

2.4.1.1 The concept of service quality (SQ) and Attitudes

Parasuraman et al. (1985) defines SQ as the difference between customer expectation and her perception of service performance. Even though the SQ concept is useful for understanding how customers evaluate services, three properties of service make it a hard concept to understand and measure - intangibility, heterogeneity and inseparability. Cronin and Taylor (1992) argued that perceived service quality is best conceptualized as an attitude.

Parkany et al (2005), in their review of theory and experimentation relating attitudes to behaviour, concluded that attitudes are very important and quite prevalent in transportation studies. A representative list of the use of attitudinal surveys in analysing PT service quality is provided by De Oña and De Oña (2014).

Five psychological properties of attitudes form the basis for using attitude measurements to evaluate rail commuters' perceived quality of PT ticketing in our analysis. These five properties are summarised by Richardson (2014) as:

- Attitude is simply an evaluation on whether the attitude object is good or bad. That is, an attitude is the value an individual put on something, often known as the attitude object, and it may be negative, neutral or positive.
- Every attitude consists of three parts. Affective (Attitudes relating to feelings and emotions, e.g. feelings about PT service quality), behaviour (attitudes relating to actual behaviour, e.g. choosing to commute by train instead of by car) and cognitive (attitudes relating to thoughts or understanding as well as speech or information).
- Attitudes play four key functions: the knowledge function helps the individual to make sense of the world (e.g. knowledge of a PT ticketing system); the utilitarian function helps to serve practical purposes and achieve goals; the ego defence function helps one to have a positive view of oneself; and the value expressive function helps to express values fundamental to who one is.
- Attitudes are measurable by correctly asking questions to establish a subject's basic attitudes on any subject. Asking many subjects many questions enable us to measure aggregate attitudes at different levels of society.
- Attitudes can be influenced by the way questions are asked and stated attitudes do not necessarily match up with how people will behave in the future or what they really think.

2.4.1.2 Conceptualising the relationship between PT ticketing quality and attitudes

The various factors that may influence the value commuters place on a given PT ticketing system are identified in Figure 2-4. This conceptual framework assumes that the desire by PT service providers and stakeholders to improve ticketing quality or reduce the generalised cost of PT ticketing leads to the implementation of carefully selected measures. These measures may be applied to the fare collection part, the fare verification part, the user part (behavioural measures) or fare policy (ticket types and all the principles, goals and constraints that service providers consider in setting and collecting fares) or a combination of these four elements. These interventions then cause objective effects in the ticketing system which further produces two types of effects - perceived effects for users and objective effects on PT system operational efficiency and service quality. How the perceived effects are perceived depends on the individual's travel behaviour which in turn is influenced by the individual's characteristics and preferences. Attitudes to changes in the PT ticketing system are then a function of the perceived effects for users, the objective effects on the PT system operational efficiency and the individual's travel behaviour. The feedback cycle indicates changes in system equilibrium that may be induced by any further changes in the ticketing system or individual's characteristics and preferences or both.

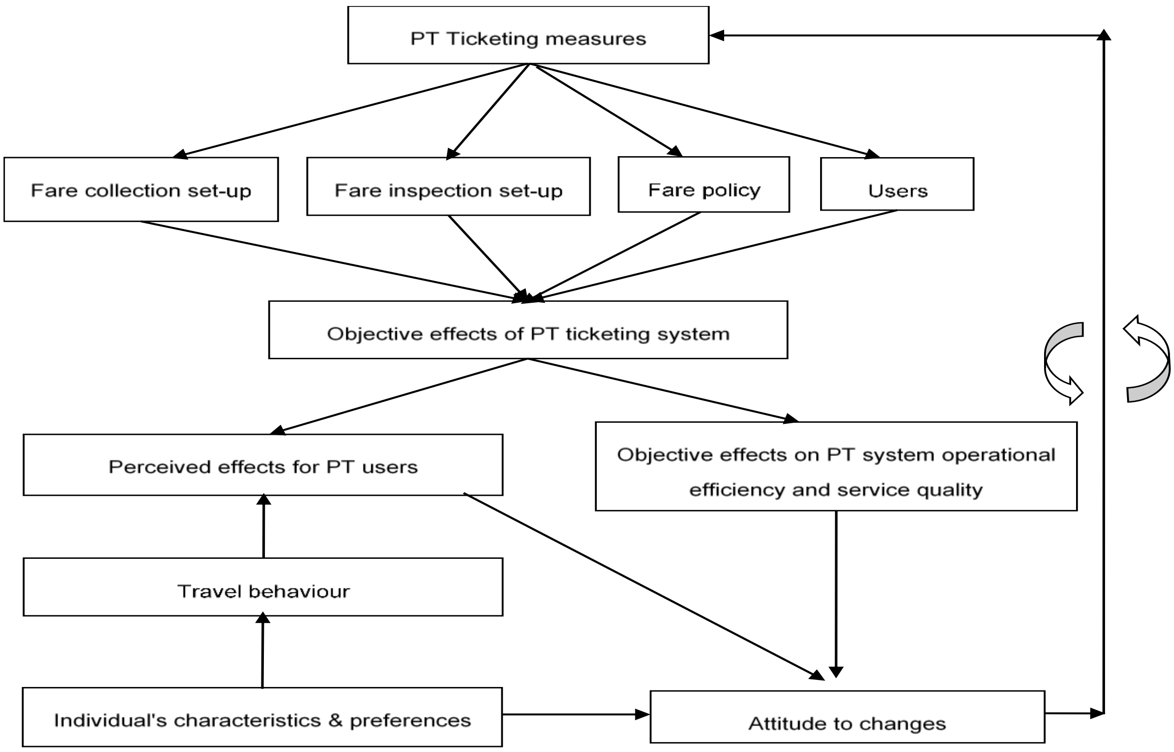

Figure 2-4: A conceptual framework for factors affecting attitudes towards ticketing

2.4.2 Measuring the attitudes of the commuters

Wardman (2014) identified three main approaches for measuring convenience and comfort in PT, namely: by measuring perceptions and attitudes; measuring strategic key performance indicators; or by measuring the detailed components of a generalised cost expression. While he argued that it is possible to objectively measure all convenience terms and value them by extending the generalised expression beyond time and cost, he pointed out that measuring convenience factors in ticketing are not easily measured in an objective manner and survey-based rating methods are hence required. In a literature review of quality of service in PT based on user surveys by De Oña and De Oña (2014), 92% of studies were based on survey rating and mostly Likert scale. The origin and description of this psychometric ordinal response scale can be found in Likert (1932). This method makes it easy to use a series of statements to measure commuters' feelings about the latent variable ticketing. An important feature of the Likert scale is that it is unidimensional. That is, its concepts are expressed in a single dimension that is easy to understand. For instance, a person is tall or short in height, fast or slow in walking. The scale is often expressed in the form of a statement with categories of discrete choices, normally ranging from strongly disagree to strongly agree. For each statement, the choice set is exhaustive and mutually exclusive.

2.4.3 Survey design

Cross-sectional data was collected from 1320 rail commuters via an en-route questionnaire survey along the corridor with the largest proportion of cross-county commuting in Sweden, the Stockholm-Uppsala corridor. The data was collected in autumn 2017 as part of the Movingo integrated ticketing project. This period was appropriate for the survey because the travel demand along the corridor for three consecutive years (2014-2016) showed that demand along the corridor peaks in the autumn. Also, similar travel surveys around Sweden had been conducted within the period September - October (Travel behaviour surveys in Stockholm, 2016 and in Malmö, 2014).

Likert scale statements measuring how an individual commuter evaluates several ticketing attributes were used in the survey. That is, given that a commuter's perception of the different aspects of a given ticketing set-up can be negative, neutral or positive, the overall level of quality of the ticketing system can be measured by averaging the Likert scale scores for the individual commuters and across commuters. Seventeen (17) ticketing attributes were used to evaluate the quality of the ticketing system. They were grouped into two dimensions. One dimension consisted of fare collection attributes, namely: convenience of ticket use, ease of getting ticket information, ticket access time, ease of buying ticket, possibility to buy ticket on-board, ease of using ticket vending machines, flexibility of buying ticket, and ease of retrieving a lost or damaged ticket. The second dimension consisted of fare verification attributes, namely: fare verification by staff, fare verification by bus driver, ease of passing through turnstiles, safety and security when passing through turnstiles, perceived congestion at turnstiles, and perceived delays at turnstiles.

The survey questionnaire had three sections: Section A consisted of eleven close-ended questions focusing on the respondents commuting habits and behaviour; part of section B was made up of nineteen 7-point Likert scale statements measuring attitudes. Finally, section C consisted of six close-ended questions that focused on collecting information on the commuters' sociodemographic characteristics. A pilot survey was first conducted on-board train on 30 commuters to check the appropriateness of the survey design. The results of this pre-test were then used to refine the survey questions.

The survey was carried out within a two-week period during peak travel hours (06:00 –09:00 and 15:00 – 18:00). The questionnaires were randomly distributed to the commuters. To increase the response rate, respondents could choose to return answered questionnaires directly to the surveyors or by self-completion and mail-back at the respondents' convenience. Respondents could also answer the survey online on-board using tablets provided by the surveyors or answer them online at their convenience elsewhere.

Based on the estimated total sample size and the expected response rate of about 35% based on previous surveys (Stockholm county travel behaviour report, 2016), the estimated minimum number of questionnaires that needed to be distributed was 1074. To ensure that the minimum expected number of responses was obtained, 1800 paper questionnaires were distributed during the fieldwork, from September 11th to September 22nd, 2017. A total of 1131fully and partially filled paper questionnaires were returned. This gives an overall survey response rate of about 63%. This is significantly higher than the expected response rate of 35%.

Of a total of 1320 returned paper and online responses, 56 % answered on-board using paper and pencil, 23% answered online and 21% answered by mailback. While most of the respondents opted for the on-board paper survey, the analysis of variance showed no statistically significant effect of the response method on the average commuters' attitudinal scores ($F = 0.864$, P-value $=0.462$). Table 2-2 summarises the sample distribution of the respondents' characteristics and travel habits. The aggregated sample distributions of the attitudes' measurements are summarised in Table 2-3, the first ten attributes are grouped as a measure of the users' experiences with fare collection and the last seven attributes are grouped as a measure of their experiences with fare verification. The attributes replacement of damaged ticket (card) and retrieval of lost ticket were not very common experiences among the respondents as 54 – 60% of them did not have opinions on these two attributes.

Table 2-2: Descriptive analysis of the sample

User characteristics (Sample size, n = 1 320)	*%*	*Commuting characteristics*	*%*
Gender		**Ticket type used**	
Female	56.9	*30 days*	78.1
Male	42.6	*90 days*	1.6
Other	0.5	*One year*	3
Age (Years)		*Other*	17.4
16 – 24	17.8	**Service Provider**	
25 – 34	29.7	*SL/UL (Integrated)*	45.8
35 – 44	20.8	*SJ*	34.1
45 – 54	18.0	*SL*	9.9
55 – 64	11.3	*TiM*	5.5
65 +	2.4	*UL*	4
Monthly gross income in SEK		*Other*	0.6
0–10 000	14	**Commuting frequency (Train)**	
10 001–15 000	7	*1 - 2 days/week*	7.4
15 001–20 000	3	*3 - 4 days/week*	25.4
20 001–25 000	4	*≥ 5 days/week*	58.1
25 001–30 000	11	*Rarely*	5.7
30 001–35 000	14	*Never*	3.4
35 001–50 000	25	**Commuting experience (Train)**	
Over 50 000	15	*< 1 year*	24.3
Do not want to give	7	*1 – 2 years*	22.5
Education		*3 – 4 years*	15.6
Higher education (3 or more years)	57.1	*≥ 5 years*	37.5
Higher education (less than 3 years)	19.0	**Ticket purchase channel**	
High school graduate	21.5	*Vending machine*	31.4
Under High school	1.2	*Sales agent*	20.3
Other	1.3	*Service provider offices*	25.7
Employment status		*Mobile phone*	15
Full-time employed	64.8	*On the internet*	3.6
Part-time employed	5.0	*On-board PT vehicle*	0.2
Full-time student	22.4	*Other channels*	3.8
Part-time student	2.0	**Use of season for other trips**	
Full-time self employed	2.5	*1-2 times a week*	21
Part-time self employed	0.6	*3 - 4 times a week*	8.2
Other (unemployed)	2.7	*≥ 5 times a week*	9.3
Received tax reduction for work trips		*No season ticket*	8.1
Yes	58.8	*Never*	9.5
No	41.2	*Rarely*	44
Travel cost paid by employer		**Commuting route**	
No	91.5	*Stockholm – Knivsta*	13
Partly	4.1	*Stockholm – Märsta*	7
Fully	4.4	*Stockholm – Uppsala*	67
		Uppsala – Märsta	3
		None commuters	11

Table 2-3: Descriptive analysis of the survey ratings.

Statements (Sample size, n = 1 259)	*Strongly agree 7 – Strongly disagree 1 (Relative frequency %)*							
Ticketing attribute statements (Overall construct reliability, Cronbach's α = 0.83)	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**No opinion (0)**
Relating to fare collection (Cronbach's α = 0.83)								
It is easy to replace damaged ticket	7	5	4	8	5	5	6	60
It is easy to retrieve lost ticket	8	5	6	9	6	5	6	54
I have the flexibility to buy or top up my ticket at any time and any where	17	15	18	16	12	6	7	9
Using a ticket vending machine is easy for me	18	21	20	16	9	4	5	8
It is acceptable that I cannot buy ticket on the bus	20	8	7	10	13	13	20	9
It is easy to get information about available ticket types	25	19	20	14	9	7	5	1
It is easy to buy or top up ticket	26	26	20	12	7	4	3	2
The time it takes to buy or top up ticket is acceptable	27	29	21	11	5	3	2	2
It is acceptable that I cannot buy ticket on the train	29	15	12	13	9	8	11	4
It is easy for me to use my ticket	36	22	16	8	4	2	3	10
Relating to fare verification (Cronbach's α = 0.72)								
Delay level at turnstiles is acceptable	3	7	12	14	17	12	18	18
It is disturbing for me to have my ticket checked by bus driver	5	3	5	6	9	15	49	8
It is smooth for me to pass through turnstiles when I am having luggage, pram, wheelchair or rollator	7	8	14	13	12	10	9	28
Congestion level at turnstiles is acceptable	7	13	19	17	12	8	8	16
I find ticket control by staff on train disturbing	8	5	6	10	10	15	42	3
I do feel safe and secured when passing through turnstiles	22	20	16	13	7	4	3	14
It is smooth to pass through turnstiles	25	22	16	12	6	3	3	12

No opinion (0) responses were excluded in the calculation of the average scores as it indicated that the respondent is yet to experience the given ticket aspect. The Cronbach's α represents the internal reliability of the latent constructs, all values are greater than 0.70, suggesting a strong reliability.

If the attitudinal questions relate to the same issue/construct, respondents are expected to get similar scores on each question. To confirm this, the Cronbach's α test was used to measure the internal consistency (how closely related the items are as a group) of the set of attitudinal questions measuring the latent constructs for fare collection and fare verification systems, which are directly non-measurable. All the α values are greater than 0.70 (Table 2-3), suggesting a strong reliability.

2.4.4 Data analysis

An important issue among researchers is how to best analyse Likert questionnaires. Parametric or non-parametric statistical procedures? Due to the ordinal nature of Likert items, non-parametric inference techniques such as Mann-Whitney U test and Kruskal-Wallis H test are often used. However, de Winter and Dodou (2010), who compared Type I and II error rates of t test and Mann-Whitney U test using five-point Likert items, concluded that the two tests have similar power. On the other hand, a Likert scale is different from a Likert item as it is made up of a series of Likert items that represent similar questions combined into a composite score. This is the case in this study. The most recent comprehensive reviews of the literature concerning the controversy of the appropriateness of using parametric procedures to analyse Likert scale data are provided by Harpe (2015) and Norman (2010). They both strongly confirmed that the use of parametric analytical procedures on Likert scale data is appropriate. Hence, the composite average scores in this study are analysed as interval data using the mean as a measure of central tendency. Parametric inference analysis of the averages of Likert scale samples is quite prevalent in the analysis of attitudinal surveys in the transport sector (Börjesson et al., 2015; Susilo and Cats, 2014; Handy et al., 2005). Common parametric inference techniques include t-test, Analysis of variance (ANOVA) and linear regression procedures.

Choosing a 0.05 significance level, all statistical analyses were done using the R programming language for statistical and computational analysis. Given that different commuters have different needs and given that the dataset composed of Likert scale data, differences between the average scores of the different commuter segments were analysed using a two-way ANOVA. ANOVA which has the test statistic F is a well-known statistical method for comparing two or more population means to examine the heterogeneity of the means in studied groups. In other words, for testing for differences among mean values of a dependent variable Y across multiple levels of an independent categorical variable (s) X if: The sample is randomly and independently drawn from the population; Y is continuous and normally distributed (or more accurately, the errors are assumed to be normally distributed); and that X has discrete groups (levels) of homogeneous variances. "ANOVA is the most commonly quoted advanced research method in the professional business and economic literature" (Aczel and Sounderpandian, 2006) and has been used by many authors for the analysis of variance in travellers' attitudes and perceptions (Soltani et al., 2019; Beck and Rose, 2016; Dütschke et al., 2016; Fraszczyk and Mulley, 2017; Malhotra et al., 2017; Pantouvakis and Renzi, 2016; Pedersen and Friman, 2011).

The sample in this study was randomly drawn from commuters along the studied corridor. The Shapiro-Wilk formal test of normality on the mean scores confirmed that the sample did not deviate from the normality assumption of parametric analysis (W = 0.993, p-value = 0.412). Performing the same test on the residuals of the ANOVA results also confirmed that the assumption of normality is valid (W = 0.996, p-value = 0.897).

To analyse the effects of respondents' characteristics, travel behaviour and the survey response method on the average scores, the assumption of homogeneous variance was checked using Levene's Test for equality of variances for all the nineteen (19) independent categorical variables that were used in the ANOVA. This test of homogeneity at 95% confidence interval produced p-values > 0.05 for all the variables except for the categorical variable "frequency of use of season ticket for none work/school trips", which was only significant at 99% confidence interval. The p-values from the Levene test are: Gender (p-value = 0.332), Age group (p-value = 0.706), Education level (p-value = 0.776), Monthly income (p-value = 0.614), Frequency of commuting by train (p-value = 0.578), Frequency of commuting by car (p-value = 0.640), Commuting experience by train (p-value = 0.451), Frequency of use of season ticket for none work/school trips (p-value =0.0028, significant at 99% confidence interval), Received tax reduction for work trips (p-value =0.398), Commuting route (p-value =0.207), Service provider (p-value = 0.464), Ticket type (p-value =0.908), Ticket purchase channel (p-value =0.893), Access mode from home to work or school (p-value = 0.191), Access mode from work or school to home (p-value = 0.418), Self-reported travel time from home to work/school (p-value =0.940), Self-reported travel time from work/school to home (p-value =0.440), Employment status (p-value =0.218), Survey response method (p-value = 0.672).

2.5 Empirical results

The results of the four sets of hypotheses that were tested are presented in sections 2.5.1 – 2.5.3.

2.5.1 Variability in the perceived quality

This section hypothesizes how a series of categorical variables (income group, commuting route, ticket type, ticket purchase channel, gender, age, level of education, frequency of commuting by train, frequency of commuting by car, train commuting experience, frequency of use of season ticket for none work/school trips, tax reduction for work trips, chosen service provider, access mode, travel time and employment status) could influence commuters' attitudes towards ticketing. Given the perceived quality of the ticketing set-up (measured by the average attitudinal scores) as the dependent variable, a Two-way ANOVA was used to simultaneously test if there is difference in the perceived quality for the different commuter segments. The null hypothesis was that the average perceived quality is the same across all the different user groups (H0: $\mu 1 = \mu 2 = ... = \mu n$). The alternative hypothesis was that the average perceived quality differs between at least one pair of the commuter groups (HA: $\mu 1 \neq \mu 2 \neq ... \neq \mu n$). The ANOVA (Table 2-5) detected significant differences in the average scores due to income, commuting route, ticket type, and ticket purchase channel. Analysis of covariance (ANCOVA) was conducted on these four variables whose main effects were found to be statistically significant in the ANOVA test. However, the test did not detect any significant interaction effects between these variables. Since the ANOVA test detected only the overall differences in the average scores among groups in four of the independent categorical variables that were included in the test, a follow-up statistical test was conducted to examine where, within the pairs of the multiple levels of the independent variables, the differences existed. The Tukey HSD (Tukey Honest Significant Differences) Post-hoc pair comparison detected significant differences in the average scores between: commuters on the Stockholm – Uppsala and Stockholm – Knivsta routes (adjusted p-value = 0.039); the income group 20 001 - 25 000 and the group that did not want to disclose their income (adjusted p-value = 0.067); and commuters using 30 days ticket and those using one year's ticket (adjusted p-value = 0.064). The test did not detect any honest significant differences in the ticket purchase channel groups.

2.5.2 Perceived quality

Seventeen (17) ticketing attributes were used to evaluate the perceived quality of the ticketing system. The attributes were grouped into six dimensions. The average perceived quality of each dimension is presented in Table 2-4.

In general, the system's average score indicates that the commuters are fairly satisfied with the entire ticketing set-up. Apart from the mean score of manual fare verification by staff, all the estimated mean scores appeared not to differ much from the neutral value of 4 on the Likert scale of 1 - 7 (Table 2-3). Are these observed differences due to chance or real? A two-tail t test was conducted to test if these means were significantly different from the neutral value of 4. Two hypotheses are thus defined: A null hypothesis, H0: $\mu 1 = \mu 2 = ... = \mu n = 4$, and an alternative hypothesis, HA: $\mu 1 \neq \mu 2 \neq ... \neq \mu n \neq 4$. The hypothesis test showed that the p-values for the system's average score, fare collection and automatic verification by turnstiles were far less than 0.000; the null hypothesis is therefore rejected and the alternative hypothesis that the mean scores for these dimensions are not equal to 4 is accepted. Hence, the observed differences could not have been due to chance but rather some systematic influence. There was however no evidence to reject the null hypothesis for the dimensions: fare payment on-board (p-value = 0.783) and fare verification (p-value = 0.438). It is therefore believed that the mean scores for these two dimensions are neutral in value.

Table 2-4: Dimensional average of attitudinal scores on a scale of 1 to 7

Attitude dimension	Mean	Standard dev.	95% Conf. interval
Fare collection	4.71	1.10	4.56 - 4.85
Payment on-board	3.96	1.94	3.71 - 4.22
Fare verification	3.95	0.96	3.82 - 4.08
Manual verification by staff	2.92	1.71	2.70 - 3.15
Automatic verification by turnstiles	4.36	1.2	4.20 - 4.52
System's average score	**4.40**	**0.85**	**4.28 - 4.51**

2.5.3 Preference for fare verification technique

Since the commuters tend to have a mildly positive attitude towards automatic fare verification by turnstiles (mean score = 4.4) but a negative attitude towards fare verification by staff (mean score = 2.9), the commuters' responded to the question "I prefer ticket checking by staff to that by turnstiles" was further investigated. Out of a total of 814 observations in the sample, 64% answered no and 36% answered yes. A One-way chi-squared ($\chi2$) goodness of fit test with random expected values was conducted to determine if the commuters showed any preferences for fare verification technique. That is, it is assumed that both options were chosen randomly (equally or 50% of the time) and that the observed values showed no preference for one option over another. The expected frequencies were greater than five for both categories. The test showed statistically significant association in the commuters' preference for fare verification, $\chi2$ (df = 1, N= 814) = 66.123, p-value = 0.000. There is therefore enough evidence to reject the null hypothesis of no preference for fare verification options and to believe that most of the commuters showed preference for automatic fare verification by turnstiles compared to manual verification by staff.

Table 2-5: ANOVA results. Significance codes: '*' 0.05

Commuter segments *(Sample size, n = 221)*	**Df**	**Sum Sq.**	**Mean Sq.**	**F value**	**Pr(>F)**
Gender	1	0.03	0.0344	0.055	0.8154
Age group	5	3.08	0.6168	0.981	0.4316
Education level	4	4.07	1.0173	1.618	0.1729
Gross monthly income	8	10.86	1.3576	2.159	0.034*
Commuting frequency (Train)	4	4.88	1.2191	1.939	0.1071
Commuting frequency (Car)	4	2.81	0.7029	1.118	0.3505
Train commuting experience (years)	3	2.19	0.7308	1.162	0.3264
Use of season for none work/school trips	5	1.85	0.3697	0.588	0.7092
Received tax reduction for work trips	1	1.07	1.0655	1.694	0.1951
Commuting route	3	5.94	1.9811	3.15	0.0269*
Service Provider	5	1	0.2006	0.319	0.9009
Ticket type used	3	6.09	2.0311	3.23	0.0243*
Ticket purchase channel	5	7.84	1.5671	2.492	0.0338*
Access mode (home - work/school)	6	2.72	0.4529	0.72	0.634
Access mode (work/school - home)	6	5.82	0.9703	1.543	0.1682
Self-reported travel time (work/school - home)	2	1.47	0.7329	1.165	0.3147
Self-reported travel time (home - work/school)	2	0.48	0.2388	0.38	0.6847
Employment status	5	2.73	0.547	0.87	0.5031
Survey response method	3	1.63	0.5431	0.864	0.4616
Residuals	**145**	**91.18**	**0.6289**		

2.6 Discussion

The research questions are discussed separately in this section based on the results and previous research works.

What factors affect commuters' attitudes towards ticketing? The analysis suggests no evidence of statistically significant effect of gender, age, level of education, frequency of commuting by train, frequency of commuting by car, train commuting experience, frequency of use of season ticket for none work/school trips, tax reduction for work trips, chosen service provider, access mode, travel time and employment status on the attitudes. Users attitudes are heterogeneous based on many factors. It was suspected that all factors included in the analysis could induce heterogeneity in the commuter's attitudes towards ticketing based on our conceptual framework (Figure 2-4) and previous research works. Whilst the commuters were quite uniform in how they evaluated the attitude object in question (ticketing), it is interesting that income, commuting route, ticket type and ticket purchase channel influenced their attitudes. The commuting route constitutes the PT environment and previous works confirmed that environment can affect travel behaviour and attitudes. The routes that were included in this study differ in aspects that may influence attitudes such convenience of ticketing, price, comfort, safety, aesthetics, reliability, frequency of service, accessibility, information provision, ease of transfers. The study by Graham and Mulley (2011) shares similarity with this study. They surveyed PT users to study their behaviour before and after the implementation of prepaid tickets in New South Wales (Australia). They confirmed that significant difference existed in the characteristics of passengers using multimodal tickets and pay-as-you-go passengers due to income and whether a journey involved transfer or not. Ticket purchase channel is associated with convenience and speed of purchase. The effect of the commuter's attitudes by ticket purchase channel was hence expected as the use of season tickets reduces the frequency of ticket purchase. For instance, using an annual ticket reduces the frequency of ticket purchase twelve times as compared to using a monthly ticket. An annual ticket is thus twelve times better in terms of the convenience of purchase and saving the time spent on ticket purchase. The effect of ticket purchase channel on users' attitudes to ticketing was also evidenced in a recent study by Allen et al. (2019), where passengers in the 35 – 44 age group were found to have the highest demand for well-functioning ticket vending machines.

What are the attitudes of PT commuters towards PT fare collection and verification? The results suggested that the commuters were slightly positive towards ticketing in general. Fare collection and fare verification (Table 2-4) were, however, evaluated differently by the commuters. They were slightly positive towards fare collection but neutral to fare verification. While we are yet to find previous studies relating to attitudes to PT fare collection and verification, the results have two main implications: that the perceived quality status of the current ticketing system is neither good nor bad and that users care about the quality of all aspects of PT ticketing and not just fares. For instance, the variations in the perceived quality of fare collection and fare verification in the study indicates that the fare verification aspects of the ticketing system under consideration need to be prioritised in improving the ticketing system and, thereby, the quality of the PT system.

Do commuters have preference for the current fare verification options? The findings further suggest that the commuters have a slightly positive attitude to automatic ticket checking by turnstiles but react negatively to manual ticket checking by staff. Fare verification by turnstiles is obviously associated with barrier effects while fare verification by staff encourages staff presence within PT environments. Staff presence offers many benefits such as enhanced perceived security and easy access to information. It was thus expected that the commuters would be more interested in interacting with fellow humans than machines. Somewhat surprisingly, the data suggested the opposite. In the case of Madrid’s Metro system, Allen et al. (2019) also reported that PT users evaluated the operation of turnstiles more positively than the kindness of security staff. A further investigation on this issue due the unexpected results confirmed that most of the commuters (about 71%) chose automatic fare verification by turnstiles over manual verification by staff. This may be explained by the fact that most commuters use their in-vehicle time to work or perform other activities and hence may not like to be interrupted by staff for fare verification reasons. Another possible explanation could be that the commuters have both a high level of perceived security and enough information about their commuting routes and, therefore, perceive the presence of staff to be less important. This might be expected not to be the case, however, for less frequent PT users.

Even though most of the commuters prefer fare verification by turnstiles, PTI (2010) confirmed that the use of turnstiles in metro and some BRT systems is relatively less effective in combating fare evasion. Additionally, it is obvious that turnstiles are associated with barrier effects resulting in: creation of queues during peak hours; delays due to faulty turnstile machines; minor accidents which may cause injuries or damage to property; fare evaders disturbing compliant users through piggy-backing or tailgating and turnstile jumping; inconveniences for travellers carrying luggage or similar loads; travellers with prams; travellers in wheel chairs; visually challenged travellers; older people and so on. Turnstiles may also pose a major risk during stampede in the event of disaster or terror attack in crowded transit stations.

Consequently, considering the commuters negative reaction to fare verification by staff and the challenges associated with fare verification by turnstiles, a logical extension of the analysis is to think of an alternative approach to fare verification, even though this is beyond the scope of our data. Comparatively, modes like private automobile and cycling hardly have ticketing requirements. This suggests that both fare verification by staff and turnstiles are sources of inconvenience for commuters. A smarter fare verification approach where fare verification is done passively without the active participation of the user may be a suitable future option. The demand for such a passive fare verification system was also mentioned in TCRP report 117 (2015), envisaging passive interaction between users' smartphone and readers located at the transit system entry points or at the doors of PT vehicles.

Does commuter familiarity with the policy of "No-ticket-purchase on-board train" breed acceptance? The possibility to purchase ticket on-board PT vehicle possibly makes tickets more accessible to users even though this might have some negative consequences on the efficiency of PT operations. As service providers in Sweden advocate "No-ticket-purchase on-board train", it was expected that PT users would advocate for the flexibility to be able to buy a ticket on-board PT vehicle or elsewhere. It however turned out that the commuters' reaction to this was neutral. This might mean that many PT commuters have probably adjusted to this policy of not being able to buy tickets on-board as many PT service providers in Sweden have eliminated payment on-board trains. Payments on-board buses partly exist today. Cash payments on-board buses are not allowed whilst payment with a bank card is penalised by many service providers. Another reason that could account for this is that most commuters in Sweden are more likely to purchase season tickets (most of which are monthly tickets) and thus have less need to purchase a ticket on-board, compared to non-frequent users.

2.7 Conclusions

Commuters' attitudes and perceived quality of PT fare collection and fare verification systems were explored in this study with the aim of evaluating the quality of the ticketing set-up before and after the implementation of the Movingo integrated season ticket project. Attitudinal surveys were administered to PT commuters along the corridor with the largest proportion of cross-county commuting in Sweden

(Stockholm – Uppsala) using PT ticketing as the attitude object. The main findings from this study suggest that:

Commuters' attitudes to ticketing were generally affected by income, commuting route (location), ticket type and ticket purchase channel, implying that these are relevant variables to be considered in evaluating the quality of a ticketing set-up.

Fare collection and fare verification systems are an integral part of PT service quality and should be analysed separately in the evaluation of PT service quality as they are perceived differently by users.

Familiarity did not necessarily breed acceptance as most commuters are familiar with the policy of 'No-ticket-purchase on-board PT vehicle' and still remained neutral to it. This provides a good example for PTA's intending to implement this kind of policy in the future.

Finally, most commuters prefer fare verification by turnstiles to manual fare verification by staff and did not like to be interrupted by staff for fare verification reasons. The commuters' perceived the inconvenience emanating from the ticketing system to be at an acceptable level even though some improvement measures are required for the fare verification aspect. This provides up-to-date information on the quality status of fare collection and verification within the study area for evaluating the perceived quality of fare collection and verification set-ups before and after the implementation of the Movingo integrated season ticket project. The commuters' preference for automatic fare verification suggests a policy direction for improving fare verification. As PT systems are increasingly being automated, a smarter fare verification approach, where fare verification is done passively without the active participation of the user, may be a suitable future option for reducing the burden of fare verification on commuters.

The study focused on commuters' attitudes to ticketing and cannot be used to generalize PT users' attitudes to ticketing. Further study on how non-commuters react to fare collection and verification is hence recommended. Future research work is also recommended on: Commuters preferred choice of fare verification, by extending the choice set – for instance by only staff, by only turnstiles, by both staff and turnstiles, by passive (smart) verification or no fare verification at all; The feasibility of the proposed passive automatic fare verification approach; and the estimation of the effects of different ticketing aspects on the overall perceived quality of PT ticketing to identify important aspects of ticketing to be included in studies relating to an overall measure of PT service quality.

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Chapter 3

Seamless ticket inspection: Proposing and exploring users' reaction to a next generation public transport ticket inspection solution

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Abstract

Ticket payment and inspection are the two main dimensions of public transport (PT) ticketing for users. Both research and technological advances have focused mainly on improving the former. In contrast, the study reported in this paper explored users' preferences for ticket inspection options and identified some factors that influenced users' likelihood of accepting "seamless ticket inspection". The dataset is part of a two-wave survey that was collected along the Stockholm – Uppsala corridor to evaluate the Movingo integrated ticketing scheme, a smartcard and mobile phone-based multiple-county commuting ticket that applies to both intercity and intracity bus and train services across the six Mälardalen regions of Sweden. McNemar's test, one-way chi-squared goodness of fit test, multinomial and nested logit models were used to analyse the samples. The findings suggest that given five ticket inspection options, the majority of the respondents chose "seamless ticket inspection". Major PT user groups such as females and young people are more likely to accept "seamless ticket inspection". Further research is recommended on particular aspects of the envisaged "seamless ticket inspection".

Keywords: *Commuter, fare collection, fare verification, ticket inspection, fare evasion, ticket forgery, convenience*

3.1 Introduction

Public transport (PT) ticketing is widely acknowledged to have impacts on passenger convenience (Zalar et al., 2017; Wardman, 2014; Anderson et al., 2013; Vuchic, 2005). Significant investments into improving ticketing procedures around the world during recent years strongly indicates that PT service providers also view ticketing as an inconvenience to users. This inconvenience can be understood as a disutility for users, stemming from the fact that ticketing is not an end by itself but a means of accessing the PT service. Making the PT service attractive thus requires attractive ticketing so as to minimise this disutility.

PT ticketing has two main dimensions for users - ticket payment and inspection. Both research and technological advances have tended to focus more on improving ticket payment, making it relatively more convenient for users to choose among different payment options and to travel across different service providers seamlessly (PTEG, 2009; Puhe 2014). The opposite is true about both occasional and continuous fare inspection, as users generally lack the opportunity to choose how they want their tickets to be inspected. Even if users were given the opportunity to choose their preferred ticket inspection approach, the choice set currently would most probably be limited to on-board and/or off-board ticket inspection by staff and/or turnstiles.

Considering the increasing digitalisation and automation of PT systems globally as well as its cost effectiveness, we strongly argued that further attention be given to using established and emerging smart card and mobile ticketing technologies to develop smarter and more user-convenient seamless ticket inspection solutions, i.e. a passive fare verification system where ticket inspection is done automatically without the active participation of the users. This study, therefore, explores this seamless ticket inspection as the next generation ticket inspection solution. Since this is a new idea, it appears attractive to start the exploration from the demand side, analysing how different user groups will react to it.

Ticket inspection may be perceived as the most profound bridge between public transport service providers (PTSP) and fare evaders (Barabino et al., 2020). The principal purposes of ticket inspection are to combat fare evasion (the usage of PT service without paying for it) and ticket forgery (production and usage of fake tickets). Understandably, these are of great concern for PTSP as it is common in particularly cities (Delbosc and Currie, 2019, Wilhelm et al., 2018). Delbosc and Currie (2019) in their review work on fare evasion grouped the shift in global fare evasion research into three perspectives: the conventional PT system perspective, the customer profiling perspective and the customer motivation perspective. At the same time, Barabino et al. (2020) in their relatively recent review paper on fare evasion classified current fare evasion research focus areas into five: fare evader-oriented, criminological, economic, technological solutions, and operational research. According to them, the technological perspective, which is the focus of this present study, aims at simplifying travellers' burden and to minimise fare evasions. From evasion measures perspective, Public Transport International, Bonfanti and Wagenknecht (2010) identified ticket inspection by staff, investing more power in inspectors, partnership with the police, communication, on-board technologies such as video surveillance, and access control by the use of turnstile as the different fare evasion measures used by PTSP.

Mass Transit (2016) pointed out that fare evasion and user satisfaction as being two of the top three challenges that new ticketing technologies need to address. Similarly, the EU Commission's Urban ITS Expert Group's (2013) guidelines on smart ticketing also pointed out the need for efficient fare inspection at turnstiles and within PT networks to combat fare evasion. Yet, minimal research has looked into the customer convenience and satisfaction perspectives of ticket inspection such as users' preferences and satisfaction with current ticket inspection approaches. Interestingly, we are also yet to find previous research on seamless ticket inspection in the transportation literature. TCRP report 117 (2015) briefly mentioned smart ticket inspection with passive interaction between users' smartphone and readers located at the transit system entry points or the doors of PT vehicles. Yet, research on seamless ticketing has mainly focused on seamless ticket payment issues.

Current ticket inspection enforcement can provoke violent reactions from users such as verbal insults and attacks on staff and compliant passengers (Delbosc and Currie, 2019; Wilhelm et al., 2018; Bonfanti and Wagenknecht, 2010). Alhassan et al. (2019) also pointed out that PT commuters were slightly positive towards automatic ticket inspection by turnstiles but negative towards manual ticket inspection by staff. Most of the respondents (71%) in the study also chose automatic ticket inspection by turnstiles over manual inspection by staff. Similarly, in the case of Madrid's Metro system, PT users evaluated the operation of turnstiles more positively than the kindness of security staff (Allen et al., 2019).

Inspection via turnstiles, however, has several disadvantages. Bonfanti and Wagenknecht (2010) pointed out that the use of turnstiles in metro and some BRT systems is relatively less effective in combating fare evasion; probably one of the reasons why many stations equipped with turnstiles are also staffed. Additionally, turnstiles are expensive to build and maintain; they can be visually and physically intrusive and may be impractical to implement under certain conditions (Delbosc and

Currie, 2019) and, this means that they are not all-inclusive and are associated with barrier effects that may result in: the creation of queues and reduction station capacity particularly during peak hours; delays due to faulty turnstile machines; minor accidents which may cause injuries or damage to properties; fare evaders disturbing compliant users through piggy-backing or tailgating and turnstile jumping; inconveniences for travellers such as those carrying luggage or similar loads, prams, physically and visually challenged travellers (particularly wheelchair users) and older people. Turnstiles may also pose a significant risk during a stampede in the event of disaster or terror attack in crowded transit stations.

Given the challenges of current ticket inspection approaches, the general lack of research on users' preference and satisfaction with ticket inspection, and the need to use established and emerging smart card and mobile ticketing technologies to develop a smarter, seamless and more convenient ticket inspection solution, the two research questions driving this study are:

- What are PT users' preferences for ticket inspection alternatives given current and future scenarios?
- What factors are associated with their likelihood of accepting a seamless ticket inspection alternative?

The two main contributions of the study are:

- It provides new information on PT users' preferences for ticket inspection and the characteristics that may influence their preferences for ticket inspection alternatives, which is relevant for both researchers and practitioners for developing more user-focused PT ticket inspection systems.
- In addition to suggesting seamless ticket inspection as the next generation ticket inspection approach in the future world of highly digitalised and automated transport systems, the study also gives insight into its acceptance by some major PT user groups. Its acceptance and technical feasibility are central to its development and operation.

The rest of the paper is organised as follows. The next section describes the methods (the study area, the survey design and analysis). Section 3.3 presents the empirical results and discussion. Section 3.4 contains our conclusions and recommendations.

3.2 Methods

3.2.1 The Case Study Area

The dataset used in this study was part of the data we collected along the Stockholm – Uppsala corridor, which has the largest share of cross-county commuting trips in Sweden, to evaluate the Movingo integrated ticketing scheme. Movingo is a smartcard and mobile phone-based multiple-county commuting ticket that applies to both intercity and intracity bus and train services within the Mälardalen region of Sweden (Figure 3-1). The studied corridor, shown in Figure 3-1, is mainly served by the National Swedish Railways (SJ), the Stockholm and Uppsala counties public transport authorities (PTAs). While SJ and the Uppsala county PTA use only staff for fare inspection, the Stockholm county uses both staff and turnstiles. Also, while Stockholm city is heavily "turnstiled", Uppsala city is zero "turnstiled", with commuters experiencing both systems daily. This makes this area a suitable case for analysing ticket inspection.

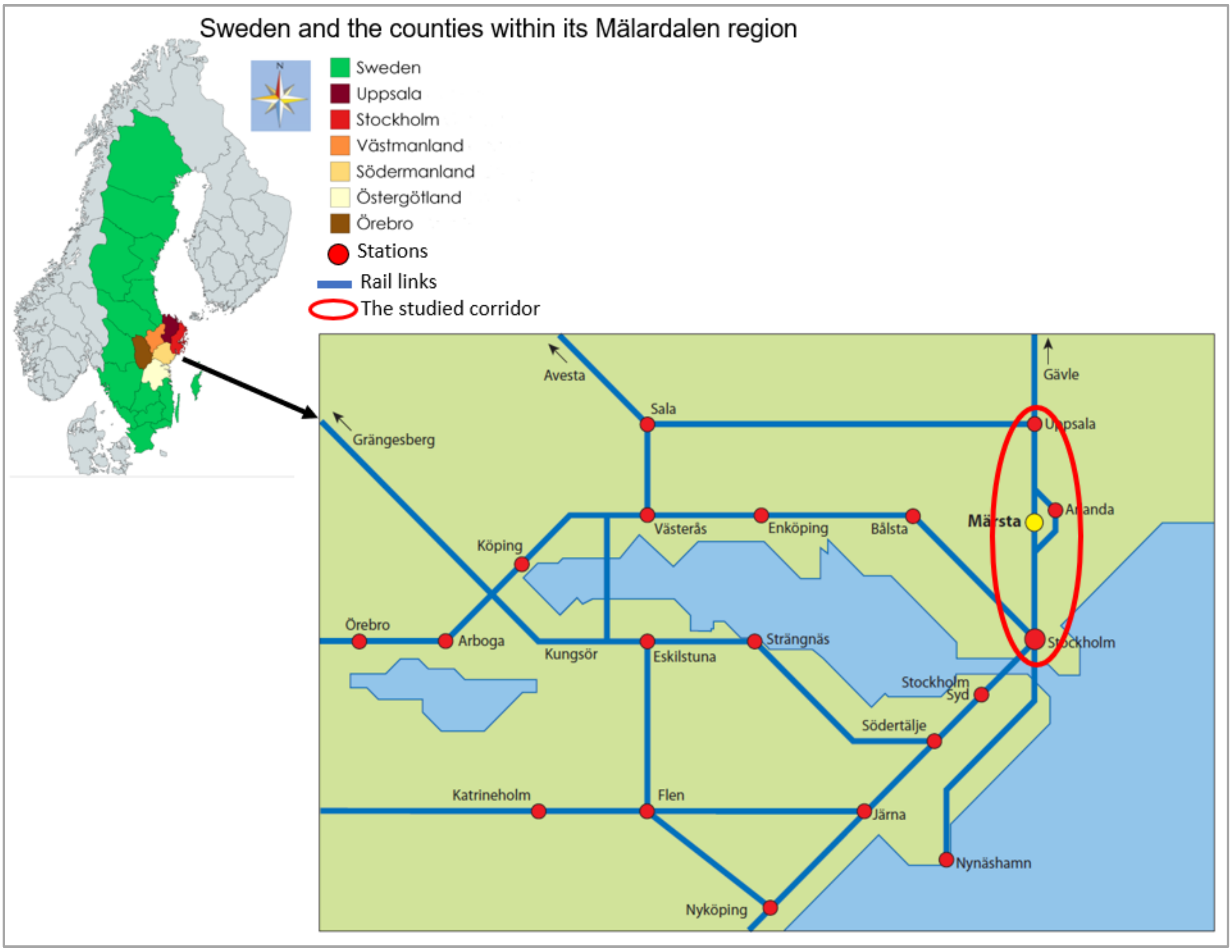

Figure 3-1: Counties and the rail network within the Mälardalen region (Banverket, 2007, Modified)

3.2.2 Survey design

To investigate user preferences for ticket inspection options and the propensity for a seamless ticket inspection among PT users, we extended the work of Alhassan et al. (2019) that investigated commuter' preference for the two most widely used fare inspection approaches (staff and turnstiles), along the Stockholm-Uppsala corridor in relation to the Movingo integrated ticketing scheme. That is, two survey datasets were collected along this corridor, containing 450 respondents in 2017 and 165 respondents in 2018. For more detail description of the dataset, the reader is referred to Alhassan et al. (2020). Figure 3-2 illustrates the respondent's revealed choices in the two samples considering staff and turnstiles (the two main current ticket inspection approaches). Over 60% of the respondents preferred ticket inspection by turnstiles to that by staff in both samples. As shown in Figure 3-2, with the same respondents, the ticket inspection choice set, which contains only two alternatives in the first survey (staff and turnstiles), was extended to five in the follow-up survey, i.e.

- automatically without a user direct involvement/seamless ticket inspection,
- by both staff and turnstiles
- only by staff
- by only turnstiles
- no to ticket inspection

While just 4% of the respondents in the sample opted for no ticket inspection at all, 33% of them was uncertain about their preferred ticket inspection option, 25% of preferred the non-existing seamless fare inspection.

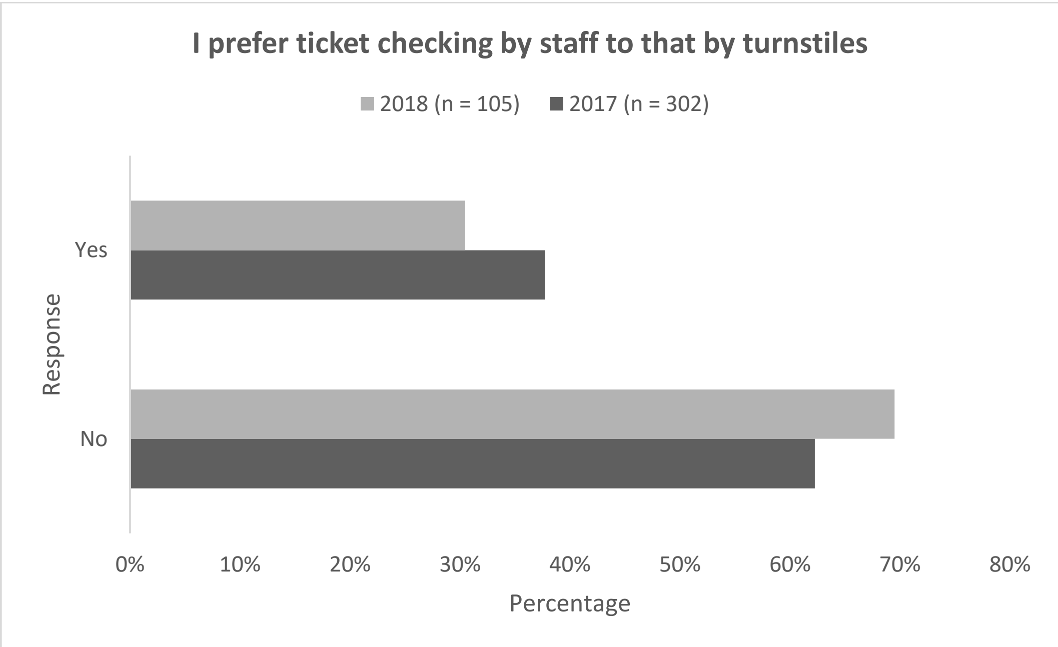

Figure 3-2: Commuters' revealed choice between ticket inspection by staff and by turnstiles in a two-wave survey

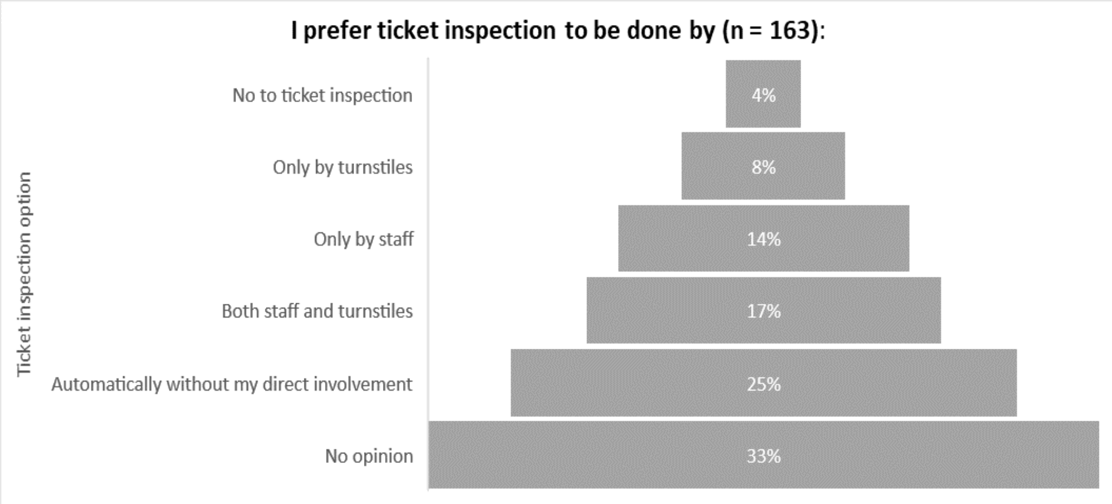

Figure 3-3: Stated choice of ticket inspection options among PT commuters

3.2.3 Analysis

Given one independent dichotomous variable, repeated measure (correlated proportions as same respondents chose between the current two main ticket inspection verification approaches - staff and turnstiles, in both surveys), McNemar's (1947) non-parametric test was considered most suitable for testing for difference in proportions in the two samples. The null hypothesis was that there is no change in the respondents' preference or proportions in the two samples (H_o: $P_1 = P_2$) The alternative hypothesis was that there is change in preference or proportions (H_a: $P_1 \neq P_2$).

By extending the choice set only in the second survey to include the hypothetical option of seamless ticket inspection, a one-way chi-squared (χ2) goodness of fit test with random expected values was conducted to determine if the respondents still showed a preference for any of the five ticket inspection ticket inspection options. I.e. the null hypothesis was H_0: All the five ticket inspection options were chosen randomly (equally or 20% of the time) and that the observed values showed no preference for the options. The alternative hypothesis was that H_a: All the five ticket inspection options were not equally chosen. Note that the "No opinion" responses were removed from the analysis since the respondents were uncertain about their choice.

Using the cross-sectional dataset from the second survey as it contains all the five alternatives, we estimated one multinomial (MNL) and two nested (NL) logit models to analyse the characteristics that correlated with the users' ticket inspection choice. We only used the second dataset in the estimation as it contained all the five ticket inspection alternatives. Apollo, the R package developed by the Choice Modelling

Centre at the University of Leeds, was used for the estimation (Hess and Palma, 2019).

Since some of the alternatives seemed to be more related and thus more likely to share unobserved effects in their random error terms, NL models with two nesting structures were considered (Figure 3-4 and Figure 3-5). The alternatives "staff and turnstiles", "turnstiles only" and "staff only" involves direct user involvement in the ticketing inspection process, and were therefore put into the same nest in the nesting structure one (Figure 3-4). Similarly, the alternatives "Seamless ticket inspection" and "no ticket inspection", do not require regular direct involvement of the user in the ticketing inspection process, and were hence put into a nest in the second NL (Figure 3-5). Since the individuals' characteristics do not vary over the five alternatives, they could enter any of the five utility functions in the model specification. The explanatory variables that were available for the modelling included gender, monthly income, education level, their response to whether PT should be made free and fully financed via tax (i.e. whether they are advocates of "free PT" or not), their perceived door-to-door travel time from home to work (self-reported), age, and ticket type. All categorical explanatory variables were dummy coded, assuming non-linearity in their levels.

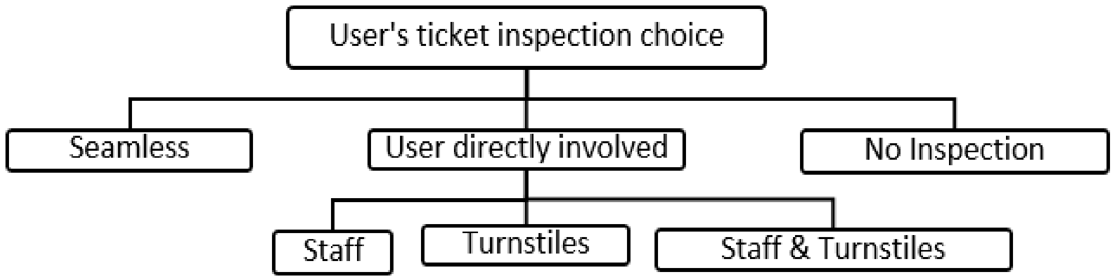

Figure 3-4: Nested logit structure 1 for ticket inspection (model NL1)

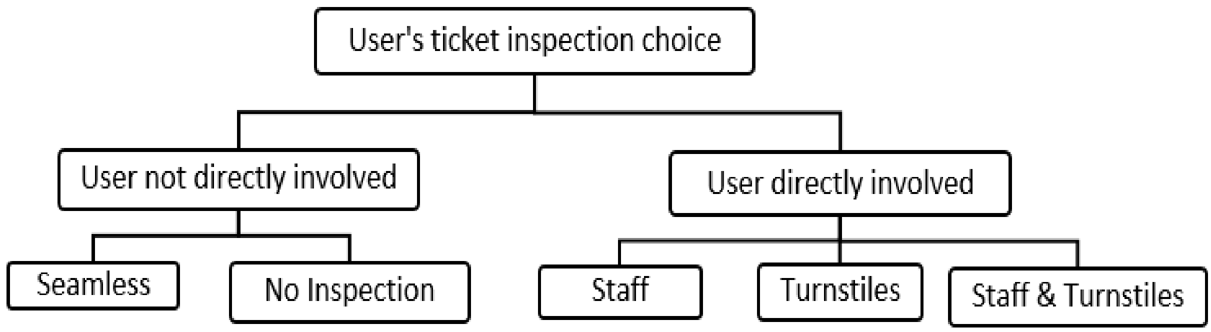

Figure 3-5: Nested logit structure 2 for ticket inspection (model NL2)

Table 3-1: Results of the estimated models (*The base alternative is "Both staff and turnstiles" (Status quo), Significance codes: 0.01 '***', 0.05 '**', 0.1'*'*)

	MNL	*NL1 (one nest)*	*NL2 (two nests)*
Number of individuals 110			
Estimated parameters	14	13	12
LL(final)	-123.58	-130.03	-145.44
Rho-sq (0)	0.30	0.27	0.18
Adj. rho-sq (0)	0.22	0.19	0.11
Likelihood ratio test statistics {-2(LL of NL1/NL2 -LL of MNL)}	-	12.91 (df = 1, p-value = 000)	43.73 (df = 2, p-value = 000)

	Seamless ticket inspection			**No ticket inspection**			**Only by staff**			**Only by turnstiles**		
	MNL	**NL1**	**NL2**	**MNL**	**NL1**	**NL2**	**MNL**	**NL1**	**NL2**	**MNL**	**NL1**	**NL2**
Variables	***Value (t-stat)***	***Value (t-stat)***	***Value (t-stat)***	***Value (t-stat)***	***Value (t-stat)***	***Value (t-stat)***	***Value (t-stat)***	***Value (t-stat)***	***Value (t-stat)***	***Value (t-stat)***	***Value (t-stat)***	***Value (t-stat)***
(Intercept)	-0.2312 (-0.61)	-0.1032 (-0.06)	-0.8176 (-2.17**)	-1.6315 (-1.48)	1.8926 (1.15)	-1.0685 (-1.75)	0.2465 (0.76)	-2.7659 (-1.15)	0.0066 (0.34)	-2.3767 (-3.26***)	-16.7691 (-1.61)	-0.0184 (-0.38)
Logsum parameter		6.3324 (2.15**)	-3.7078 (-1.35) 6.2028 (3.22***)									
Age (Years)												
16 - 34	2.0987 (3.82***)	-11.4563 (-11.97***)	2.1602 (4.11***)	-8.1648 (-7.45***)						-11.4491 (-14.24***)	-20.7299 (-2.48**)	
35 - 54 (base)												
55+	2.4586 (3.18***)	6.9638 (3.36***)	0.6231 (1.11)	4.2729 (3.39***)						4.3368 (4.47***)	20.0021 (1.86*)	
Monthly gross income in SEK												
0000 - 20000							-1.5665 (-1.92*)	-4.9762 (-2.07**)	-0.0382 (-0.39)			
20001 - 35000							-1.0110 (-1.41)	-0.6545 (-0.40)	-0.0264 (-0.35)			
Over 35000 (base)												
Gender												
Male	-0.9280 (-2.00**)	-1.5370 (-1.66*)	-0.8884 (-1.95*)									
Female (Base)												
Home to Work Door-to-door travel time(Respondents self-reported)				-0.0218 (-11.01***)	0.0050 (0.42)	-0.0189 (-3.27***)						

3.3 Empirical Results and Discussion

3.3.1 Preferences for ticket inspection options

With McNemar's Chi-squared value (with one degree of freedom) of 0.5926, and an associated p-value of 0.4414, the null hypothesis could not be rejected. Suggesting that there was no statistically significant difference in the respondents' preference for ticket inspection in the two dependent datasets. It is thus believed that most of the commuters still prefer automatic ticket inspection by turnstiles over manual ticket inspection by staff in the two survey waves. This could generally be explained by the fact that the Movingo scheme did not include any direct interventions that target improvements in ticketing inspection. It is however surprising that the respondents did change their preference for ticket inspection by turnstiles over that by staff even though the implementation of Movingo resulted in interoperability challenges in the first year, where the Movingo ticket media could not directly open turnstiles (Alhassan et al., 2020).

With the extended choice set of five ticket inspection options in the follow-up survey, the One-way chi-squared ($\chi 2$) goodness of fit test showed statistically significant association in users' preference for the ticket inspection options, that is, $\chi 2$ (df = 4, N= 110) = 31.727, and p-value = 0.000, suggesting that most of the respondents showed a preference for seamless ticket inspection over current approaches.

3.3.2 Factors associated with users' choice of ticket inspection approaches

Table 3-1 shows the results of the estimated MNL and NL models, given ticket inspection choice as the dependent variable and a set of user characteristics as the explanatory variables. The parameter signs were generally similar in all the three models. Given the data in this study, The MNL model provides the best fit model by examining the likelihood ratio test results in Table 3-1. The logsum parameters for both nested models fall outside the interval [0, 1], which is a precondition for the validity of nested logit models (Koppelman and Bhat, 2006). In addition to the MNL providing the best fit for the dataset, the inconsistency of the logsum parameter estimates with the NL theory further motivated the rejection of the estimated NL models.

The results suggest that with the status quo as the reference alternative, PT users in the age category 16-34 years and 55+ years are more likely to accept seamless ticket inspection relative to people in the age category 35-54. As younger adults are more likely to use technology than older adults (Czaja et al., 2006), their choice for seamless ticket inspection was expected. It is, however, surprising that people who are 55 years and above also preferred seamless ticket inspection. This may be due to their general need for convenience and calmness. Similarly, females are more likely to choose this new approach relative to males. Given that females patronise PT services more than males in the study area (Johansson-Stenman, 2002; Polk, 2004), this implies this area has good potential for implementing seamless ticket inspection. Concerning income, very high-income groups have a higher propensity to choose ticket inspection by staff. This could be because people with very high income tend to travel on first-class train tickets. Thus, often getting the opportunity to enjoy services from staff. PT users with perceived short door-to-door travel time opted for no ticket inspection. This is keeping with expectations given they have short travel distances and any encounter (s) with ticket inspectors or delays at turnstiles may increase their travel time.

3.4 Concluding Remarks

Using the Stockholm - Uppsala corridor in Sweden, this study was conducted to analyse PT users' preference for ticket inspection alternatives and their reaction to seamless ticket inspection, the next generation ticket inspection solution, and to analyse some associated factors that can influence users' choice of fare inspection. Explicitly, two main research questions have been addressed:

- What are PT users' preferences for ticket inspection alternatives given current and future scenarios?
- What factors are associated with their likelihood of accepting a “seamless ticket inspection” alternative?

The findings suggest that:

- The users generally prefer automatic ticket inspection to that by staff and then, digitally automated ticket inspection to mechanically automated (turnstiles). That is, given only turnstiles and staff as the only ticket inspection alternatives, the McNemar's Chi-squared test confirmed that the respondents' choice of ticket inspection by turnstiles over that by staff did not change over time (in the two survey waves). However, by extending the choice set to five alternatives, the majority of the respondents opted for seamless ticket inspection.

- Major PT user groups such as females and young people have a high tendency to accept seamless ticket inspection, implying that there is a potential market for its implementation.
- People in the high-income class are more likely to choose ticket inspection by staff.
- Users' preference for ticket inspection alternatives correlates with their characteristics. Suggesting that as PT users generally have the freedom to choose how to purchase their tickets, most of them will embrace the freedom to choose how their tickets should be inspected.

Given that the study focused on a corridor, with most of the respondents being commuters, we recommend that the analysis be extended to a wider area and wider PT users. We also see the need for research on the potential for seamless ticket inspection to reduce or prevent hostilities between users and ticket inspectors, the acceptable number of ticket inspections users expect per trip or per day, as well as the technical feasibility of seamless ticket inspection.

Acknowledgement

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Chapter 4

The Movingo integrated ticket: Seamless connections across the Mälardalen regions of Sweden

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Abstract

The need for improved public transport (PT) ticketing in ever-growing deregulated PT markets has made well-designed integrated ticketing systems a priority area of intervention for PT service providers around the world. Yet, very little practical evidence of its impacts are reported in Sweden and in the world at large. The focus of this study was the impacts of the Movingo integrated ticketing scheme in terms of PT patronage, user satisfaction and the perceived quality of the ticketing set-up. Three travel surveys were conducted along the Stockholm-Uppsala route. Methods including logistic regression and correlated t-test were used to analyse the samples. The findings suggest that the scheme made rail commuting attractive resulting in an overall increase of about 24% in ticket sales with 3% - 15% of some car commuters reporting that they patronised PT services after the project. The scheme also resulted in increased rail commuter satisfaction. The overall perceived quality of the ticketing set-up did not however improve due to interoperability challenges. Service providers' uncertainty about equitable distribution of revenue among the participating service providers, interoperability challenges and the lack of interest among most of the participating service providers to sell Movingo tickets are some issues to be addressed.

Keywords: *commuters, integrated ticketing, user satisfaction, perceived quality, public transport patronage, ridership*

4.1 Introduction

The need for improved public transport (PT) ticketing in ever-growing multimodal and deregulated PT markets makes well-designed integrated ticketing schemes a priority area of intervention for PT service providers and stakeholders around the world. PTEG's (2009) global review of these schemes confirmed that their benefits are often promoted heavily based on postulated benefits and that the actual post implementation benefits are not often captured or reported to the public.

Evaluation of integrated transport policies is a standard requirement in many organisations. Yet, Preston (2012) still maintained that there is lack of practical evidence on the successes of integrated transport policies. Integrated ticketing is one of the areas with very little reported practical evidence (PTEG, 2009).

The objective of this paper is thus to evaluate the Movingo integrated season ticket scheme that was implemented in the Mälardalen region of Sweden in October 2017.

Since there is currently no defined framework for evaluating integrated ticketing schemes within the implementing organisation and in Sweden as a whole, this evaluation is based on three major organisational and national transport policy goals. Increasing PT usage for commuting within the Mälardalen region was the main goal of the scheme and doubling PT use by the year 2020 with 2006 as the base year is a national goal in Sweden. This together with increasing user satisfaction and improving PT quality are strategic goals for all the public transport authorities (PTAs) in Mälardalen. The study thus focused on the impacts of the Movingo project in terms of PT ridership, user satisfaction and users' perceived quality of the ticketing set-up.

The main contributions of the study are 1) It identifies various areas for improving Movingo and integrated ticketing schemes in general. 2) It furnishes the implementing agencies with knowledge on the extent to which the Movingo project impacted their strategic goals. 3) It also adds to the wider literature on the benefits of integrated ticketing schemes, an example that interested practitioners and researchers may draw from.

The rest of the paper is organised as follows. The next section provides a review of ticket and fare integration. Section 4.3 describes the study area and the Movingo project. Section 4.4 presents the data collection, analyses methods and results. Section 4.5 discusses some key lessons from the Movingo project, and the final section provides some concluding remarks.

4.2 A review of ticket and fare integration

May et al (2006) identified four main types of integration within the field of transportation - operational integration, strategic integration between policy instruments, integration with land use and with policy instruments in other sectors; and institutional integration within and between local, regional, national and international governments. PT integration cuts across all four. The main objective of PT integration is to provide users with a broad set of destination and mode choices in a convenient, accessible, comfortable, safe, fast and affordable manner (Ibrahim, 2003). Chowdhury and Ceder (2016) identified fare and ticketing integration as one of the key dimensions of PT integration. These normally occur at the same time, as smart card and mobile phone technologies help users to travel with different transport service providers and the payments to the different service providers are automatically done in back-office.

PTAs around the world are implementing integrated ticketing schemes to remove or reduce the barriers of travelling across operators that can result from deregulated PT markets and to increase synergy by combining different modes. Some major benefits of PT ticketing integration to users, service providers and society include: increased PT usage, improved passenger satisfaction, modal shift, increased revenue, decreased transaction and administration costs, social benefits, reduced fraud, contribution to city life and identity, enhanced data acquisition, reduced boarding and dwell times, improved access to services, etc. (White, 2009; PTEG, 2009; Abrate et al, 2009). Major examples that incorporated all major PT services include the Hong Kong Octopus card, launched in 1997, and the London Oyster card, introduced in 2002 (Smart Card Alliance, 2003). In Groningen, the Netherlands, Cheung (2004) evaluated the effectiveness of the Tripperpas smart card and pointed out that technical reliability was relevant in winning user confidence and that check-in-check-out was a drawback for users. In Beijing, Chen et al (2005) evaluated an integrated fare initiative and concluded that reasonable pricing of PT was a challenge. Shon (1989) investigated PT fare integration in London and concluded that although there was some revenue lost to the service provider, it was beneficial to both users and society. Similarly, Oporum (2005) analysed the effect of automatic fare collection (AFC) in New York City and confirmed that it was beneficial to society. Free transfer and fare discount elements of the AFC encouraged PT ridership, with the value of free transfer estimated at 0.77 USD. Furthermore, Welde (2012) concluded that the fully interoperable smart card in Trondheim (Norway) gave a positive net present value.

While there is growing literature on the benefits of integrated ticketing, Preston (2012) still maintained that the general lack of practical evidence on the successes of integrated policies contributes to the failure of these policies. This is confirmed by Iseki et al (2007) who found out that many PT managers in the USA were uncertain about the benefits of these schemes.

4.3 Case study area

4.3.1 The Movingo integrated season ticket project

PTAs in Sweden are separate entities focusing on their regions of jurisdiction, resulting in regional differences in regulations, pricing and ticketing systems. Ticketing integration among PT service providers, with a long-term goal of achieving a nationally integrated ticketing system, is thus of policy interest in Sweden. The current dominance of PTAs in the Swedish PT market has facilitated integrated ticketing at city and county levels. The challenge, however, remains with intercounty and national integration of ticketing.

Commuting has been increasing annually in Sweden since 1993. 31% of the working population commuted beyond municipal boundaries in 2006 (SKL, 2008).

The need for integrated ticketing beyond county boundaries consequently motivated the Movingo project. Movingo is a smartcard and mobile phone based multiple-county commuting ticket that applies to both intercity and intracity bus and train services within the Mälardalen region. It is implemented by the six adjoining PTAs in the region (Figure 4-1) and a commercial rail service provider (the Swedish Railways, SJ). Its main aim is to increase commuting by PT. It started in October 2017 with frequent travellers as the target group. Users can buy a season ticket that is valid for at least two of the participating counties. Movingo currently has only three ticket options - one month, three months and one year. The Stockholm – Uppsala route, shown by the red ring line in Figure 4-1, is the focus of this study as it has the largest share of commuting trips in the region. The pricing strategy for Movingo is both flat (within counties) and distance-based (between intercity train nodes). Movingo tickets are currently sold by only the Swedish National Railways Company (SJ).

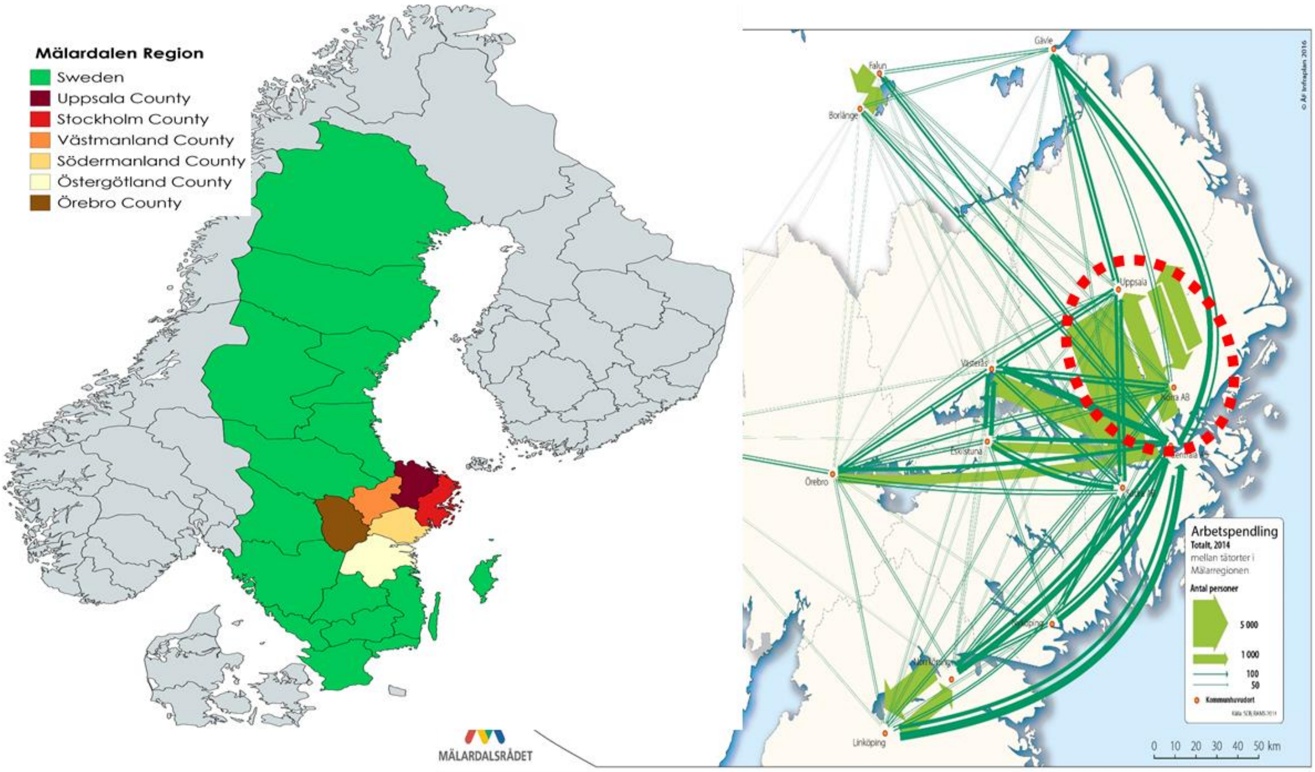

Figure 4-1: The Mälardalen region and the total number of work commuters among its urban areas in 2014 (Adopted from MÄLARDALSRÅDET, 2016)

4.3.2 The corridor before and after the Movingo project

Commuting either by car via the E4 motorway or by PT are the two main alternatives for commuters between Stockholm and Uppsala. The National Swedish Railways (SJ), the Stockholm county PTA (SL) and the Uppsala county PTA (UL) are the main train service providers. Before the year 2013, only SJ's commuters could make direct trips between the two cities. The SL and UL lines were separate, and their commuters needed to change train at the county border. These two lines were integrated in 2013 to form the SL/UL line that provide direct services between Stockholm and Uppsala. The available tickets before Movingo were SJ's season and single journey tickets as well as the SL/UL integrated season and single journey tickets (which are valid for all SL and UL services). The Movingo integrated season ticket, which integrated SJ, SL and UL services was launched in 2017 and the SJ's season ticket was removed. Thus, the available ticket options after the implementation of Movingo are the SL/UL integrated season and single journey tickets, Movingo (the SL/UL/SJ integrated season ticket) and the SJ's single tickets. As Movingo is a season ticket, the analysis thus focuses on only the season tickets.

4.4 Data collection and analysis methods

4.4.1 Data Collection

4.4.1.1 Two-wave rail commuter survey

In the first survey, PT commuters were contacted en-route on the Stockholm-Uppsala corridor in September 2017, before the project implementation. A pilot survey was first on 30 commuters, conducted on-board train, as a means of refining the questionnaire.

The survey was carried out within two weeks during peak hours. The respondents could choose to return answered questionnaires directly to the surveyors or by self-completion and mail-back. They could also answer the survey online on-board using tablets provided by the surveyors or answer them online at their convenience elsewhere. Based on the estimated total sample size and the expected response rate of about 35% from previous surveys (Stockholm county travel behaviour report, 2016), the estimated minimum number of questionnaires that needed to be distributed was 1074. 1800 paper questionnaires were distributed and 1131 of them were returned, giving an overall survey response rate of 63%, which is significantly higher than the expected response rate. Of the total of 1320 returned paper and online responses, 56% answered on-board using paper and pencil, 23% answered online and 21% answered by mailback. While most of the respondents opted for the on-board paper survey, the analysis of variance showed no statistically significant effect of the response method on the average attitudinal scores ($F = 0.864$, P-value =0.462).

In the follow-up survey, 450 of the respondents who participated in the first survey and agreed to participate in the follow-up survey were contacted via email and asked to complete the questionnaire again online in September 2018, one year after the project implementation. A total of 165 responses were received, implying that wave 2 represents 36.7% of the respondents in wave one who agreed to participate in wave 2, and 12.5% of the total respondents in wave 1.

The survey included Likert scale statements measuring how an individual commuter evaluates several ticketing attributes. That is, given that a commuter's perception of the different aspects of a given ticketing set-up can be negative, neutral or positive, the overall level of quality of the ticketing system can be measured by averaging the Likert scale scores for the individual commuters and across commuters (Table 4-1). The first ten attributes are grouped as a measure of the users' experiences with fare collection and the last seven attributes are grouped as a measure of their experiences with fare verification. The attributes replacement of damaged tickets and retrieval of lost tickets were not very common experiences among the respondents as 54% – 60% did not give their opinions on these attributes. If the attitudinal questions relate to the same issue, respondents are expected to get similar scores on each question. To confirm this, the Cronbach's α test (Table 4-1) was used to measure the internal consistency (how closely related the items are as a group) of the set of attitudinal questions measuring the latent constructs for fare collection and fare verification systems, which are not directly measurable. Many studies in transportation consider Cronbach's alpha values of around 0.70 or better as acceptable.

As shown in Table 4-2 and described in appendix C1, both survey waves also included questions about the respondents' commuting habits and behaviour and socioeconomic characteristics. In the follow-up survey, Movingo users were asked to comment on why they chose it. The responses were grouped into five themes – increased accessibility, time savings, cost savings, comfort and convenience. Figure 4-2 summarises the frequencies for these five themes. Most of them stated that they chose Movingo because of increased accessibility while a few of them chose it because of convenience.

Movingo users also stated their overall satisfaction with Movingo and its specific aspects. As shown in Figure 4-3, 70% of them were generally satisfied with Movingo. Except for the mobile ticketing aspect, at least 50% of the respondents are satisfied with each of the different aspects of Movingo.

As in most multiple surveys, a significant level of attrition occurred as 63.3% of the respondents fell out. However, as shown in Table 4-2, this did not significantly affect the representativeness of the sample. The distribution in Table 4-1 suggests a small amount of dropout attrition in the ratings of the 17 statements. In addition, the Shapiro Wilk test of normality on the composite scores produces p-values > 0.05 (Wave 1: W = 0.98366, p-value = 0.0868. Wave 2: W = 0.99105, p-value = 0.3903), indicating that the attrition was of random nature as the distributions of the survey samples in both waves are not significantly different from a normal distribution.

4.4.1.2 Cross-sectional survey of car commuters

A cross-sectional survey was conducted for car commuters along the Stockholm – Uppsala section of the E4 motorway. The objective was to estimate the proportion of them that patronised PT after the implementation of the project. Registration numbers of private cars were randomly recorded during peak hours. Addresses linked to these vehicle registration numbers were then extracted from the Swedish national car registry. Vehicle registration numbers that were linked to addresses outside Stockholm and Uppsala were filtered out. The survey questionnaires were then sent to the respondents by post together with a paid-reply envelope for the subsequent mail back of the completed questionnaire. They also had the option to respond online. The survey was closed after four weeks without sending reminders to respondents. 475 surveys were sent out and 96 of them were completed and returned, giving a response rate of 20%. This is far lower than the response rates in the PT surveys but typical of car travel surveys in the study area.

Since the integrated ticketing scheme was the only PT improvement measure at the time of the survey, the respondents were required to answer the dichotomous question “I started commuting by rail in or after autumn 2017”. Out of the 96 respondents, 9.4% answered yes. The survey sample is described in appendix C1.

4.4.1.3 Ticket sales data

As presented in section 4.3.2, the SJ season ticket was removed after the implementation of Movingo. The available season ticket options for the commuters were then the SL/UL and Movingo season tickets. The sales data for SL/UL season ticket before and after the Movingo project is compared with that for the Movingo ticket in Figure 4-5. Between October

2017 (the implementation month of Movingo) and March 2019, SJ reported an increase of about 24% in overall season ticket sales. We have not been granted access to the raw ticket sales data to perform our own analysis of it. However, since we aim to understand the trends in the demand for the two season ticket options, we report the monthly ticket sales as a percentage of the total number of tickets that were sold for this given period due to organisational data restrictions. The demand for season tickets is generally low in December and lowest in July since these are normally holiday months in Sweden.

As shown in Figure 4-4, after the implementation of Movingo there were significant sales, accompanied with decreases in the demand for the existing SL-UL integrated season ticket of between 0.9% to 4.7%.

Table 4-1: Descriptive analysis of the survey ratings.

Ticketing attribute statements (Overall reliability, Cronbach's $\alpha_1 = 0.83$, $\alpha_2 = 0.71$)	7	6	5	4	3	2	1	No opinion (0)
Relating to fare collection ($\alpha_1 = 0.83$, $\alpha_2 = 0.70$)	**Relative frequencies in %, presented in two dimensions (Wave 1, Wave 2)**							
It is easy to replace damaged ticket	7,4	5,6	4,5	8,5	5,3	5,4	6,8	60,65
It is easy to retrieve lost ticket	8,3	5,6	6,5	9,7	6,3	5,6	6,9	54,61
Flexibility to buy my ticket any time and any where	17,24	15,16	18,18	16,13	12,8	6,7	7,8	9,5
Using a ticket vending machine is easy for me	18,17	21,24	20,19	16,8	9,13	4,5	5,8	8,5
It is acceptable that I cannot buy ticket on the bus	20,19	8,10	7,8	10,14	13,10	13,13	20,19	9,6
It is easy to get information about available ticket types	25,30	19,19	20,26	14,7	9,8	7,2	5,5	1,2
It is easy to buy a ticket	26,34	26,25	20,18	12,12	7,4	4,6	3,2	2,0
The time it takes to buy a ticket is acceptable	27,40	29,21	21,24	11,8	5,2	3,1	2,4	2,0
It is acceptable that I cannot buy ticket on the train	29,32	15,13	12,14	13,11	9,9	8,8	11,11	4,2
It is easy for me to use my ticket	36,29	22,15	16,17	8,6	4,6	2,4	3,8	10,14
Relating to fare verification ($\alpha_1 = 0.72$, $\alpha_2 = 0.69$)								
Delay level at turnstiles is acceptable	3,10	7,8	12,12	14,14	17,13	12,9	18,9	18,24
It is disturbing for me to have my ticket checked by bus driver	5,3	3,3	5,5	6,5	9,8	15,10	49,59	8,5
It is smooth for me to pass through turnstiles when I am having luggage, pram, wheelchair or rollator	7,5	8,7	14,8	13,7	12,8	10,9	9,10	28,45
Congestion level at turnstiles is acceptable	7,11	13,10	19,13	17,17	12,13	8,8	8,10	16,19

(Sample sizes: Wave 1, n = 1 259 and for Wave 2, n = 165). The relative frequencies of the ratings for the before (Wave 1) and after (wave 2) cases are presented as comma-separated in the table. The Cronbach's alphas α1 and α2 represent the internal reliability of the latent constructs in wave 1 and 2 respectively. No opinion (0) responses were excluded in the calculation of the average scores as it indicates that a respondent is yet to experience the given ticketing aspect.

Table 4-2: Descriptive analysis of the sample

Characteristics	*Wave 1 (%), n =1320*	*Wave 2 (%), n =165*
Gender		
Female, Male, Other	56.9, 42.6, 0.5	54.5, 44.8, 0.6
Age (Years)		
16 – 24,25 – 34,35 – 44,45 – 54,55 – 64,65+	17.8,29.7,20.8,18.0,11.3,2.4	4.8, 24.8,18.8,28.5,20.6, 2.4
Monthly gross income in SEK		
0–10 000	14	5.5
10 001–15 000	7	6.1
15 001–20 000	3	0.6
20 001–25 000	4	3.0
25 001–30 000	11	6.7
30 001–35 000	14	13.9
35 001–50 000	25	33.9
Over 50 000	15	24.8
Do not want to give	7	5.5
Education		
Higher education (3 or more years)	57.1	75.2
Higher education (less than 3 years)	19.0	11.5
High school graduate	21.5	12.7
Under High school	1.2	0.6
Other	1.3	-
Employment status		
Full-time employed	64.8	78.8
Part-time employed	5.0	2.4
Full-time student	22.4	12.7
Part-time student	2.0	1.2
Full-time self employed	2.5	1.8
Part-time self employed	0.6	1.2
Other (unemployed)	2.7	1.8
Received tax reduction for work trips		
Yes, No	58.8, 41.2	63.6, 36.4
Travel cost paid by employer		
No, Partly, Fully	91.5, 4.1, 4.4	94.5, 3.0, 2.4
Current Service Provider		
SL/UL, Movingo, SJ, SL, TiM, UL, Other	45.8, -, 34.1, 9.9, 5.5, 4, 0.6	19.4,51.5,17.0,7.9,1.2, 2.4,0.6
Commuting frequency by train *(days/week)*		
1 – 2, 3 – 4, ≥ 5, Rarely, Never	7.4, 25.4, 58.1, 5.7, 3.4	6.1, 20.6, 67.3, 4.2, 1.8
Commuting experience by train		
< 1 year, 1 – 2 years, 3 – 4 years, ≥ 5 years	24.3, 22.5, 15.6, 37.5	4.2, 24.8, 19.4, 51.5
Ticket purchase channel		
Vending machine	31.4	37.6
Sales agent	20.3	12.7
Service provider offices	25.7	13.3
Mobile phone	15	33.3
On the internet	3.6	1.8
On-board PT vehicle	0.2	1.2
Use of season for non-commuting trips		
1-2 times a week	21.0	21.8
3 - 4 times a week	8.2	6.7
≥ 5 times a week	9.3	7.9
I do not use season ticket	8.1	6.1
Never	9.5	9.1
Rarely	44.0	48.5

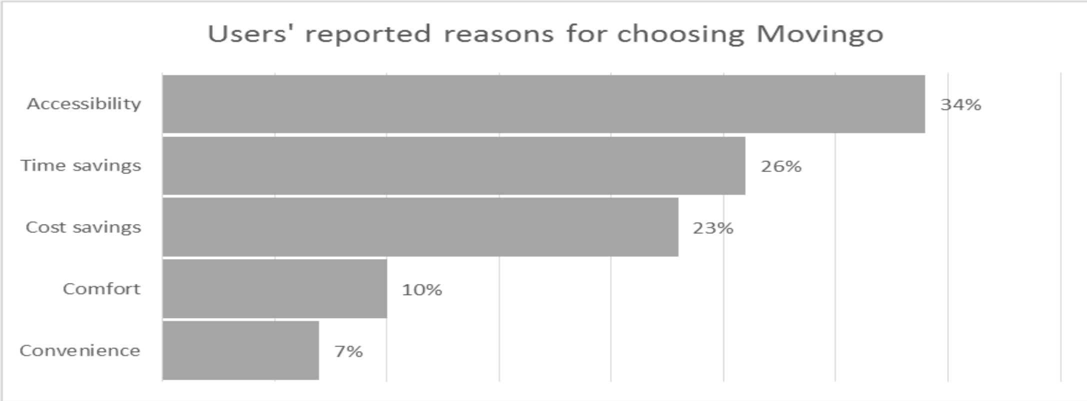

Figure 4-2: Users' revealed reasons for choosing Movingo

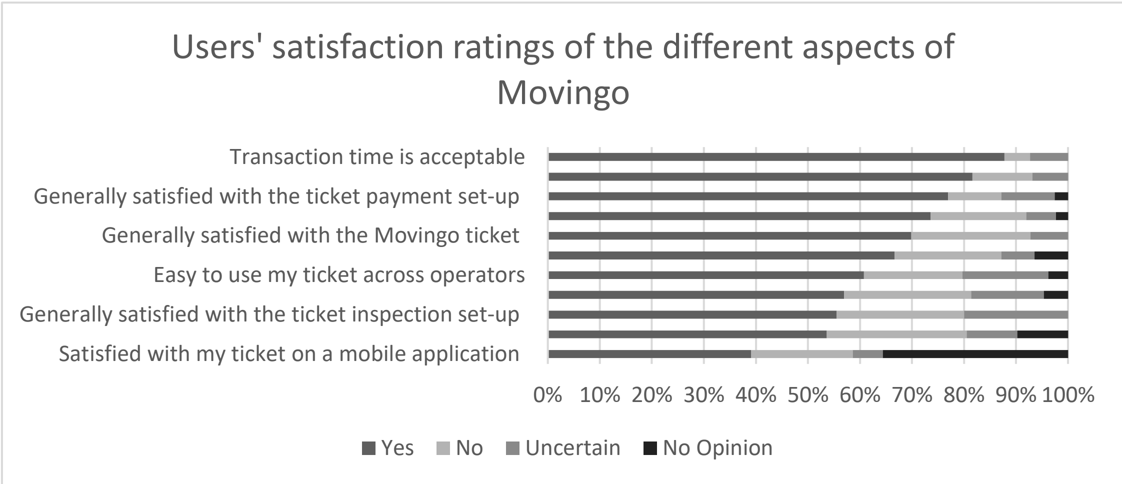

Figure 4-3: Satisfaction and perceived quality of the different aspects of Movingo

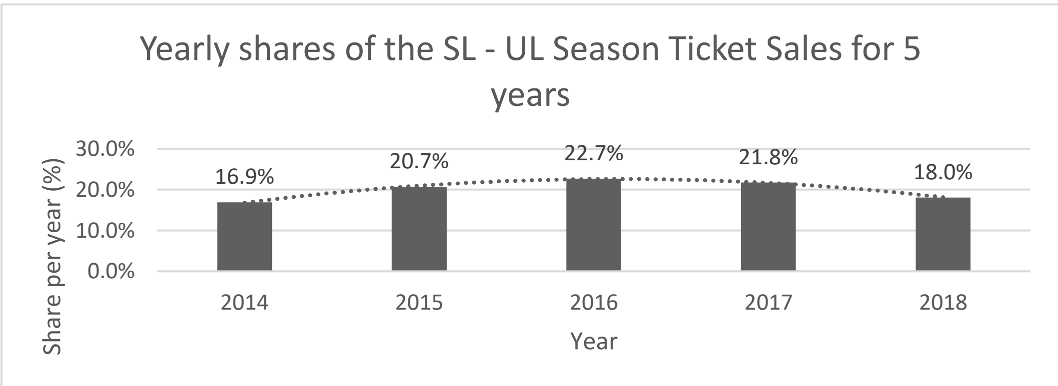

Figure 4-4: Annual shares of the total SL/UL season tickets sold between 2014 & 2018

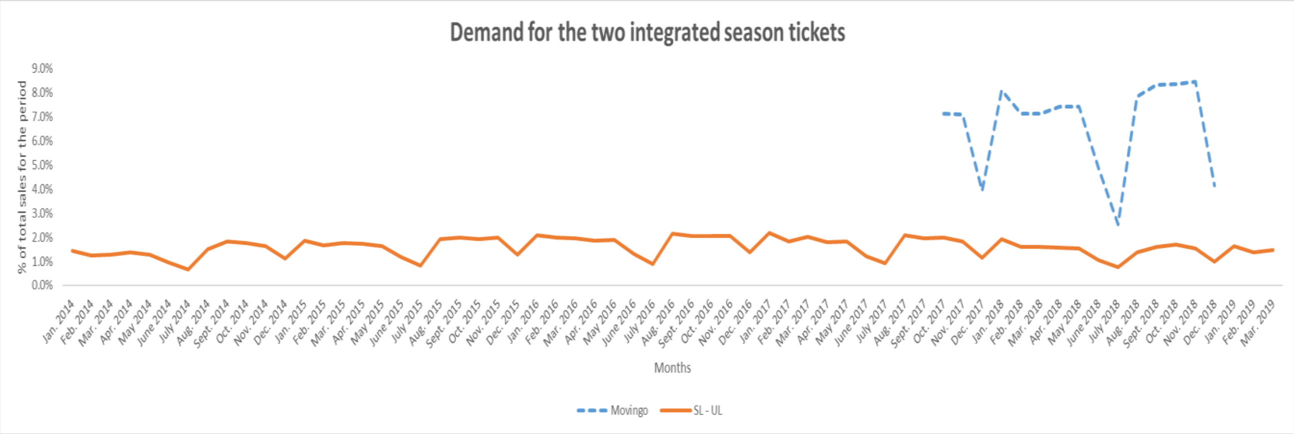

Figure 4-5: Monthly sale proportions of the Movingo ticket and the SL – UL season ticket over time (UL 2019)

4.4.2 Methods

The collected data was analysed using the methods described in this subsection. The effect of Movingo on PT patronage was analysed by the statistical estimation of proportions and by comparing changes in season ticket sales before and after the project. Since the same individuals participated in both waves of the PT survey, a correlated t-test was used to analyse the observed differences in the perceived quality of ticketing before and after the project. A logistic regression was used to analyse the variables that correlated with users' satisfaction with Movingo.

4.4.2.1 Dependent sample t-test

Fifteen out of seventeen attributes (Table 4-1) were grouped into six quality dimensions (Table 4-3) and used to evaluate the perceived quality of the ticketing system. Ease of replacing damaged and lost tickets was excluded in computing the dimensional averages since the majority of the respondents did not experience these two aspects.

Were the observed differences in the mean attitudinal scores in the two waves statistically significant or they were due to chance? The Shapiro Wilk test of normality on the mean scores of both samples produces p-values > 0.05, hence, normality was assumed. Also, since it was the same respondents in both surveys, it was also assumed that the two samples were dependent. Consequently, a two-sided correlated t-test was used to compare changes in the perceived quality of ticketing before and after

Movingo (Aczel and Sounderpandian, 2006). The two hypotheses that were tested for all the six quality dimensions are:

- A null hypothesis that the difference in the mean attitudinal scores for each quality dimension before and after the integration is 0, H0: μ1 = μ2,
- An alternative hypothesis that true difference in means is not equal to 0, HA: μ1 ≠ μ2.

4.4.2.2 Estimation of the proportion of car commuters using Movingo

Given that the sample proportion of car commuters that used rail services after the project is an unbiased point estimator of the population proportion, the proportion of car commuters using rail due to the integrated ticketing was estimated at the 95% confidence level. The estimate of the population proportion (p) whose estimator is (p̂) is approximately normally distributed if n is sufficiently large (np>5 and nq>5, where q = 1 - p). The mean of the sampling distribution is the population proportion p with standard deviation $\sqrt{pq/n}$. The (1-α) 100% confidence interval, CI, for the population proportion is $p = \hat{p} \pm Z_{\frac{\alpha}{2}}\sqrt{\frac{\hat{p}(1-\hat{p})}{n}}$ where p̂, the estimated sample proportion, is equal to the number of successes in the sample divided by the sample size, n (Washington et al, 2011).

4.4.2.3 Logistic regression modelling

As observed in this study and in previous studies, the proportion of satisfied users in smart ticketing projects is usually high. Yet, very few studies have mathematically modelled how user satisfaction with integrated ticketing relates to user and service characteristics. The object of this analysis is to identify a well-fitting mathematical model that describes the relationship between the users' satisfaction and a set of explanatory variables. Since the dependent variable was binary in its outcome (satisfied or not satisfied), a logistic regression analysis is the preferred method due to its robustness, ease of interpretation and diagnostics. That is,

$$y = \begin{cases} 1, \ if\ satisfied,\ otherwise \\ 0 \end{cases}$$

$$Logit = ln\left(\frac{\mathrm{Prob}_{Satisfied}}{1-\mathrm{Prob}_{Satisfied}}\right) = b_0 + b_1X_1 + \cdots + b_nX_n$$

For a detailed description and application of this method, the reader is referred to Hair Jr., et al (2010) and Washington et al (2011).

4.5 Results and discussion of some key lessons from the Movingo project

The findings are presented and discussed in the following three sections.

4.5.1 Ridership impacts

The main goal of the Movingo project is to increase commuting by PT within the Mälardalen region. In the literature, the majority of the reported benefits of integrated ticketing focus on ridership impacts (PTEG, 2009). Kamargianni et al. (2016) reported that while significant patronage effects were observed in Stockholm, Manchester, Vienna, Hamburg, Singapore, Tampere, the Netherlands, Washington and in San Francisco, the case in France had the most significant effects in terms of increased PT patronage, where the declining trend (-12% between 1945 and 1975) in PT usage was reversed to an overall increase of 33% from 1975 to 1993.

In the case of Movingo, SJ ticket sales data shows that, between October 2017, when the Movingo ticket was introduced, and March 2019, there was an overall increase of about 24% in ticket sales. This indicates Movingo has had a strong impact on ridership, despite the limitations on access to the ticket implied by it only being available from SJ, and not from any of the six participating PTAs. Three possible sources of this increase are discussed below.

- New commuters to the corridor: This study lacks the data needed to estimate the proportion of new commuters to the corridor.
- Car commuters: Some car commuters may have started using PT for all or some of their commuting trips after the scheme. From our sample of car commuters, the 95% confidence interval for the proportion of car commuters who reported that they began to patronise rail services after the project was 3% - 15%. This is very small compared to the Flash Eurobarometer's (2011) opinion study of integrated ticketing's potential to attract car users to PT, where one in two EU citizens stated that they would definitely consider using PT often, given a single multimodal ticket. The huge difference in these two findings is, however, not surprising for three main reasons: 1). The conditions for the car users' choice in Flash Eurobarometer's

study were purely hypothetical and the respondents may not have considered many practical factors, 2). Only car commuters were surveyed in this study whilst Flash Eurobarometer's survey considered a wide group of car users. 3). The benefits of Movingo were probably not attractive enough for most of the car commuters to change travel mode. As shown in the survey sample described in appendix B, many practical factors were in play such as the proportions of the respondents who had access to free parking at work, access to annual tax benefits for work trips, a need to drive children to school on their way to work, or use the car during work, all of which might have made car more attractive for these commuters. This means 9% of car commuters with specific characteristics (not 9% of all commuters along the corridor) were attracted to PT by the Movingo scheme. As summarised in table 6-1, the sample further suggests that car commuters who chose Movingo were those without access to free parking at work, without access to a company car for trips to/from work, without a need to drive children to school on their way to work, or without a need to use the car during work. Also, the mean door-to-door self-reported travel time to or from work for car commuters who chose Movingo was not statistically different from that of PT commuters. Travel time is a significant determinant of mode choice for commuting. A one-sample t-test confirmed that the mean door-to-door self-reported travel time from home-to-work trips was not statistically different from that of from-work-to-home trips for the car commuters in the sample. The same applied to the PT commuters. The perceived mean door-to-door travel time to or from work for all the PT commuters was about 80 minutes, that for the car commuters who did not choose Movingo was about 50 minutes and that for the car commuters that chose Movingo was 76 minutes. A two-sample t-test confirmed that the mean perceived door-to-door travel time to or from work for the car commuters who chose Movingo was not statistically different from that of the PT commuters ($t = -0.7217$, $df = 9.2334$, p-value = 0.4884). Thus, in terms of travel time, car commuters whose perceived travel time is about the same as that of PT commuters who found the multicounty integrated ticket attractive. This is not strange as the out-of-pocket cost of commuting by car is generally higher than that of PT, and the Movingo ticket further reduced the out-of-pocket cost of commuting by PT. Thus, the findings suggest that 9% of commuters with specific characteristics patronised PT services after implementing the Movingo scheme. Yet, given the current dataset, the study could not directly relate this 9% to the 24% increase in sales. Yet, the attraction of car commuters to PT due to the Movingo scheme is also reflected in the annual report of the Association of Swedish Public Transport (SKT), the PT barometer (2018). With the exception of the Östergötland county that recorded a very small decrease in PT market share, all the other counties covered by the project recorded an average of about 2% increase in PT market share between 2017 and 2018. Also, in the analysis of users' willingness-to-pay (WTP) for the Movingo multi-regional and multi-operator integrated season ticket, the coefficient of the integrated ticketing attribute was larger than that of travel time, cost and service frequency (Alhassan et al. 2020), suggesting that the attractiveness of the ticket to users is not just due to the improved convenience of ticketing but also the many synergistic effects of the integration that reduced the generalised cost of PT commuting. This is further confirmed by the users' revealed reasons for using Movingo, shown in Figure 4-2. Fares, service frequencies, transfers and zones were integrated, leading to travel time savings, cost savings, increased service frequency, increased geographic accessibility, increased convenience and comfort for Movingo users. The studied corridor is the largest cross-county commuting corridor in Sweden. Hence, the ridership impact of the project is expected to be greater in this corridor compared to the other project areas.

- PT commuters who changed from the existing Swedish National Railways' (SJ) season ticket and the existing SL-UL integrated ticket to Movingo: The then PT users who now patronised Movingo were mostly users of the SJ's unintegrated season tickets and that of the SL – UL integrated season ticket. The majority of them were users of the SJ season ticket since this ticket was no longer available after the implementation of Movingo. A few of them were users of the SL-UL integrated season ticket as the demand for this ticket decreased by an average of 3% (Figure 4-4 & Figure 4-5) after the Movingo project. Users of both Movingo and the SL – UL season tickets have access to the entire PT networks in Stockholm county (SL) and Uppsala county (UL). However, only Movingo users have additional access to both the Swedish National Railway line and the combined SL – UL line between Stockholm and Uppsala. SL – UL users only have additional access to the integrated SL – UL line between the two cities. The SJ line is faster as it provides direct services between the two cities or serving just two intermediate stops (Märsta and Knivsta). The SL – UL line is comparatively slow as it serves at up to twenty-five (25) stations between the two cities. In addition, Movingo offers 10% – 30% fare reduction, depending on the intercity journey distance. The shift of some users from the SL – UL integrated season ticket to the Movingo integrated season ticket implies that even though integrated ticketing, in general, has positive effects on PT ridership, the synergistic effect of integrating service providers with differentiated products provides better ridership effects compared to integrating service providers with similar products. The shift between the two rail lines in the study area has a positive effect on reducing congestion on-board the SL-UL line and the competition for seats on the section of this line within Stockholm's county territory during peak hours. This is because this line serves all stops within Stockholm, thus, mixing passengers traveling within Stockholm and those traveling directly to Uppsala, Märsta and Knivsta. The then intercity users of SL- UL train who now use Movingo now travel faster and relatively more comfortably without competing with intracity passengers on the SL-UL line for seats. As discussed in point number two above, the attractiveness of the integrated season ticket to the users of the existing integrated season ticket is not just due to the improved convenience of ticketing but also the synergistic effects of the integration that reduced their generalised cost.

4.5.2 Impact on user satisfaction

User satisfaction with Movingo was analysed through the development of a regression model. The respondents' self-reported reasons for choosing Movingo, summarised in Figure 4-3 and described in section 4.4.1, together with the explanatory variables provided in Table 4-2, were used in the modelling. Different specifications of the model were considered, as shown by the overall goodness-of-fit measures in Table 4-4, the reported model is considered to be the best fit model, as it is 50% to 60% better than the reference models (zero or constants only models). The five explanatory variables that were statistically significant are gender, frequency of commuting by train, stated reason for choosing Movingo, the extent to which respondents use their season tickets for non-commuting trips and whether the respondent advocates for free PT or not.

User satisfaction is an important gauge of perceived quality. Mass Transit (2016) identified customer satisfaction as one of the three top challenges to be solved by new ticketing technologies. The results of this analysis indicated that 70% of Movingo users are satisfied. This high satisfaction rate was expected as previous studies such as that of Cheung (2007) reported that 75% of the respondents were satisfied in the case of Rotterdam. Also, DfT (2010) anticipated that 7 of 10 respondents in Greater Manchester, West Midlands and Bristol would be satisfied with integrated ticketing.

Except for the mobile ticketing aspect of Movingo, at least 50% of the respondents are satisfied with each of the ten different aspects of Movingo. This is again not surprising as Blythe (2004) found out that over 90% of the respondents in the case of the combi-card in Tampere (Finland) reported ease of transaction and speed of transaction as the leading advantages of the card. In the case of Movingo, over 80% of the respondents are satisfied with these two aspects. However, only 39% of the respondents were satisfied with Movingo on mobile phones. This might be due to interoperability problems between mobile devices and turnstiles. The rating for this aspect might now have improved, since this problem was resolved after the follow-up survey.

Most of the users of Movingo ranked increased accessibility to a wide range of destinations, time savings and cost savings as the three top reasons for their choice of Movingo as a mobility tool. This supports previous findings highlighting the importance of these three factors (Balcombe et al, 2004; Ortúzar and Willumsen, 2011). Accessibility, which is one of the main dimensions of the Swedish national transport policy, may be argued to be the main purpose of traveling. Surprisingly, ticketing improvements are often associated with convenience and comfort, yet fewer respondents associate their choice of Movingo with these two factors.

The results further suggest that being a male commuter increases the likelihood of being satisfied with the multiple-county integrated ticketing compared to a female. This was not expected, as females generally tend to have higher trip chaining tendencies compared to males (Susilo et al., 2019). Even though high trip chaining may imply a high demand for integrated ticketing, males tend to commute longer distances compared to females in

Sweden and may thus be more satisfied with the multiple-county integrated ticketing. People commuting five or more days per week are less likely to be satisfied with multicounty integrated ticketing relative to those commuting four or fewer days per week. This is likely to be because people who commute four or less days per week will generally have more time to make non-commuting trips such as recreational trips with their season tickets, thus increasing their satisfaction with integrated ticketing. The results confirmed that, at 1% significance level, commuters who rarely or never use their integrated season tickets for non-commuting trips are less likely to be satisfied with multiple-county integrated ticketing compare to those who use them for non-commuting trips. The majority (83%) of the 23% unsatisfied users were within this group, implying that they do not need integrated tickets as their origin-destination choices with Movingo are mainly limited to home-work and work-home. Yet, they were forced to choose Movingo as all season tickets now available for intercounty trips are integrated, and they preferred Movingo. While most of the respondents stated that they chose Movingo because of increased geographic accessibility (Figure 4-2), commuter cost savings due to integrated ticketing had the most positive effect on users' satisfaction compared to increased geographic accessibility, time savings, increased convenience and comfort. Finally, the results also indicate that commuters advocating for free PT are more likely to be satisfied with multicounty integrated ticketing relative to non- advocates.

Table 4-3: Statistical summaries of the average attitudinal scores on a scale of 1 - 7

Attitude dimension	Mean Wave 1, Wave 2	t value (p-val)	Standard Dev. Wave 1, Wave 2	Coefficient of Variation Wave 1, Wave 2	95% Conf. interval Wave 1, Wave 2
Fare collection	4.67, 4.76	-0.36 (0.71)	1.19, 1.10	0.25, 0.23	4.48 - 4.86, 4.56 - 4.93
Payment on-board	4.04, 4.18	-0.41 (0.68)	2.18, 2.03	0.54, 0.49	3.69 - 4.38, 3.86 - 4.50
Fare verification	3.33, 3.09	1.61 (0.11)	1.35, 1.25	0.41, 0.40	3.11 - 3.55, 2.90 - 3.29
Manual verification by staff	2.34, 2.19	0.88 (0.38)	1.72, 1.65	0.74, 0.75	2.06 – 2.61, 1.94 - 2.44
Automatic verification by turnstiles	3.74, 3.46	1.58 (0.12)	1.69,1.68	0.45, 0.49	3.47 - 4.01, 3.21 - 3.70
System's average score	4.05, 3.99	0.85 (0.40)	0.99, 0.91	0.24, 0.23	3.89 - 4.21, 3.85 - 4.12

It is also possible that the Movingo project impacted user satisfaction positively across the entire Mälardalen region. The annual report of the Association of Swedish Public Transport, the PT barometer (2018), reported an average of 2.6% increase in user satisfaction across all the participating counties between 2017 and 2018.

Table 4-4: Satisfaction with Movingo *- Significance codes: 0.01 '***', 0.05 '**', 0.1'*'*

Explanatory variables	Parameter estimate	Std. error	z value	Pr (> |z|)
Intercept	2.47298	2.15533	1.147	0.25123
Gender				
Female (base level)				
Male	2.34868	1.08804	2.159	0.03088**
Monthly gross income in SEK				
0–35 000 (base level)				
35 001–50 000	0.01581	1.15462	0.014	0.98907
Over 50 000	-0.13027	1.11940	-0.116	0.90735
Education				
High school graduate (base level)				
University graduate	1.91591	1.28510	1.491	0.13600
Commuting frequency by train				
≤4 days/week (base level)				
≥ 5 days/week	-3.47409	1.66727	-2.084	0.03719**
Change in work location				
No (base level)				
Yes	-1.13902	2.17301	-0.524	0.60016
Why do you prefer Movingo?				
Increased accessibility (base level)				
Convenience	-1.18992	1.61942	-0.735	0.46247
Cost savings	3.29163	1.71395	1.920	0.05480*
Time savings	-1.81058	1.34204	-1.349	0.17730
Time savings and accessibility	0.58841	1.61325	0.365	0.71531
Time savings and comfort	-2.67817	1.31319	-2.039	0.04141**
Use of season ticket for non-commuting trips				
1-2 times a week (base level)				
3 - 4 times a week	16.32314	1879.88412	0.009	0.99307
≥ 5 times a week	-1.57030	1.91489	-0.820	0.41219
Never	-4.75148	1.76886	-2.686	0.00723***
Rarely	-0.01094	1.13432	-0.010	0.99231
PT be made free and fully financed by tax				
No (base level)				
Yes	2.44599	1.17971	2.073	0.03814**
Model estimation fit				
Number of observations	82			
AIC	76.84			
Loglikelihood at convergence	-21.420			
Loglikelihood at zero	-56.838			
Loglikelihood for constant only	-43.160			
Rho-sq at constant	0.504			
Rho-sq at zero	0.623			

4.5.3 Impact on the perceived quality of the ticketing set-up

Statistical summaries of the attitudinal scores for the six dimensions are presented in Table 4-3. The relative measure of dispersion in the dimensional averages, coefficient of variation (CV), given by the ratio of the standard deviation to the mean score, generally indicates small variations in the averages in both waves.

For all respondents, no statistically significant differences were found in the mean scores before and after the project, as p-values for the differences in mean scores in the two samples were far greater than 0.05 (Table 4-3). The null hypothesis of no difference in the mean score of each of the quality dimensions before and after could not, therefore, be rejected. The same is true for Movingo users except for the dimension of automatic fare verification by turnstiles, where there was enough evidence to reject the null hypothesis of equal mean in the two samples ($t = 2.3288$, $df = 77$, $p\text{-value} = 0.0225$). It is therefore believed that Movingo users' perceived quality of automatic fare verification by turnstiles decreased by about 7.5%. This was mainly due to poor interoperability as Movingo users could not directly open turnstiles in Stockholm with either their smart cards or mobile tickets. This interoperability problem was also experienced in the SL/UL integrated season ticket project in 2013 and still exists, as a user of this ticket is still required to keep her receipt and show it together with the SL's access card to be able to use the PT system within Uppsala county. Only Movingo users with mobile tickets can now open the turnstiles in Stockholm. This was after the follow-up survey was conducted.

In the Netherlands, Cheung (2004) pointed out that the technical reliability of the Tripperpas smart card technology was relevant in winning user confidence. This implies that interoperability should always be considered as one of the goals of integrated ticketing projects.

4.6 Concluding remarks

The purpose of this study was to analyse the impacts of the Movingo integrated season ticket project in the Mälardalen region of Sweden, focusing on its impacts on PT patronage, user satisfaction and the perceived quality of the ticketing system.

Movingo was largely successful as it made rail commuting more attractive to commuters. There was an overall increase of about 24% in rail usage with 3% - 15% of car commuters reporting that they patronise rail service after the project.

About 70% of Movingo users are satisfied mainly due to increased geographic accessibility, cost savings and time savings. Over 80% of the respondents were satisfied with the ease and speed of the transactions. Movingo on a mobile application was the aspect with the least satisfaction, as only around 39% of the respondents were satisfied with this aspect. Being a male commuter, or a commuter who uses an integrated season ticket for non-commuting trips or an advocate for PT to be made free have positive effects on satisfaction with multicounty integrated ticketing.

The overall perceived quality of ticketing did not however improve due to interoperability challenges, suggesting that a complete integration of all relevant aspects of ticketing is crucial for realising the full benefits of integrated ticketing schemes. The perceived quality of automatic verification by turnstiles decreased by about 7.5% for Movingo users after the implementation of the project because of poor interoperability.

In general, the findings of this study provide evidence that the project to some extent contributed to SKT's reported 2.6% average increase in PT user satisfaction and 2% average increase in PT market share across the participating counties between 2017 and 2018.

In terms of policy implication, like many integrated ticketing schemes around the world, whilst the Movingo scheme is largely successful, service providers' uncertainty about equity in revenue distribution among the participating organisations, technological challenges and the lack of interest among most of the participating agencies to sell Movingo tickets are important challenges that need to be addressed.

The study envisaged the need for further research in a number of areas. Firstly, developing a transparent and effective method for optimal distribution of revenue among participating PTAs in integrated ticketing could reduce or eliminate PTAs' uncertainty about equity in revenue distribution. Secondly, interoperability challenges of the project are gradually being addressed and a third follow-up survey is recommended. Finally, a standardised evaluation framework for the integrated ticketing scheme in Sweden is a potential research area.

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Disclosure statement

On behalf of all authors, the corresponding author declares that there is no conflict of interest.

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Chapter 5
Public Transport Users' Valuation and Willingness-to-pay for a Multi-regional and Multi-operator Integrated Ticketing System

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Abstract

Willingness-to-pay (WTP) is an institutionally accepted approach for driving the monetary values of transport policy measures in many countries. Public transport service providers around the world are implementing integrated ticketing schemes to improve synergy and to remove or reduce the barriers to travelling across operators that are created by multimodal and deregulated public transport markets. Yet, users' preferences and WTP for integrated ticketing systems is mostly unexplored, leaving policymakers with little means of evaluating their potential economic benefits. Consequently, this case study was conducted to estimate PT users' WTP for multi-county and multi-operator integrated ticketing. Multinomial and mixed multinomial logit models were estimated using SP data, collected in relation to the Movingo multi-county and multi-operator integrated season ticket scheme in Mälardalen, Sweden. The findings showed strong evidence of users WTP for regional ticketing integration. Users' valuation of the integration is estimated to be at least 26% of the average integrated monthly ticket price. Non-commuters' mean WTP is estimated to be 42% higher than that of commuters. Women showed less variability in their WTP compared to men. Still, men's mean WTP is estimated to be about 100% higher than that of women. A higher proportion of men are willing to pay over 50% of the average integrated season ticket price to get the benefits of an intercounty integrated ticketing system. The resulting range of WTP values could be used in cost-benefit-analysis to infer policy conclusions about the value of integrated ticketing for users and society.

Key words: *commuters, integrated ticketing, season tickets, public transport, willingness-to-pay, valuation*

5.1 Introduction

Public Transport (PT) authorities and service providers around the world are investing in integrated ticketing schemes to remove or reduce the barriers to travelling across operators that are created by multimodal and deregulated PT markets. Faced with choices about whether to invest in such schemes and, if so, which systems to invest in, decision-makers frequently turn to some form of economic evaluation, involving the assessment of the costs and the benefits of the investment. However, little evidence exists on the benefits of integrated ticketing, the user-benefits in particular, despite indications that the benefits of integrated ticketing could be significant. For instance, the UK Department for Transport (2009) estimated the net benefits of national-level integrated smart ticketing to be over £1bn per year. This paper aims to provide evidence that could support decision-makers in their pre-implementation evaluation of integrated ticketing schemes.

Pre-implementation and post-implementation evaluation studies are common elements of the transport system planning process. While post-implementation evaluation studies are relevant for assessing the performance of implemented measures, pre-implementation evaluation studies help decisionmakers to choose the best course of action by assessing the positive and negatives effects of competing-alternative proposals. The best alternative is usually the one which is feasible and superior to all other options based on some criteria. Cost-Benefit-Analysis, Cost-Effectiveness-Analysis (CEA) and Multi-criteria Analysis (MCA) are the three broad approaches for analysing investment appraisal decisions (Pearce et al. 2002). While the third approach applies weighting, the first two approaches require good estimates of costs and benefits in monetary terms. The estimation of costs and benefits in money terms is the central concept of economic efficiency, which seeks to ascertain whether the financial value that investment creates for society is higher than the financial costs that are incurred by society. In contrast to CEA, CBA considers the preferences of individuals and has gained popularity and acceptance in, for example, in health, environmental, and transport economics (Kjær, 2005).

Value judgements differ across countries and institutions, and there is no such thing as a universally correct economic evaluation approach. CBA, argued to be the only economic evaluation approach that is well-founded in welfare economic theory (Kjær, 2005), is widely applied for the economic appraisal of transport investments around the world and is required by law in certain countries, depending on the size of the investment (Mackie et al., 2014; Lindberg and Nerhagen, 2013).

The application of the CBA approach requires good estimates of costs and benefits in monetary terms. This raises the need for the pricing of non-market products such as travel time, convenience, comfort, safety, service frequency, reliability, information provision, ease of transfers, vehicle conditions and aesthetics (Björklund and Swärdh, 2015; Olsson et al., 2001; de Menezes and Vieira, 2008; Ramjerdi et al., 2010; Wardman, 2001; Hensher, 2006a; Hensher, 2006b; Ramjerdi et al., 2010; Börjesson, 2010; Opurum, 2012; Polydoropoulou et al., 1997; Molin et al., 2009). However, information on users' value of integrated ticketing is not readily available for estimating user-benefits in CBA, leaving policymakers no means of effectively evaluating their potential economic benefits.

If money is used as both a means of funding transport policy interventions and as a standard measure of welfare, then one may argue that measuring the benefit of a transport policy intervention requires the measurement of how much the individual is willing to give up in order to get the benefit, known as willingness-to-pay (WTP) or the willingness-to-accept (WTA) compensation. The WTP measure has become an institutionally accepted means of obtaining monetary values from RP and SP studies in many developed countries (Ortúzar et al., 2000). Interestingly, investments into integrated ticketing have been increasing over the last decade. Yet, there is still very limited evidence on the monetary value of integrated ticketing systems to users. This knowledge is particularly very useful for decisionmakers who have adopted CBA approaches for appraising transportation investments.

The research question addressed in this policy-oriented research is then, how much both commuters and non-commuters are willing to pay for a multi-county and multi-operator integrated ticketing system. To this end, a stated preference (SP) dataset was collected as part of a travel survey that was conducted along the corridor with the largest proportion of cross-county commuting in Sweden, Stockholm – Uppsala, before the implementation of the Movingo integrated season ticket project. Movingo is a smartcard and mobile phone-based multi-county commuting ticket covering both intercity and intracity bus and train services for all counties within the Mälardalen region of Sweden.

In Sweden, the CBA, even though not required by law, is commonly applied in evaluating transportation investments with reference to the overall transport policy goal of ensuring economic efficiency and sustainability in the provision of transportation services (Lindberg and Nerhagen, 2013). Consequently, the Swedish Transport Administration (responsible for infrastructure) and the Swedish Transport Agency (responsible for traffic management and the development of traffic rules and regulations) have jointly developed a CBA handbook and a CBA calculation tool, "SamKalk" (Lindberg and Nerhagen, 2013, Eliasson, 2006). The CBA handbook and calculation tool are widely used by local governments, public transport authorities (PTAs), consultants and researchers for the appraising transport-related investments.

Consequently, to contribute to the need to infer policy conclusions about the value of integrated ticketing for users and society, PT users' WTP for an integrated ticketing system, a quantitative measure of the trade-off between integrated ticketing and ticket cost, and the role of context and socio-demographic variables in the trade-off process was analysed by estimating and comparing two discrete choice models, the multinomial logit (MNL) and multinomial mixed logit (MNML) discrete choice models. Unlike the standard MNL, the MNML allows for the analysis of the random distribution of the WTP values across the different user segments.

The main contributions of the study are:

- It provides a range of WTP values for appraising multi-county integrated ticketing schemes in the study area and in similar locations elsewhere.
- To the best of the authors' knowledge, it is the first of its kind to provide some evidence for justifying investments in integrated ticketing schemes, by providing a quantitative summary of our knowledge on the marginal effect of multi-county integrated ticketing.
- It adds to the wider literature on PT valuation studies that interested practitioners and researchers may draw from for the purposes of appraising integrated ticketing schemes.

The rest of the paper is organised as follows. The next section covers a review of the literature. Section 5.4 describes the methods. Section 5.5 presents the results. Section 5.6 focuses on discussing the results, and the final section provides some concluding remarks.

5.2 Literature Review

The demand for integrated mobility platforms, promoted by developments in information and communication technologies (ICT), has been increasing over the last decade. One form of integrated mobility platform is the one that is popular among conventional PT operators, where PT operators make multimodal PT services available to users via integrated and smart ticketing. The other form, known as Mobility-as-a-service (MaaS), is essentially an extension of the one provided by conventional PT operators to include more personalised services and travel modes such as car rental, car sharing, taxi and bicycles. Users buy mobility services instead of buying means of transport in both forms of integrated platforms, and integrated and seamless mobility is the central idea behind both forms (Kamargianni et al. 2016; Pangbourne et al., 2020). In the present study, we focused on users' valuation of intercounty integrated mobility platforms that are provided by PT operators (operationalised by integrated tickets options to users). Pangbourne et al., 2020 pointed out that even though MaaS as a new business model has a good potential for increased mobility for people who can afford it, it does not address transport poverty compared to subsidised conventional PT integrated mobility services. Also, it is just beginning to get acceptance in urban mobility and is currently limited to within city mobility.

The CBA approach requires good estimates of costs and benefits in monetary terms. Considering the three fundamental methods for pricing products (i.e. based on total production cost, based on competitors' price levels and market-led or value-based), value-based pricing is more appropriate and widely used for pricing non-market products as it allows the measurement of trade-offs between price and product features (Jobbar and Fahy, 2006). Value-based pricing approach thus requires the identification of the values of the different components of a product that influence an individual's WTP for the product. In the case of the PT service, these are often the service quality attributes and the characteristics and context of the individual.

That is, due to the need for reasonable estimates of costs and benefits in monetary terms for investment appraisal decisions, there have been substantial transportation studies examining WPT for PT improvements. Given that consumers' choices reflect their preferences, McFadden (1997) pointed out that the social desirability of transportation improvements can be deduced from choice behaviour. Choice behaviour is extensively studied in transportation for the relative valuation of attributes (Wardman, 2004; Li and Hensher, 2011; Matyas and Kamargianni, 2019; Batley et al., 2017) and/or for forecasting travel demand (Paulley et al., 2006; Beser and Algers, 2002). The valuation of integrated ticketing is the focus of this study, and it is argued here that, thus far, this has been absent from valuation studies.

PT quality is of high importance for both PT service providers and regulatory agencies for retaining current users and attracting new users. As a basis for prioritising investments in PT quality improvements, many previous studies focused on the valuation of specific PT service attributes such as travel time, convenience, comfort, safety and security, service frequency, reliability, information provision, ease of transfers, vehicle conditions and aesthetics (Björklund and Swärdh, 2015; Olsson et al., 2001; de Menezes and Vieira, 2008; Ramjerdi et al., 2010; Wardman, 2001; Hensher, 2006a; Hensher, 2006b; Ramjerdi et al., 2010; Börjesson, 2010; Opurum, 2012).

Ticketing and fare integration constitute one of the five dimensions of integrated PT (Chowdhury and Ceder, 2016). These two integrations typically occur at the same time as smart card and mobile phone technologies help users to travel with different transport service providers, with the payments to the various service providers automatically administered in a back-end system. As at least two PT service providers integrate their services in an integrated ticketing set-up, ticketing integration can be considered as a composite PT attribute due to its synergistic positive effects on many attributes such as travel time savings, cost savings and high service frequency, comfort, convenience, etc. These benefits of integrated ticketing make it an essential part of transport policy in many countries and regional unions like the EU (Puhe, 2014; Turner and Wilson, 2010). The International Association of Public Transport also envisaged enabling people "to travel within, between and through cities, regions and borders without the need to change the ticketing media they use" (UITP, 2007). However, previous studies focus less on ticketing aspects compared to aspects such as fare, travel time, safety and reliability (Chowdhury and Ceder, 2016).

PT service providers around the world are investing heavily in integrated ticketing schemes to remove or reduce the barriers of travelling across operators (increasingly important as a consequence of deregulated and multimodal PT markets) and to increase synergy by combining the attributes of the different modes (May et al., 2006). The Oyster in London, SL Access card in Stockholm, Combi-card in Tampere, Octopus in Hong Kong, Charlie card in Boston, UL card in Uppsala, Myki card in Melbourne, PASMO and Suica card in Tokyo are but a few schemes (UK department for transport, DfT, 2010; Blythe, 2004).

Even though the demand for integrated ticketing is evidently high, research analysing users' preferences regarding integrated ticketing has, until now, focused on opinion surveys rather than on assessments of WTP. Surveys of users' opinions have served to confirm the importance of integrated ticketing to users. According to Flash Eurobarometer's (2011) survey on the future of transport within the EU, the proportion of respondents who stated that they would definitely consider using PT often given a single multimodal ticket was between 31% (in Latvia) and 73% (in Greece). Only 31% of car users across the EU said they would not consider using PT frequently even with the availability of a single multimodal ticket. More than 60% of car users in Spain, Cyprus and Greece stated that they would definitely consider using PT more frequently if a single ticket for their whole journey is available.

Despite the wide-spread implementation of integrated ticketing systems around the world, most PT stakeholders are still uncertain about the benefits of these schemes. This was confirmed by Iseki et al. (2007) in the case of PT managers in the USA. Many barriers, such as political and bureaucratic struggles among local governments, can make it challenging to invest in regional ticketing systems collectively. Opinion studies are beneficial for highlighting the importance of integrated ticketing to users, thereby motivating stakeholders to invest in integrated ticketing schemes collectively. Yet, opinions hardly offer information on the economic value of these schemes as input for appraising these schemes. WTP studies are of particular importance, as they enable evidence of the monetary value of integrated ticketing to users to be developed for the economic appraisal of these schemes.

5.3 Methods

5.3.1 The Case Study Area

Movingo is a smartcard and mobile phone-based multi-county commuting ticket that applies to both intercity and intracity bus and train services for all counties within Mälardalen, Sweden (Figure 5-1). It is implemented by six adjoining Public Transport Authorities (PTAs) and three commercial service providers - the Swedish national railways (SJ), TIB and Trosabussen. In 2019, Mälardalen had a total population of about 4.1 million – about 40% of the total population of Sweden (SCB, 2020c). Figure 5-3 summarises the population distribution over the counties. Movingo took off in October 2017 with the main aim of providing commuters with a broad set of destination and mode choices in a convenient and affordable manner. It provides frequent travellers with the option to choose a season ticket that is valid for at least two of the participating counties. It currently has only three ticket options - one month, three months and one year. Options for periods less than 30 days are unavailable.

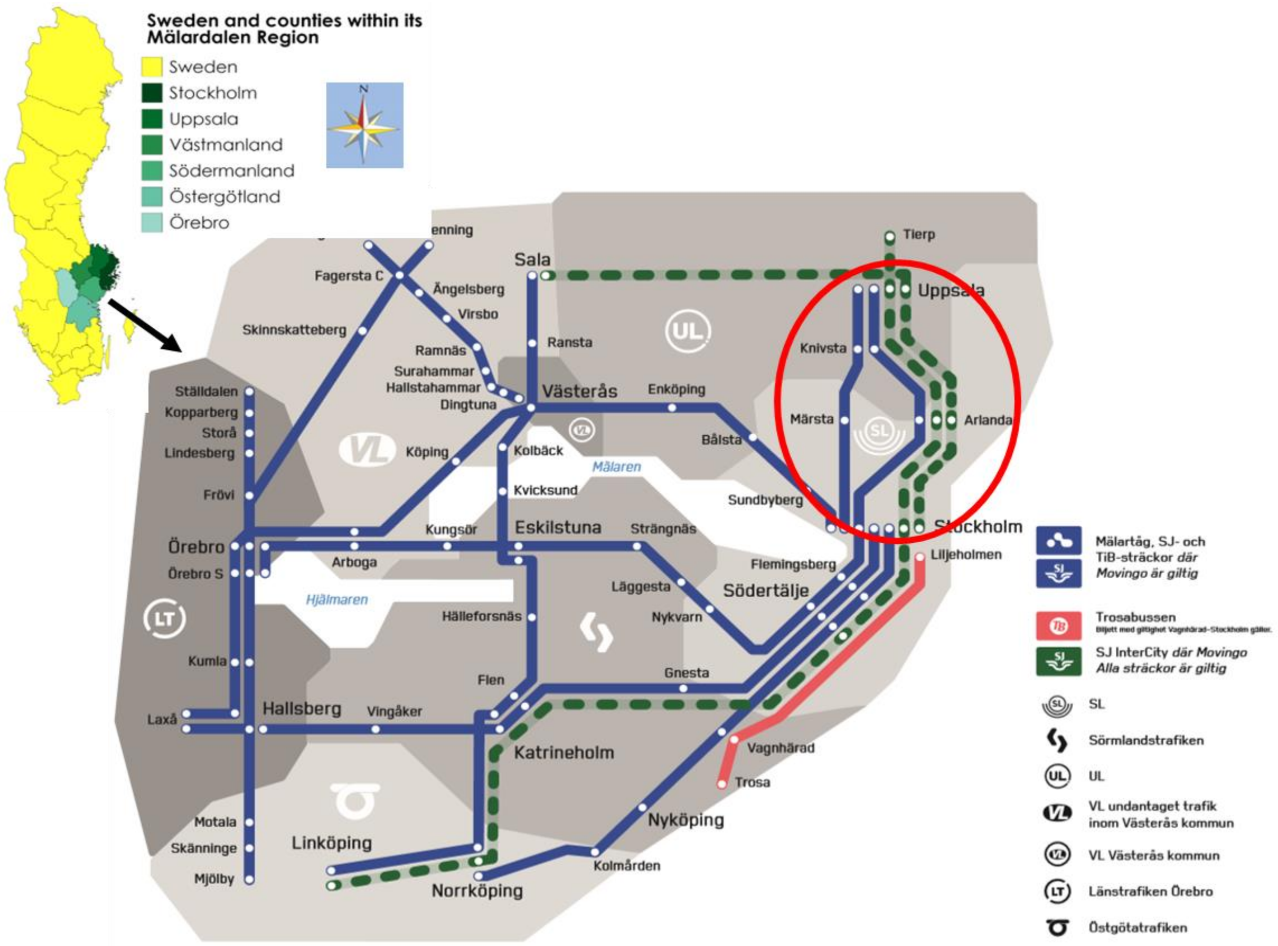

Figure 5-1: - Cities, rail network, operators & tariff zones in Mälardalen (studied corridor red-circled) (Mälardalstrafik MÄLAB AB, 2020, modified)

The pricing strategy for Movingo is both flat (within the city) and distance-based (between intercity train stations). The price floor is set at 1000 SEK/Month (93 Euro), and the price ceiling is set at 3200 SEK/Month (297 Euro) with only students getting a 25% discount. Stockholm county and Uppsala county are each considered as a zone.

The main user benefits of Movingo include seamless transfers across different PT modes within the entire Mälardalen region, improved convenience for users as they no longer need to hold more than one ticket, simplified fare and zone structure, easy to commute by PT, flexibility to buy ticket anytime and anywhere, time savings through reduced queues at ticket sale's points, discounts for only students, reduced transaction and administration costs, reduced fraud and enhanced data acquisition.

The analysis focused on the Stockholm–Uppsala corridor (marked by the red ring line in Figure 5-1), which has the largest proportion of cross-county commuting trips in Sweden. Statistics Sweden, SCB, (2020a) data from 2004 to 2018 showed that the number of people above 16 years commuting to work outside their municipality of residence is increasing in the study area and Sweden as a whole (Figure 5-2). The only year that did not experience an increase was 2009, probably due to the then global economic crises.

The main PT service providers along the corridor before and after the implementation of the Movingo scheme are SJ, Stockholm county PTA (SL) and the Uppsala county PTA (UL). SL and UL, which both offer subsidised services integrated their services in 2013. That is, with the SL/UL integrated ticket, commuters between Stockholm and Uppsala do not need to make transfers at the counties' border as before, since the two PT lines were merged into one line. Under the Movingo scheme in 2017, SJ, which offers unsubsidised services with relatively high fares and high quality integrated their services with SL and UL. SJ's commuter ticket was removed after the launch of Movingo. Hence, the SL/UL and Movingo integrated season tickets are currently the available ticket options for PT commuters between Stockholm and Uppsala.

MaaS has recently been introduced in Stockholm city by UbiGo in collaboration with Stockholm City, SL, Move About, Herz and Cabonline. With this multimodal package, people within Stockholm city can access PT, car rental, car sharing, taxi and bicycles with a monthly subscription. While broadly analysing users' WTP for a regionally integrated ticketing system where many service providers work together under the Mobility as a Service (MaaS) model would be policy-relevant as MaaS is gradually gaining acceptance by public sector decisionmakers, the present analysis was limited to only PT integrated mobility platform because MaaS in the study area is presently limited to Stockholm city (not regional) and was not part of the Movingo integrated ticketing scheme.

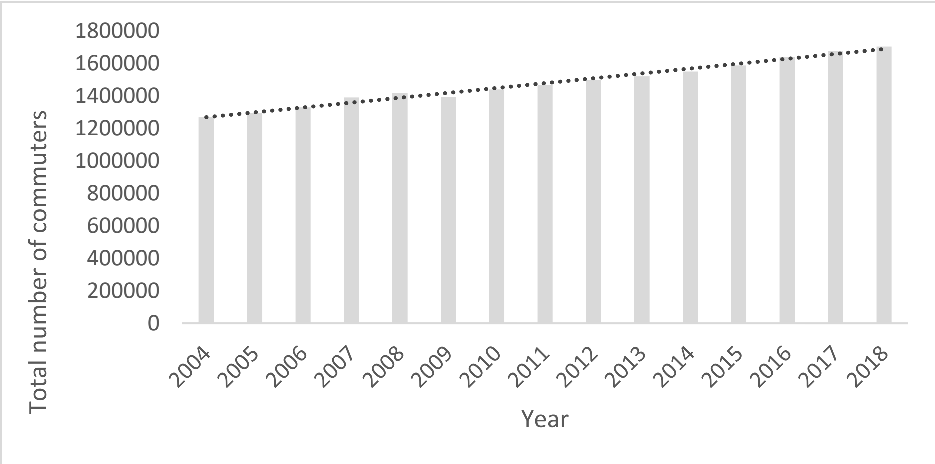

Figure 5-2: Total number of people (>16 years) commuting outside their resident municipality in Sweden (SCB data, 2020a)

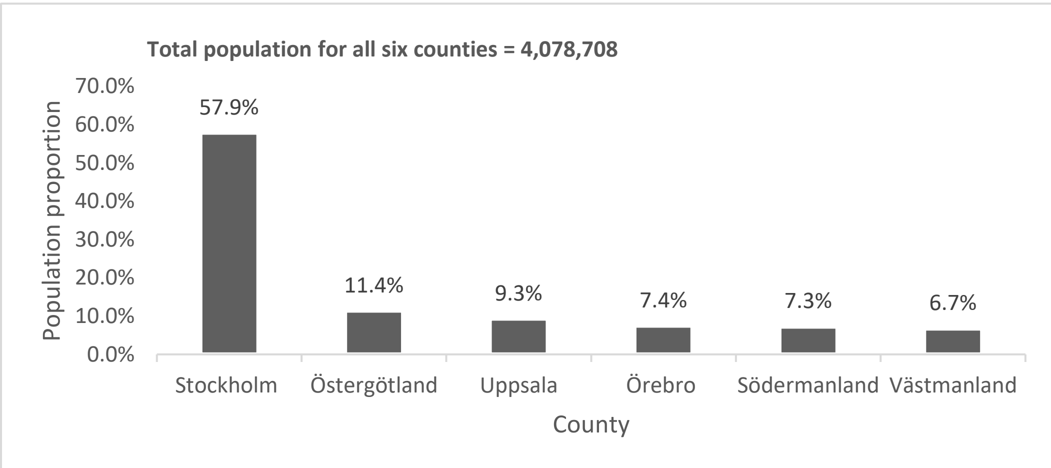

Figure 5-3: Population Distribution Mälardalen (SCB data, 2020c)

5.3.2 Conceptualising integrated ticketing

May et al., (2006) pointed out that synergy and removal of barriers are two major values of transport system integration. Ticketing integration refers to an arrangement among passenger transport service providers that makes multimodal transport services accessible to users by permitting them to use the same ticket on every part of the same journey regardless of the ticketing media or geographic boundary. Its aim to provide users with a broad set of destination and mode choices in a convenient, accessible, comfortable, safe, fast, and affordable manner (Ibrahim, 2003).

Some major benefits of PT ticketing integration according to PTEG's (2009) international review of these schemes include: increased PT usage, improved passenger satisfaction, modal shift, increased revenue, decreased transaction and administration costs, social benefits, reduced fraud, contribution to city life and identity, enhanced data acquisition, reduced boarding and dwell times, improved access to non-transport related services, etc. White (2009) and Abrate et al. (2009) also confirmed some of these benefits. Integrated ticketing thus produces three significant effects - user-related, service provider related and broader societal effects.

Consequently, Figure 5-4 proposes a conceptual framework for analysing integrated ticketing. It assumes that the deregulation of the PT market into at least two operators stimulates integrated ticketing. The object of integration is then to remove or reduce the barriers of travelling across operators that are created by the deregulation and to increase synergy by combining the attributes of the different modes.

The user-related effects (i.e. the resulting attributes of the integrated PT system) then interact with the individual decision-makers' socio-economic characteristics to induce changes in preferences and subsequently the choice of their preferred integrated season ticket from a finite choice set.

5.3.3 Economic and econometric theoretical framework

The microeconomic concept of consumer preferences indicates whether a consumer likes one good or set of goods more than another. This helps in understanding how consumers compare (or rank) the desirability of different sets of goods based on the assumptions that their preferences are complete, transitive and that more is better. These three assumptions allow the algebraic or graphical representation of consumer preferences as utility functions. A utility function attempts to measure the level of satisfaction a consumer gets from any set of goods and services. Since consumers naturally compare the set goods or services that they are faced with to choose the best according to their judgement, the underlying assumption for the analysis of consumer choice behaviour is often based on some choice or decision rule. These decision rules which describe the internal mechanisms used by the individual faced with the choice problem to process the information available to him/her and make a unique choice are classified by Ben-Akiva and Lerman (1985) into four - dominance, satisfaction, lexicographic rules and utility.

Transport economics is much founded on the argument that transport is essentially a derived demand (Button, 1982). Hence, decisions on whether to travel and how to travel are largely treated as rational attempts to maximize utility associated with accessing places and facilities whilst minimizing the disutility associated with travelling.

On the other hand, this economic perspective is sometimes considered as an oversimplification since human behaviour is sometimes systematically irrational and real-world choices can be situational or context dependent (Mokhtarian and Salmon, 2001; Jain and Lyons, 2008).

At the same time, ticketing system improvements such as integrated ticketing constitute economic investments. An economic evaluation of these investments is therefore required for providing information on whether the benefits of the investments outweigh the cost, justifying expenditure to funders and taxpayers and evidence for cost-effective solutions for future considerations. The economic approach of rational choice was therefore considered more appropriate for addressing the research question, to what extent are commuters willing to pay for a multi-county and multi-operator integrated ticketing system, given these individual commuter' socio-economic characteristics and life context?

The embodiment of rational behaviour modelling is discrete choice modelling based on the random utility theory (RUT), which has extensively been used in transportation research. The general postulate in discrete choice modelling is that the probability that an individual chooses an alternative from a given set of finite alternatives is a function of the individual's socio-economic characteristics, context variables and the relative attributes of the alternative (Ortúzar and Willumsen 2011).

Previous research confirmed that people rationally accept longer commutes for better work incentives such as higher salaries (Beck and Hess, 2016). The following four propositions are hence considered in applying the RUT mathematical model for quantifying commuters' WTP for regionally integrated ticketing:

- Intercounty commuting is primarily a derived demand emanating from the need to satisfy some regular commitments made by the individual.
- The decision to long-distance-commute and the choice of the means for commuting are rational decisions made by the individual as this is often a well-planned decision by the individual.
- That PT ticketing constitutes some form of disutility for the individual commuter as it is not an end by itself but a means of accessing the PT service.
- That the individual commuter has the ability to discriminate among alternatives in a given a choice set while the analyst has limited knowledge, i.e. intercounty commuters' choice of a season ticket is associated with the individual's socio-economic and life context such previous commuting experience, the need to use of season ticket for none commuting trips like recreation and picking up of children, access to tax return for work trips, etc.

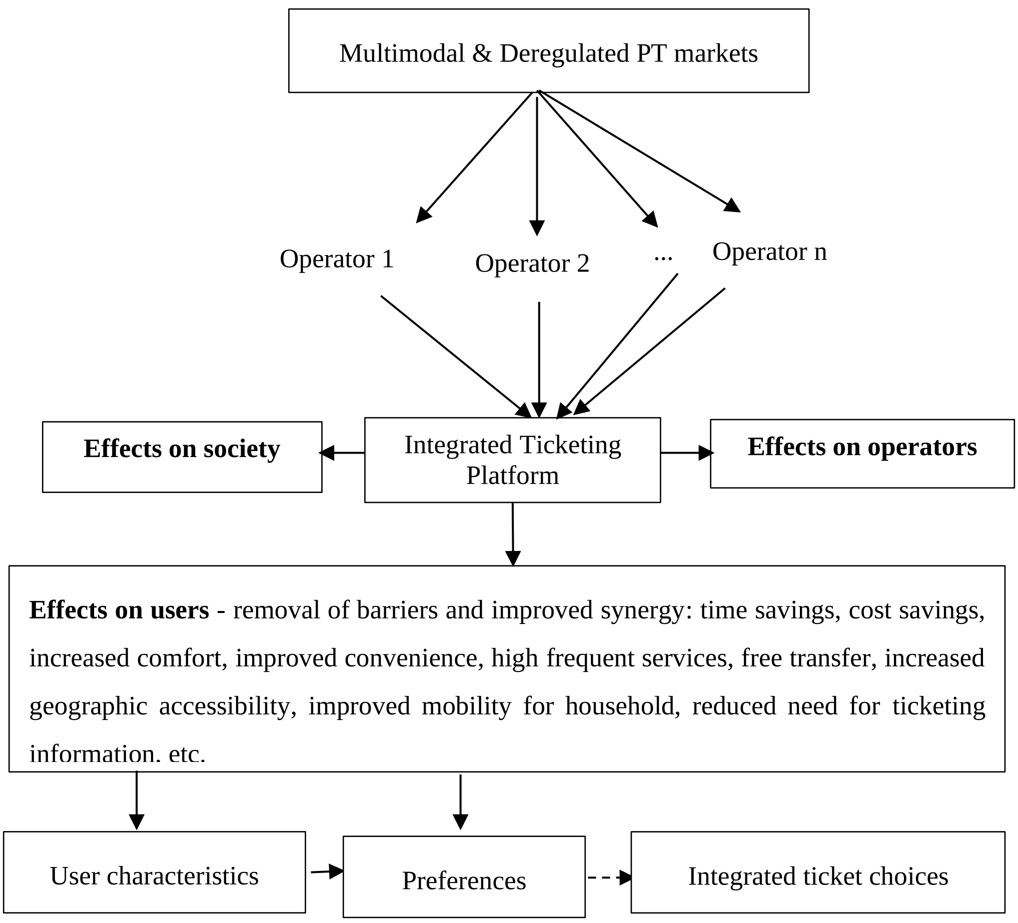

Figure 5-4: Conceptual framework for analysing integrated ticketing

5.3.4 Survey design, sampling, administration, and data structure

A two-wave surveyed was conducted among rail commuters en-route the Stockholm-Uppsala corridor in September 2017, just before the implementation of the Movingo integrated ticketing scheme and one year after the implementation (September 2018).

The first wave survey questionnaire included questions on respondents': commuting habits and behaviour, ticket choice and experiences relating to ticketing, sociodemographic characteristics, and ten (10) unlabelled and fractional orthogonal designed stated preference (SP) choice scenarios. Figure 5-6 provides an example of the SP choice scenarios and the attributes and their levels. The survey questionnaire was piloted on thirty (30) passengers and refined before the survey was finally conducted from September 11th - 22nd, 2017, during weekday peak hours (6 am – 9 am and 3 pm – 6 pm). The questionnaires were randomly distributed among the respondents on board trains and at train stations. Respondents could return the answered questionnaire directly to the surveyors or by self-completion and mail-back. They could also answer using paper and pen, online on-board train using tablets provided by the surveyors or online at their convenience elsewhere. The overall response rate was 63% and higher than the expected response rate of 35%. The dataset used in this analysis has a sample size of 524 individuals and is described in Table 5 - 1. Users of the age group 65+ years had the lowest representation. This was expected as the survey was conducted during peak hours, and this group of users are principally retired workers. This does not affect the analysis as people who commute to work and/or school was the target group in the Movingo scheme.

In the second wave, about 450 respondents who agreed to a follow-up survey after the implementation of the Movingo scheme were contacted in September 2018, i.e. one year after the launch of Movingo. A total of 165 of them answered the survey, resulting in a response rate of 36.7%. About half of these respondents were Movingo users and their self-reported reasons for choosing the integrated season ticket, Movingo, were reported by Alhassan et al. (2020), as summarised in Figure 5-5. Most of them stated that they chose Movingo because of increased geographic accessibility, followed by travel time savings, cost savings and comfort, while a few of them stated that they chose it because of improved convenience. This implies that the attractiveness of the integrated ticket is not just due to the improved convenience of ticketing but also the synergistic effects of the integration that reduced users' generalised cost.

The standard methods for empirically estimating the monetary value of non-market goods like seamless transfer are normally based on SP and/or revealed preference (RP) data. The two-wave survey described above, therefore, provided data on both the users' RP and SP. The RP data was collected in the second wave as Movingo was already implemented by then. Both RP and SP are useful and well-established data collection method in transportation research. A major advantage of RP over SP is that it deals with actual choices and measurement biases relating to SP are hence avoided. At the same time, a condition for using RP is that there is a market demand curve for the product in question and economic evaluation is usually more complex than this. Thus, RP merely captures "use value" while SP can capture total economic value (Kjær, 2005). Ortúzar and Willumsen (2011) also pointed out that RP has some practical weaknesses relating to survey costs and the difficulty of discerning the independent effects of attributes that are not easily observed such as quality, convenience and comfort. That is, the RP data on the choices in this study did not provide enough variations in the choices or preferences for efficiently estimating the value of the integrated ticketing attribute to users. Specifically, the RP dataset lacks variation in the price of the Movingo ticket among the respondents, and the service frequency is about the same and even the travel time is about the same since we only have access to in-vehicle travel time between Stockholm and Uppsala central stations but not the door-to-door travel times. Trade-off analysis was the object of this study. Hence, the SP or pseudo panel dataset was used as it has a higher sample size and addressed the practical limitation that was associate with the available RP dataset. This RP dataset was rather used in the impact evaluation the of the Movingo scheme with respect to some major PT policy goals in the study area – increased ridership, user satisfaction and improved quality of PT ticketing (Alhassan et al., 2020). Both this impact evaluation and the current economic evaluation related study, even though quite different in their focus, confirmed that PT users are very positive to integrated ticketing.

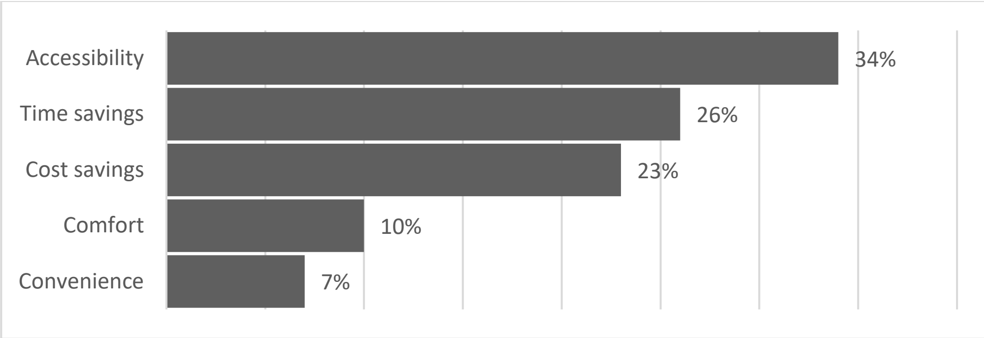

Figure 5-5: Revealed reasons for the choice of the Movingo integrated season ticket

Attributes	Number of levels	Attribute levels
In-train-time (min)	4	45, 40, 50, 55
Headway (min)	4	10, 15, 30, 60
Monthly ticket price (SEK)	6	1530, 1600, 2070, 2170, 2200, 2300
Ticket integration	3	1, 2,3

Scenario 1	**Alternative A**	**Alternative B**	**Alternative C**
In-train-time	50 min	45 min	40 min
Train departs every	30 min	30 min	10 min
Monthly ticket price (SEK)	1 600	2 170	2 300
Monthly ticket is valid for	All SL & UL lines	Only regional train (SJ) Stockholm ↔ Uppsala	All SL & UL lines + Regional train (SJ) Stockholm ↔ Uppsala
In this scenario, I will choose (please tick one):	[ ]	[ ]	[ ]

Figure 5-6: Attributes in the choice task and their assigned levels & an example of the choice scenarios

5.3.5 Model specification and estimation

PT users' WTP for integrated ticketing and how it varies across the different user groups were analysed by estimating and comparing MNL and MNML models. The MNL formulation, which is based on the I.I.D assumptions has: a restricted substitution pattern, does not allow for random taste variation and does not account for correlation in unobserved factors over time (Train, 2009). These three limitations of the standard logit model are handled by the MNML, a very flexible model that can approximate any random utility model (Train, 2009). The MNML model thus allowed us to analyse random taste variation in the WTP for integrated ticketing. That is, with the fixed-parameter specification of the utility function in the standard MNL, only a point estimate for WTP can be obtained. However, with the random parameter specification in the MMNL, the corresponding WTP measure is also a random variable.

Table 5-1: Descriptive analysis of the sample

Sample characteristics (Sample size, n = 524)	
Gender	*Female (56%), Male (43%), Other (1%)*
Age (Years)	*16-24 (19%), 25 – 34(37%), 35 – 44 (22%), 45 – 54 (13%), 55 – 64 (9%), 65+ (1%)*
Monthly gross income in SEK	*00000–15000 (24%), 15001–25000 (8%), 25001–35000 (26%), 350001–50000 (26%), Over 50 0001 (6%)*
Education	*Higher education - 3 or more years (58%), Higher education-less than 3 years (19%), High school graduate (20%), Other (2%)*
Employment status	*Full-time employed (67%), Part-time employed (4%), Full-time student (28%), Part-time student (1%), Other - unemployed (1%)*
Received tax reduction for work trips	*Yes (60%), No (40%)*
Travel cost paid by employer	*Yes (6%), No (94%)*
Survey response method	*Paper on-board (51%), Post back (23%), Web on-board (19%), Web (7%)*
Ticket type used	*30 days (89%), 90 days (1%), One year (2%), Other (8%)*
Current Service Provider	*SL/UL-integrated (60%), SJ n(26%), SL (6%), TiM (4%), UL (4%)*
Commuting frequency (Train)	*1 - 2 days/week (8%), 3 - 4 days/week (26%), ≥ 5 days/week (63%), Rarely (3%)*
Commuting experience (Train)	*< 1 year (24%), 1 – 2 years (22%), 3 – 4 years (16%), ≥ 5 years (38%),*
Ticket purchase channel	*Vending machine (23%), Sales agent (26%), Service provider offices (35%), Mobile phone (13%), On the internet (3%)*
Use of season for other trips	*1-2 times a week (25%), 3 - 4 times a week (10%), ≥ 5 times a week (10%), Never (11%), Rarely (4%)*
User type	*Commuter (93%), Non-commuter (7%)*

Given the three propositions in section 5.3.3, the value that a commuter c assigns to a given season ticket alternative i for commuting between origin p and destination q given the choice set of season ticket alternatives C_j is given by the utility function U_{cipq}, in equation (5-1)

$$U_{cipq} = V_{cipq} + \varepsilon_{cipq} \qquad (5\text{–}1)$$

Where V_{cipq} is the deterministic part of the utility and the ε_{cipq} is the random part.

Considering our dataset, equation (5-1) is further expressed as:

$$U_{cipq} = \beta_1 t^v_{pq} + \beta_2 F_{pq} + \beta_3 H_{pq} + \beta_4 ETI + \cdots + \beta_z X_{cz} + \alpha_k \qquad (5\text{–}2)$$

Where; t^v_{pq}= in vehicle time, F_{pq}= fare charged for the trip between origin *p* and destination *q*, H_{pq}= Headway, *ETI* = a dummy coded variable for ticketing integration, X_{cz} = a socio-economic characteristic, z, of an individual commuter, c, $\beta_{1\ldots z}$ are the marginal effects of each specified attribute and socioeconomic characteristic on travel utility (weights attached to each cost elements with dimensions appropriate for converting all attributes into common units such time or money), and α_k = a parameter representing unobserved part of the utility.

The market share of each season ticket alternative will be given by the probability that an individual commuter c chooses season ticket alternative i from the given choice set of season ticket alternatives C for commuting between origin p and destination q can be computed using equation (5-3)

$$\mathrm{P}(\mathrm{i} \mid C) = \mathrm{P}\,(U_{cipq} \geq U_{cjpq}, \forall \mathrm{j} \in \mathrm{C}, \mathrm{j} \neq \mathrm{i}\,) = \frac{\mathrm{e}^{U_{cipq}}}{\sum_j \mathrm{e}^{U_{cjpq}}} \quad (5\text{-}3)$$

The probabilities of the MNML are then the integrals of the standard logit model (equation (5-3)) over a density, i.e.

$$\mathrm{P}(\mathrm{i} \mid C) = \mathrm{P}\,(U_{cipq} \geq U_{cjpq}, \forall \mathrm{j} \in \mathrm{C}, \mathrm{j} \neq \mathrm{i}\,) = \int \left(\frac{\mathrm{e}^{U_{cipq}}}{\sum_j \mathrm{e}^{U_{cjpq}}} \right) f(\beta \mid \theta) d\beta \quad (5\text{-}4)$$

Where $f(\beta \mid \theta)d\beta$ is the density function of β with θ being the vector of parameters of the density function, specified mean and variance if normal distribution is assumed.

Different model specifications were tested. Using 500 Halton draws, random parameters were assumed to be normally distributed in the estimation of the MNML model. Both the MNL and the MNML models were estimated using the 2017 version of the R code developed by the Choice Modelling Centre at ITS, University of Leeds, now known as Apollo (Hess and Palma, 2019).

The Marginal rate of substitution, MRS, or WTP estimate, between some given attributes of interest is an important output from discrete choice models. A money related variable such as price and cost are commonly included in the trade-off to express the MRS in monetary terms (Hensher et al, 2015). Using the trade-off between the integrated ticketing attribute and the price of a monthly ticket, the marginal WTP distributions, as a measure of the value of multi-county ticketing integration for different user groups, are estimated. The estimates describe how much the cost attribute would be required to change given one-unit change in the integrated ticketing attribute, such that the change in total utility will be zero. Thus, the WTP estimate is given by the derivative of the integrated ticketing attribute with respect to the cost attribute, i.e.

$$WTP_i = \frac{\Delta x_i}{\Delta x_c} = \frac{\frac{\partial u}{\partial x_i}}{\frac{\partial u}{\partial x_c}} = \frac{\beta_i}{\beta_c} \qquad (5\text{-}5)$$

Where u is the utility function, β_i is the marginal utility for integrated ticketing and β_c is the marginal disutility for cost.

The random parameter specification in the MMNL helped us to analyse the corresponding WTP measure as a random variable, thus capturing random taste variations across the different user segments. I.e., assuming a normally distributed WTP measure, 10000 simulated random draws were used to generate the WTP distributions for the various user groups (Figure 5-7). A separate model was run for each of the subgroups. Since the cost is the denominator in the WTP estimations, its distribution and range implied that the WTP distribution may or may not have finite moments (Daly, Hess and Train, 2012). To handle this issue, the mean WTP values were estimated from the simulated draws by transforming the normal distributions into lognormal distributions.

5.4 Empirical Results

Under the random utility maximisation assumption, an MNL and a MMNL models were estimated to examine users' WTP for integrated ticketing. Since the choice experiment was unlabelled, generic parameters were estimated for all the four attributes included in the model (Figure 5-6). The socio-economic and context variables that were included in the model are provided in Table 5-1. Assuming nonlinearity, all categorical explanatory variables were dummy coded. The model estimation results are presented in Table 5-3. All the attributes have the expected signs and, all the estimated parameters for the attributes were statistically significant at 1% significance level. The model fitness statistics (Table 5-2) suggest that both models fit the data well. Since the MNML formula can collapse back into the MNL, outputs of the models were compared using the likelihood ratio test and the Akaike Information Criterion (AIC). The MMNL model provides the best fit model for the dataset based on the model comparison results in Table 5-2.

The probability density functions of the WTP distributions (Figure 5-7) as a characteristic of a lognormal distribution start at zero, increase to the mode and then decrease.

The 30-days season ticket is the most widely used season ticket in Sweden, and about 90% of the respondents used this season ticket. This makes it interesting to interpret the WTP distributions in relation to the available 30-days integrated season tickets. Thus, the prices for the 30-days integrated SL/UL and Movingo tickets are 1730 SEK and 2200 SEK respectively, making the average 30-days integrated season ticket price 1965 SEK. The WTP distributions are thus also reported as a percentage of the average 30-days integrated season price in Figure 5-8.

As illustrated in Figure 5-8, the WTP distributions suggest that there is less variability among commuters compared to non-commuters and that women differ less in their WTP values compared to men. There is less likelihood that commuters' and non-commuters' valuation of integrated ticketing will exceed 50% of the average integrated monthly ticket price.

The WTP values are reported in monetary Swedish Krona (SEK) values but in some cases, they are presented as a percentage of the average 30-days integrated season ticket price in parenthesis. All the user groups' valuations of a multi-county integrated ticketing system are less than the average monthly integrated season ticket price. The mean WTP estimate for:

- all respondents is 507 SEK/Month (about 26% of the average 30-days integrated season ticket price)
- only commuters is 390 SEK/Month (about 20% of the average 30-days integrated season ticket price)
- non-commuters is 554 SEK/Month (about 28% of the average 30-days integrated season ticket price)
- men is 465 SEK/Month (about 24% of the average 30-days integrated season ticket price)
- women is 231 (about 12% of the average 30-days integrated season ticket price)
- the income group, 25001-35000, has the highest mean WTP value of 441 SEK/Month (22% of the average 30-days integrated season ticket price). The income group with the lowest mean WTP estimate is the income group with a gross monthly income of 15001–25000; the mean value for this group is 192 SEK/Month (10% of the average 30-days integrated season ticket price). The mean WTP estimates for the rest of the income groups are 255 SEK/Month for the lowest income group (gross monthly income 0-15000 SEK/month), 257 SEK/Month for the 35001-50000 income group and finally, 260 SEK/Month for those with gross monthly income greater than 50000 SEK/Month.

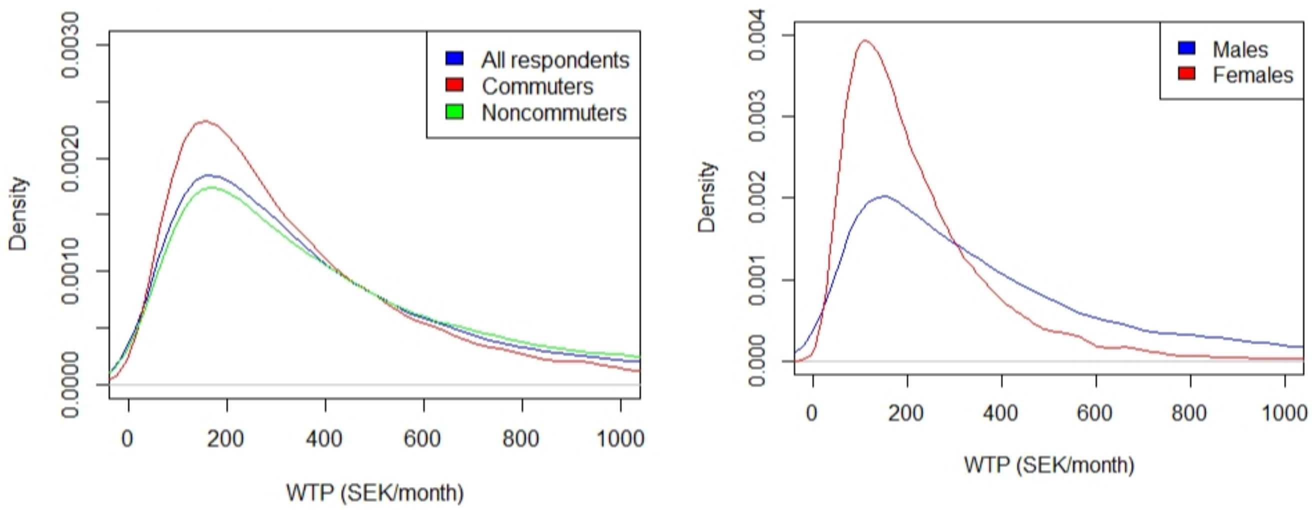

Figure 5-7: WTP distributions for multi-region ticketing integration

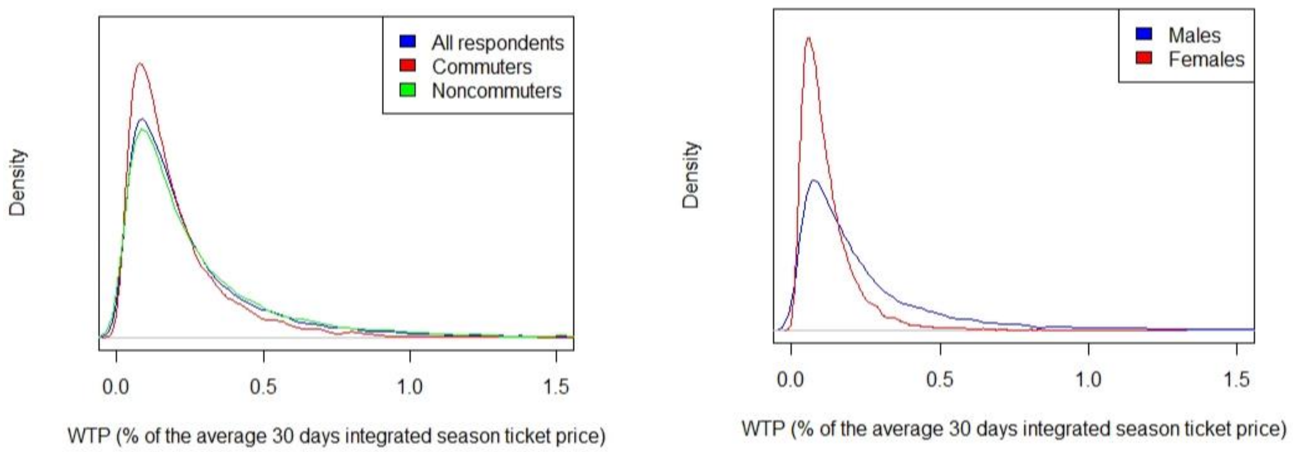

Figure 5-8: WTP distributions as % of the average 30 days integrated ticket price

Table 5-2: Comparing the two estimated models

Model fitness statistics	MNL (28 parameters)	MMNL (32 parameters)
LL (0)	-2878.364	-2878.364
LL(C)	-2543.594	-2543.594
LL (final)	-1970.166	-1593.157
Rho-sq (0)	0.32	0.45
Adj. rho-sq (0)	0.31	0.44
Rho-sq (C)	0.23	0.37
Adj. rho-sq (C)	0.21	0.36
AIC	3996.33	3250.31
BIC	4160.72	3438.18
Likelihood ratio test, LR = [-2 ($LL_R - LL_U$)] ~χ^2 = 754.018, df = 4, p-value = 0.0000		

Table 5-3: Estimation results of the MNL and MMNL models for intercounty integrated ticketing

Variables	*MNL (*28 parameters)			MMNL *(*32 parameters)					
	Mean	*Std. err.*	*t-stat*	*Mean*	*Std error*	*t-stat*	*Std dev*	*Std error*	*t-stat*
Alternative specific constants									
ASC A	0.0439	0.4333	0.10	0.8594	0.8191	1.05			
ASC B (Base)	-	-	-	-	-	-			
ASC C	-0.2746	0.2299	-1.19	-1.0519	0.3773	-2.79***			
Attributes									
In-train time (min)	-0.0624	0.0087	-7.15***	-0.1308	0.0212	-6.16***	-0.1403	0.0266	-5.28***
Monthly ticket price (SEK)	-0.0019	0.0007	-2.72***	-0.4111	0.1235	-3.33***	0.4897	0.0468	10.46***
Headway (min)	-0.0099	0.0034	-2.90***	-0.0029	0.0060	-0.49	-0.0283	0.0074	-3.84***
Ticket integration	0.2293	0.0086	26.58***	0.7932	0.0712	11.14***	0.7835	0.0766	10.22***
User characteristics									
Monthly gross income (SEK)									
00000–15000 (Base level)									
15001–25000	-0.9622	0.2331	-4.13***	-1.0880	0.4447	-2.45**			
25001–35000	0.1234	0.1955	0.63	-0.0039	0.3415	-0.01			
350001–50000	-0.1226	0.1903	-0.64	-0.3760	0.3372	-1.11			
Over 50 000	0.0731	0.2248	0.33	0.0389	0.3861	0.10			
Education									
University (>3) (base level)									
University (<3)	-0.2144	0.1236	-1.73*	-0.9880	0.4350	-2.27**			
High school graduate	-0.3358	0.1258	-2.67***	-1.0840	0.4555	-2.38**			
Other	0.4377	0.3097	1.41	2.4202	1.3179	1.84*			
Commuting experience									
≥ 5 years (Base level)									
3 – 4 years	0.5639	0.1943	2.90***	0.5393	0.3310	1.63			
1 – 2 years	0.4220	0.1728	2.44**	0.4328	0.3064	1.41			
< 1 year	0.4210	0.1667	2.52	0.4920	0.2981	1.65*			
Use of season ticket for none commuting trips									
1-2 times a week	0.4084	0.1636	2.50**	0.3092	0.2885	1.07			
3 - 4 times a week	0.0926	0.2211	0.42	-0.0178	0.3896	-0.05			
≥ 5 times a week	0.6241	0.2612	2.39**	0.5619	0.4376	1.28			
Rarely (Base level)									
Never	0.1041	0.2088	0.50	0.1526	0.3731	0.41			
Ticket type used									
30 days (Base level)									
90 days	-0.1570	0.5011	-0.31	-0.0401	1.4136	-0.03			
One year	0.3732	0.3556	1.05	1.3971	1.1928	1.17			
Other	0.5820	0.1786	3.26***	1.4850	0.6502	2.28**			
Received tax reduction for travel to/from work									
Yes	-0.1943	0.1010	-1.92*	-0.3214	0.3608	-0.89			
No (Base level)									
Ticket purchase channel									
Service provider offices (Base level)									
Vending machine	0.0153	0.1301	0.12	-0.3119	0.4693	-0.66			
Sales agent	0.3064	0.1201	2.55**	0.5558	0.4405	1.26			
Mobile phone	0.1328	0.1617	0.82	0.1868	0.5841	0.32			
On the internet	-0.3921	0.3047	-1.29	-0.4212	0.8772	-0.48			

Significant codes: '' 0.10, ' **' 0.05, '***' 0.01. Note that the cost variable in the MMNL was divided by 100 to avoid overflow of the WTP distribution and this has to be taken into account in calculating the WTP*

5.5 Discussion

The preference for integrated ticketing and, for that matter, the WTP for its benefits, was associated with the individual's socio-economic characteristics and life context and the relative attributes of the alternative PT service that the available season tickets offer. This is in line with the RUT (Ortúzar and Willumsen 2011).

The findings suggest that the mean WTP value for men is higher than that of women. Men's distribution of WTP is also more positively skewed, indicating that a relatively high proportion of men have higher WTP values than women. These were expected as men generally have a higher monthly income than women in the study area (SCB, 2020b). Also, men have longer commuting distances than women (SCB, 2020a) and hence, have relatively more need for multi-county integrated ticketing. Besides commuting, the mean WTP value for women may be associated with their high tendency for trip chaining in the study area (Susilo et al., 2019). This gender difference in WTP for integrated ticketing was expected as women and men tend to have differential travel behaviour. In policy terms, the WTP values indicate that regional level integrated ticketing may be a good strategy for meeting the needs of both female and male long-distance-commuters. This implies that a regionally integrated system has good potential for supporting a pro-PT policy. This was evident in the increase in ticket sales after the implementation of Movingo.

Surprisingly, the results further indicate that non-commuters have a higher mean WTP value compared to commuters. This finding was least expected as it contradicts the PT planners and decisionmakers belief that frequent travellers have more need for interregional integrated ticketing; hence why the Movingo scheme was designed for this user group. It may be the case that the commuters compare the cost of the monthly ticket price in the SP choice scenarios to the price of their current season tickets while non-commuters compare it to the price of a single journey ticket, which is relatively expensive. The policy implication of this empirical evidence is then that, interregional integrated ticketing projects will achieve higher impacts if they are designed to meet the needs of both frequent and non-frequent travellers.

In the case of income, the findings suggested that the lowest income group (gross monthly income 0-15000 SEK/month) and the highest income groups have about the same mean WTP value (i.e. 13% of the average 30-days integrated season ticket price). This was also quite surprising as the choice of rail for interregional trips is associated with increasing income level. At the same time, the studied integrated ticketing scheme does not just provide long-distance rail services between the counties but also bus, underground and light rail services within counties. Also, most of the respondents in this group are most likely young people with low income but a relatively high need for mobility. Besides, most of the respondents in the lower-income group are possible captive users of PT and thus place a high value on the increased geographic accessibility offered by regional ticketing integration. In terms of policy, the high WTP associated with the lowest income group indicates that interregional ticketing integration of subsidised PT services has a strong potential for improving regional accessibility and for reducing transport poverty, particularly in relation to long-distance trips. Thus, in contrast to MaaS that currently offer services to people who can afford it (Pangbourne et al., 2020), integrated ticketing may be made part of policy interventions that focus on reducing transport poverty.

A season ticket is a form of mobility tool (Scott and Axhausen, 2006). Intuitively, PT service packages, normally operationalised by integrated ticket options, allow users to select the best combination of the PT service attributes from among the participating PT operators that match their travel needs (Ibrahim, 2003). This makes integrated ticketing a composite or packet PT attribute and the service attributes of integrated PT systems will generally vary. In the context of the case study and in line with the conceptual framework for integrated ticketing in Figure 5-4, the intercounty integrated ticketing system offered benefits such as travel time savings, cost savings and frequent services to users. This is further confirmed by the respondents' revealed reasons (Figure 5-5) for choosing Movingo after its implementation. A comparison of the parameter estimates in the modelling results also suggested that the integrated ticketing attribute is composite in nature as it has the highest value. This is not inconceivable considering some of the following direct synergistic benefits that the Movingo integrated season ticket scheme offers to users along the studied corridor:

Travel time savings: The integration of the tickets provides direct services across county borders. PT commuters thus reduce daily travel time by eliminating interchange time at county borders. For instance, before the Stockholm and Uppsala counties integrated their ticket in 2013, PT users travelling between Stockholm and Uppsala were forced to change train at Upplands Väsby station, and this is obviously associated with interchange wait time. Also, Movingo users between Stockholm and Uppsala also have the option of choosing direct or skip-stop services to save about 15 minutes of their in-vehicle time per trip.

Cost savings: The integration of fares among the three operators resulted in reduced fare for an unlimited number of PT journeys covering a wider area for the season ticket's validity period, hence providing some cost savings to PT commuters. Considering the three service providers in the case study, the monthly ticket prices for the Stockholm's PTA, the Uppsala PTA and the National Swedish Railways are 890 SEK, 880 SEK and 2070 SEK respectively. Consequently, users of the SL/UL integrated monthly ticket get a 6.2% discount (110 SEK), and users of the integrated monthly ticket for all the three service providers (i.e. Movingo) get a discount of about 43% (1640 SEK) compared to if they were to buy the individual monthly tickets for each of the three service providers.

Service frequency: along corridors operated by multiple service providers, service frequency tends to increase due to combined headways. For instance, Movingo users between Stockholm and Märsta during peak hours have a combined headway of 10 minutes, while none Movingo users have a headway of 30 or 15 minutes depending on their chosen operator.

Free transfer: Integrated ticketing increases the convenience of transfer across service providers. Opurum (2012) analysed the value of free transfer and found out that its value for full-time employed people was between 0.22 USD (about 2 SEK) and 0.77 USD (about 7 SEK).

Increased geographic accessibility for users: Increased easiness of reaching opportunities within a wider area as users can travel as much as they want within the season ticket's validity period. Also, as the season tickets are not personalised, season ticket owners have the opportunity of allowing other people, especially family members, to use their idle tickets. Hence, some households may even decide to own both a car and a season ticket as household's mobility tools Scott and Axhausen (2006).

Fare zones: The complexity in the zone and fare structures is significantly reduced, and this may have positive effects on user convenience and ridership.

Even though the service attributes of integrated PT systems generally vary, this case analysis clearly demonstrates that integrated ticketing is a multipurpose policy intervention strategy for policymakers seeking to improve seamless mobility across PT operators in deregulated PT markets.

In terms of generalisability of the findings, while the study provided empirical evidence of users' WTP for the benefits of integrated ticketing, it is important to highlight that the resulting WTP estimates will be more applicable for the economic evaluation of comparable integrated ticketing schemes and in similar settings. This is because the dataset used in deriving the values was based on an inter-county PT system, with service characteristics quite different from within the city or within county PT and MaaS systems.

5.6 Conclusion

CBA and CEA of transport investment appraisal decisions require reasonable estimates of costs and benefits in monetary terms. WTP is an institutionally accepted approach for driving the monetary values of transport policy measures in many developed countries such as Sweden, where policymakers are currently contemplating nationally integrated ticketing. This case study has consequently been conducted to estimate PT users' WTP for multi-county and multi-operator integrated ticketing. MNL and MNML models were estimated using an SP dataset that was collected prior to the implementation of the Movingo multi-county and multi-operator integrated season ticket scheme in Mälardalen, Sweden, in autumn 2017.

The analysis showed strong evidence of users WTP for regional ticketing integration. Users' valuation of the integration is at least 26% of the average integrated monthly ticket price. Due to the pervasive and synergistic nature of integrated ticketing, users valued it higher than travel time savings, cost savings and high service frequency. Its estimated coefficient was even higher than the simple addition of the absolute values of the coefficients of these three attributes, perhaps due to some other unobserved benefits of integrated ticketing. While this finding may be associated with the characteristics of the case study, it is still plausible to expect that an integrated platform will provide a higher value to users than its individual service attributes. This implies that integrated ticketing can be considered as a multipurpose policy intervention strategy for policymakers seeking to improve seamless mobility across PT operators in deregulated PT markets.

This is evident in the UK Department for Transport (2009) estimate of the annual net benefits of national-level integrated smart ticketing.

Passengers belonging to the lowest income group have the highest mean WTP value for a multi-county integrated ticketing system, suggesting that integrated ticketing has strong potential for improving accessibility and reducing transport poverty particularly in relation to long-distance trips.

Commuters differ less in their preference for integrated ticketing compared to non-commuters. Yet, non-commuters' mean WTP is about 3% higher than that of commuters. The policy implication of this is that, even though Movingo was designed for frequent travellers, interregional integrated ticketing platforms will achieve higher impacts if they are designed to meet the needs of both frequent and non-frequent travellers.

Men have a higher mean WTP value compared to women, and a higher proportion of men are willing to pay over 50% of the average integrated season ticket price for the benefits of an intercounty integrated ticketing system. Yet, women showed less variability in their WTP. This gender difference in WTP for integrated ticketing confirms differential travel needs among women and men and, intercounty integrated ticketing could thus be made part of policy measures that focus on addressing gender disparities in long-distance commuting and increasing PT patronage.

In terms of the wider policy implications, the study provides a quantitative summary of our knowledge of the marginal effect of multi-county integrated ticketing and is the first of its kind to provide evidence on PT users WTP for integrated ticketing. The resulting range of WTP values from this study could be used as a starting point in cost-benefit-analysis to infer policy conclusions about the value of interregional integrated ticketing for users and society. Having demonstrated the feasibility of estimating WTP for integrated ticketing here, we would argue that further such studies be conducted by planners, policymakers and researchers working with CBA, to build on the evidence we provide, so as to establish an agreed set of values for use in CBA.

The study proposes the areas for further research:

- Firstly, inter-county integrated ticketing was the focus of the present study, reflecting regional PT characteristics. The derived WTP values may thus not be applicable to city or county level ticketing integration, and further studies are needed in driving the WTP values at city or county level.

- Secondly, the study focused on individual users, yet some businesses and organisations patronise integrated season tickets, and it will be relevant to examine their WTP for a multi-county integrated ticketing system.
- Also, as the MaaS model is gradually gaining acceptance at least in urban mobility, it will be policy-relevant to examine users' WTP for a regionally integrated ticketing system where many service providers (PT operators and so-called mobility operators) work together under the Mobility as a Service (MaaS) model.

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Chapter 6
Examining the effect of integrated ticketing on mode choice for interregional commuting

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Abstract

Public transport (PT) service quality improvements are generally expected to have positive effects on a shift from car to PT. The effects of improvements such as integrated ticketing is often overlooked in mode choice analysis. Given the widespread implementation of integrated ticketing schemes globally and the evidence confirming the positive substitution effects between car and season ticket ownerships, the objective of the study reported in this paper is to examine the correlation between mode choice for commuting and multi-regional integrated ticketing. A stated preference survey was conducted along the E4 motorway between Stockholm and Uppsala, Sweden. Subsequently, binary and mixed logit models were estimated. The results suggest that the effect of integrated ticketing on mode choice for commuting is positive. The findings further show that given integrated monthly tickets, car commuters of the high-income category are less likely to shift to PT, more frequent car commuters are less likely to change to PT compare to less frequent car commuters, male car commuters compared to females are more likely to switch to PT for commuting and people commuting with a company car have the tendency to stick to car commuting. The methodological and policy implication of this positive association is that integrated ticketing should be included in demand modelling to improve both the accuracy of the estimates and the policy decisions that are based on these estimates. Further research on the marginal effects of the number of operators that are involved in a specific integrated ticketing scheme is recommended.

Keywords: *public transport, integrated ticketing, season tickets, commuters, mode choice, service provider, operator*

6.1 Introduction

Efforts to improve transport planning and sustainable travel patterns has necessitated a considerable amount of research aimed at the detail measurement and understanding of travel mode choice. The attributes of a given transport mode such as journey time, cost, service frequency and convenience are widely acknowledged to be some of the significant factors that influence travel mode choice behaviour (Ortúzar and Willumsen, 2011, Ben-Akiva and Lerman, 1985).

This research hypothesises a positive association between integrated ticketing and commuting mode choice. By offering user-benefits such as travel time savings, cost savings, improved convenience, improved service frequency, free transfer, increased geographic accessibility, improved mobility for household and less need for ticket information (PTEG, 2009; Alhassan et al., 2020; White, 2009), integrated ticketing reduces the generalised cost of public transport (PT) usage. These are some of the reasons why the implementation of integrated ticketing schemes around the world is on the increase. However, the understanding of how, through its impacts on modal attributes, integrated ticketing affects mode choice, is yet very limited.

Integrated ticketing improves the PT service by allowing users to travel across service providers easily. There is a substantial amount of investments into these schemes around the world (PTEG, 2009) and they have obviously become an integral part of both national and international integrated transport policies in countries like the UK, the Netherlands, Sweden and in the EU (Puhe, 2014; Turner and Wilson, 2010). Interestingly, there is currently limited knowledge on the extent to which integrated ticketing influences mode choice behaviour. This study thus seeks to provide empirical evidence on the relevance of integrated ticketing, particularly those covering a wide geographic area, as a significant factor in predictive travel mode choice analysis.

Comfort, convenience, speed, individual freedom, flexibility, and status are well-known attractive factors of the car. Hence, inducing a shift from car to more sustainable modes such as PT often motivates the implementation of measures that improve the PT service quality. Implementing PT service quality improvements are often expected to have positive effects on PT demand (Kol-TRAST, 2012; Paulley et al., 2006). While the effect size of the individual improvements varies, the extent to which some relevant PT service improvements such as integrated ticketing influences mode choice are apparently overlooked in travel demand analysis. This oversight may lead to the underestimation of PT demand in travel demand forecasting, and this implies that the positive impacts of these overlooked PT interventions on the resulting consequences of travel demand such as congestion, emissions and poor accessibility may also be underestimated.

For instance, in the case of the current Swedish Transport Department's travel demand forecast, the recently implemented Movingo integrated ticketing scheme across the Mälardalen regions, constituting about 40% of the total population of Sweden (SCB, 2020a), was not captured in the forecast. This scheme, however, evidently increased rail communing across the regions (Alhassan et al., 2020).

In the UK, the estimated net benefits of national-level integrated smart ticketing is over £1bn per year (UK Department for Transport, 2009), and while the Public Transport Executive Group (2009) acknowledged the positive impact of integrated ticketing on modal shift, the extent to which it does could not be found in its global review of the benefits of integrated ticketing.

The main contribution of this study is that it has provided empirical evidence on the relationship between integrated ticketing and mode choice for intercounty commuting, which to the authors' knowledge has not been investigated by previous work. Thus, we seek to draw the attention of researchers, transport planners and policymakers to the fact that regional integrated ticketing needs to be included as a potential determinant of mode choice in travel demand analysis.

The rest of the paper proceeds as follows. Section 6.2 covers a review of the literature on PT ticketing and mode choice. Section 6.3 describes the study approach. Section 6.4 presents the findings and discussions. Section 6.5 provides conclusions and recommendations for further research.

6.2 Literature review

The literature on travel mode choice behaviour has increasingly recognised the interconnection between travel mode choice and many factors such as:

- Socioeconomic and demographic (individual/household-specific) factors such as gender, age income, immigration status and employment status (Klein and Smart, 2017; Johansson-Stenman, 2002; Polk, 2004; Zhou, 2012; Schmöcker et al., 2007; Matthies et al., 2002; Smart, 2015)

- Transport mode-specific factors such as travel cost, travel time, safety, security, parking facilities, service frequency, comfort level and convenience (Limtanakool et al., 2006; Chlond et al., 2014; Larsen and Rekdal, 2009)
- Natural environment-specific factors such as topography, environmentalism and weather conditions (Rieser-Schüssler and Axhausen, 2012; Liu, Susilo and Karlström, 2015)
- Built environment-specific factors such as spatial development patterns, urban form, workplace relocation and residential relocation (Buehler, 2011; Schwanen and Mokhtarian, 2005; Scheiner and Holz-Rau, 2013)
- Transport and land-use policies such as measures to restrict car use, transit-oriented development, incentives and bus priority (Evangelinos et al., 2018)
- Trip-specific factors such as trip type, trip time, the need to carry for instance luggage (Ortúzar and Willumsen, 2011)
- Psychological factors such as attitudes, subjective norms, perceived behavioural control, intension, previous experience, habits, situation, commitments, affect, exposure (Lanzini and Khan, 2017; Nerhagen, 2003; Simma and Axhausen, 2003; Johansson et al., 2006; Heinen et al., 2017; Bamberg, Ajzen, and Schmidt, 2003; Heinen and Chatterjee, 2015; Ababio-Donkor et al., 2020; Gärling and Axhausen, 2003).

This present study focuses on transport mode-specific factors. The economic liberalisation of PT markets in most countries provides PT operators with the possibility to compete by differentiating their products and applying yield management and price discrimination to maximise revenue and to better assign customers to services (Wardman and Toner, 2003). This market arrangement means a wide variety of ticket types are offered and often creates a problem for customers who need to travel using more than one PT operator to complete their trips. Hence, ticketing improvements such as integrated ticketing and mobile ticketing, as aspects of PT mode-specific factors, tend to increase the attractiveness of the PT service (Buehler and Pucher, 2012; EPTG, 2009; Kamargianni et al., 2016; Alhassan et al., 2020).

Besides, most PT trips are performed with season tickets as most people, such workers and students regularly need to travel to the same destination daily. For instance, the season ticket is the most used ticket type in Sweden, and its usage has increased from 57% to 63% between 2017 and 2018 (SKT, 2018). In Germany, the season ticket share of the ticket market is about 75% (Chlond et al., 2014).

Paulley et al. (2006) however pointed out that the effects of prepaid ticketing systems on PT demand are not clear and may depend for instance on discount levels and other conditions such as unlimited journeys within a given tariff zone (s) for a given period. On the other hand, Chlond et al. (2014) investigated season ticket users' behaviour in Germany using panel data. They found that season ticket owners were multimodal in behaviour as the share of people with car availability owning season tickets had increased since 1995, and that they used season tickets for mainly work, business and educational trips. Similarly, car availability and level of education were found to be significantly correlated with season ticket use in Valencia, Spain (Ruiz, 2004). Also, Scott and Axhausen (2006) and Simma and Axhausen (2010) confirmed a positive substitution effect between car ownership and season ticket ownership. In another study, Sommer and Lambrecht (2016) proposed and discussed the potential of the concept of tenant tickets as a form of mobility management strategy for increasing PT usage in Germany. Furthermore, Wardman and Toner's (2003) analysis of train ticket types in the UK focused on understanding the competition among train ticket types. Similarly, Mesoraca and Brakewood (2018) synthesised mobile ticketing applications in the United States and revealed that only a few commuter rail operators had fully integrated ticket transfer policies. In Europe, an opinion survey on the potential of integrated ticketing (a single multimodal ticket) to attract car users within EU countries to PT was generally very positive (Flash Eurobarometer, 2011).

Interestingly, it is still hard to find literature on the quantitative estimates of the influence of season ticket integration on the attractiveness of PT to car commuters (people who commute exclusively by car and those who commute sometimes by car and sometimes by PT). Previous work covering the relationship between car usage and season ticket patronage tends to focus more on measuring the use of season ticket as a form of mobility tool. To the knowledge of the authors, and as confirmed by EPTG's (2009) review of the benefits of PT integrated ticketing, the extent to which integrated ticketing as a form of PT service improvement makes PT more attractive to car users is yet to be investigated. The objective of this study is thus to empirically contribute to this knowledge gap by analysing the association between integrated ticketing and mode choice for cross-county commuting between Stockholm and Uppsala, Sweden.

6.3 Methodology

The econometric approach of discrete choice modelling and psychological methods currently dominate transportation mode choice research. Given that: commuting is primarily a derived demand towards satisfying the need to travel to the same destination regularly, that the decisions to commute and to choose commuting mode are reasonably planned, and that ticketing is a derived demand towards getting access to PT service, the discrete choice modelling framework based the random utility theory (Ortúzar and Willumsen 2011) was considered as the most suitable theoretical framework for guiding the research design, data collection, analysis and interpretation of the enquiry into commuting mode choice as a function of ticketing integration.

It is consequently, assumed that the likelihood that a commuter between Stockholm and Uppsala chooses a car or PT for some or all his/her commuting trips is a function of the individual's socioeconomic characteristics and the attributes of these two available modes. We now turn to explain the case study corridor and the key details of the methods employed.

6.3.1 The Stockholm – Uppsala corridor as a case study

The corridor between Stockholm and Uppsala, known as ABC-corridor, an urban planning acronym in Swedish for Work, Residence and Centre (Arbete, Bostäder & Centrum) in the Swedish urban planning sector, is characterised by many activities such as socioeconomic, educational, historical and cultural activities that cause it to attract the largest number of cross-county trips in Sweden. Figure 6-2 and Figure 6-3 provides a summary of the data from Statistics Sweden between 2004 and 2018. The number of people travelling to work outside their resident municipality tends to be increasing among the municipalities along the corridor. But this is higher for males relative to females. The E4 motorway and the east coast rail infrastructure facilitates mobility along this corridor. Figure 6-1 shows the corridor and the 2030 estimated accessibility to major destinations along the corridor with PT. The main PT service supplies within the corridor are the Stockholm county public transport authority (PTA), SL, the Uppsala county PTA (UL) and the Swedish national Railways (SJ).

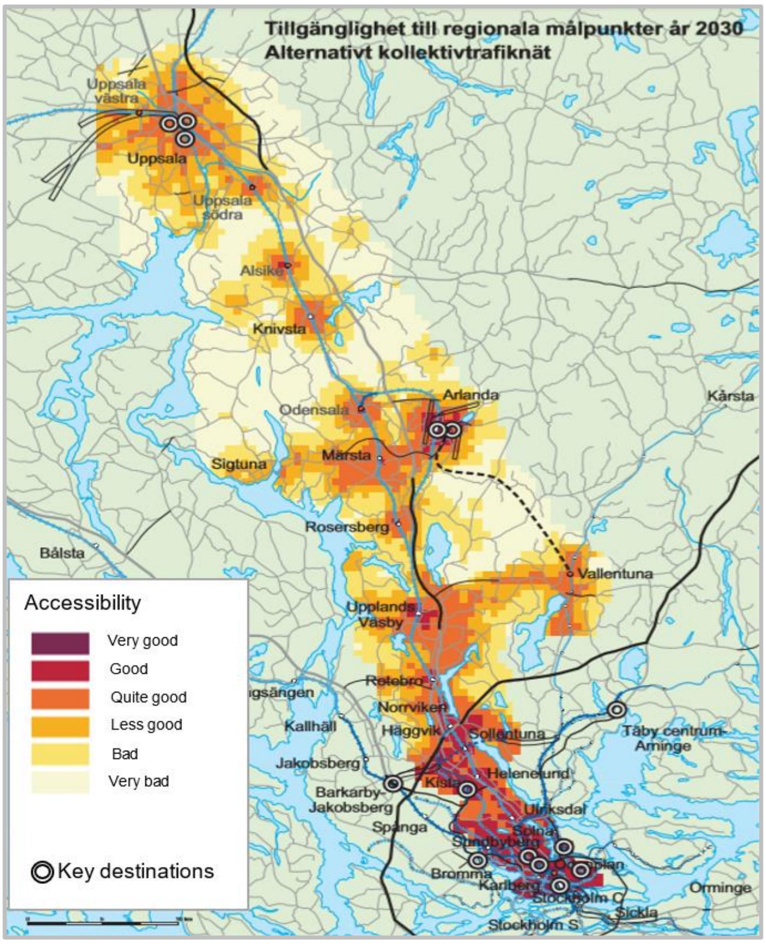

Figure 6-1: 2030 forecast for PT accessibility to key destinations along the ABC-Corridor (ABC – Samarbetet, 2007)

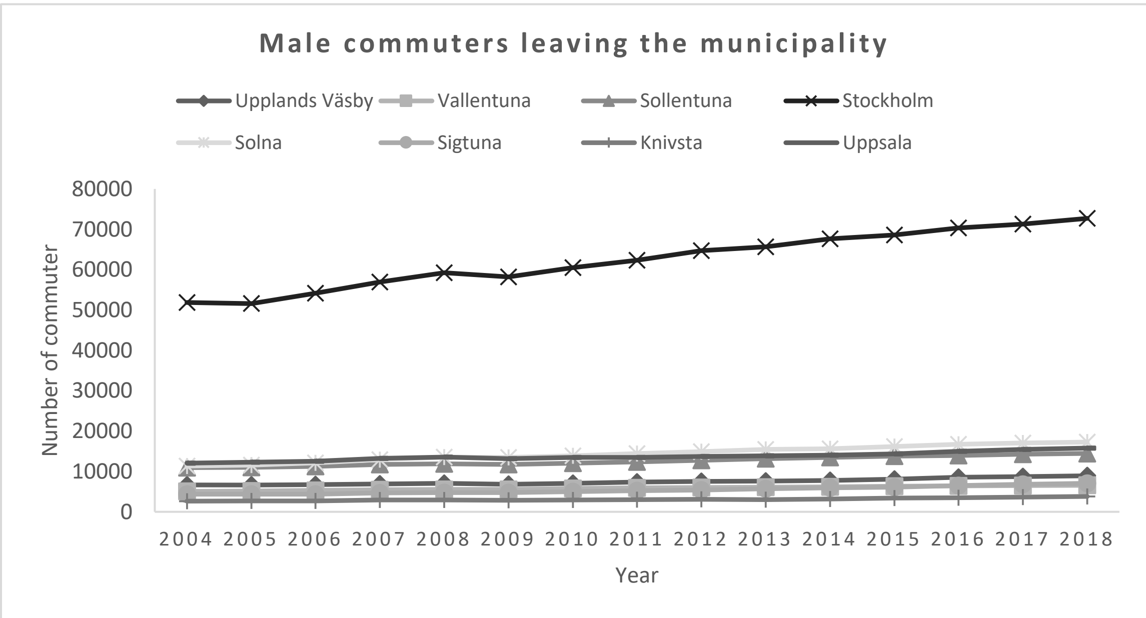

Figure 6-2: The number of men commuting outside their resident municipality by year (SCB data, 2020b)

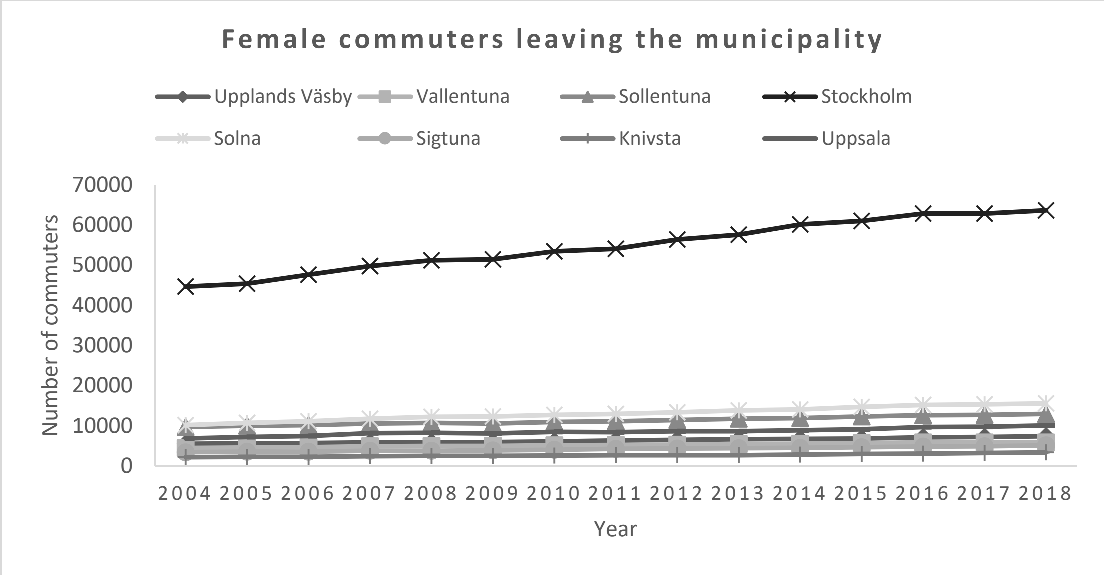

Figure 6-3: The number of women commuting outside their resident municipality by year (SCB data, 2020b)

Transport supply along the corridor has developed over time through collaborative work among the stakeholders such as the ABC collaboration which involves the municipalities (Stockholm, Solna, Sollentuna, Upplands Väsby, Vallentuna, Sigtuna, Knivsta and Uppsala) that are located along the corridor and other stakeholders.

Since PTAs in Sweden are generally separate units with different pricing and ticketing systems, ticketing integration has been one of the areas of collaboration between the Stockholm and Uppsala county PTAs. That is, in 2013, SL and UL integrated their tickets along the corridor into the SL-UL ticket, with which passengers have access to all services provided by SL and UL. This gives passengers the opportunity to travel between Stockholm and Uppsala and to travel within each of these two cities with one multimodal ticket. In 2017, all the main PT service providers along the corridor (SL, UL and SJ) as part of the Movingo integrated scheme, launched a common smartcard and mobile phone-based multiple-county season ticket known as Movingo, which is valid for both intercity and intracity bus and train services across the six counties in Mälardalen region. Like most season tickets in Sweden, Movingo which aimed at increasing PT commuting across all counties within the Mälardalen region has options that are valid for unlimited trips for 30 consecutive days, 90 consecutive days or one year. As presented in the literature review section, commuters typically choose the 30-day ticket (monthly pass) and hence, our analysis focused on monthly ticket.

6.3.2 Survey design and sample descriptive statistics

We conducted extensive background research in the questionnaire design phase. Adopting the random utility theoretical framework for the analysis coupled with the lack of suitable secondary dataset for the investigation implied designing and conducting a cross-sectional travel survey among car commuters along the Stockholm - Uppsala section of the E4 motorway. The survey included both stated preference (SP) scenarios and revealed preference (RP) question on the mode choice for commuting. That is, the survey consisted of three parts. Part A collected data on the respondents' travel habits and behaviour such as PT patronage after the launch of the Movingo integrated season ticket, commuting frequency and experience, park-and-ride patronage, receipt of tax reduction for work-related trips, access to free parking at the workplace, access to a company car for trips to work, the need to drive children to school, if travel cost to work is fully or partially taken by the employer and if one's work routines require regular use of a car. Part B contained SP questions that gathered data on choices and trade-offs made by the respondents. Part C focused on collecting the respondents' socioeconomic data.

The fieldwork involved randomly recording private car registration numbers along the E4 motorway during peak hours (6 am – 9 am & 3 pm – 6 pm). This is because most commuters are expected to be travelling within these hours. Post addresses connected to the sampled vehicles were extracted from the national Swedish car registry. Only post addresses in Stockholm and Uppsala were kept. Four hundred and seventy-five questionnaires (475) were then posted, together with paid-reply envelopes for participants to mail-back their completed survey. The option to respond through the web was also provided. The survey was closed after four weeks without any reminders. Ninety-six (96) completed survey questionnaires were received, representing a response rate of 20%. This is within the expected bounds and sufficient for the purpose of the analysis.

The sample data collected in part A & C of the survey are summarised in Table 6 - 1. 27% of the survey participants reported that they need to use a car to undertake some routines at work and this, suggests that car is the default travel mode to work for this group since they need it at work. 90%

stated that they pay the full cost of their travel to and from work. Nevertheless, 59% stated that they got an annual tax reduction for trips to and from work. This may serve as an economic incentive for some respondents in this group to commute by car. 21% of the participants reported that they need to drive children to school, and this is likely to make commuting by PT unattractive to this group. Just 7% of the sampled respondents stated that their employers take the cost of their trips to and from work. 38% of them reported that they had access to free parking at work, often viewed as serving as an incentive to commute by car. Very few (6%) of them stated that they patronised park-and-ride services. Majority of the respondents (52%) reported that they never commuted by PT and 46% of them stated that they commute at least five days per week. Concerning commuting experience, 64% said that they have commuted for at least five years.

The integrated ticketing schemes was the only PT improvement intervention along the corridor between October 2017 and April 2018, i.e. as of the time the data was collected. Hence, the respondents were asked to respond to the dichotomous question "I started commuting by rail in or after autumn 2017". Even though the sample suggests that most of the respondents have commitments and incentive that possibly make commuting by car more attractive than PT, the integrated scheme had some positive impact on mode choice for commuting as 9% per cent of the respondents stated that they started patronising PT services after the implementation of the Movingo scheme. Given that this data was collected about half a year after the launch of Movingo, this number is expected to increase as Movingo becomes more popular. The National Swedish Railways later after the survey reported an overall increase of approximately 24% in season ticket sales due to the implementation of the Movingo scheme.

The respondents' socioeconomic data including age, gender, monthly income, employment status and level of education, were also collected. As summarised in Table 6 - 1, 32% were females in the sample and 68% of them were males. This was expected as the proportion of male motorists is higher than that of females. Even though the age distribution in the sample is quite even, the age group 16 – 34 year had the least representation (15%). In terms of education, more than half of the respondents (54%) stated that they had at least three years of university education and, this reflected the high proportion of people with university education in both

Uppsala (34.1%) and Stockholm (35.5%) municipalities (SCB, 2018). With regards to income, the least represented group was respondents with gross monthly income over 50,000 SEK. Few people have monthly income higher than 50,000 SEK/Month in the study area as the average monthly income for people over 20 years in Uppsala municipality was 26,000 SEK/Month and that in Stockholm was 31,000 SEK/Month as of 2017 (SCB, 2018). As expected of commuters as the target study group, 88% of the respondents reported that they were full-time employed.

Table 6-1: Descriptive statistics of the survey sample

Sample characteristics (Sample size, n = 96)	
Gender	*Female **(**32**%),** Male (68%)*
Age (Years)	*16 – 34 (15%), 35 – 44 (24%), 45 – 54 (29%), 55+ (30%)*
Monthly gross income in SEK	*00000–30000 (11%), 30001–50000 (75%), Over 50000 (13%)*
Education	*Higher education - 3 or more years (54%), Higher education-less than 3 years (25%), High school or below (22%)*
Employment status	*Full-time employed (88%), Part-time employed (7%), Other (5%)*
Car usage under work	*Yes (27%), No (74%)*
Travel cost paid by employer	*Yes (10%), No (90%)*
Drive children to school	*Yes (21%), No (79%)*
Company's car	*Yes (7%), No (93%)*
Free parking (work)	*Yes (38%), No (62%)*
Received tax reduction for work trips	*Yes (59%), No (41%)*
Park and ride patronage	*Yes (6%), No (94%)*
Frequent traveller (Stockh – Upps)	*Yes (62%), No (38%)*
Commute by rail after Movingo	*Yes (91%), No (9%)*
Commuting frequency (Car)	*1 - 4 days/week (31%), ≥ 5 days/week (46%), Rarely (23%)*
Commuting experience (Car)	*< 1 year (9%), 1 – 4 years (21%), ≥ 5 years (64%), N/A (6%)*

In terms of PT usage among the respondents, 9.4% of them stated that they currently patronised PT services. 17% of these were females, and the majority (83%) were males. Also, 33% were in the age category 16 – 34 years, 44% in the age category 35 – 54, and then 22% were over 55 years. Besides, 67% of them have some form of university education, and 33% of them had a high school education. 11%, 33% and 33% stated that they commuted by train 1 - 2 times/week, 3 - 4 times/week and five or more times/week respectively. About 22% stated that they rarely commuted by train.

Table 6-2: Attributes and their levels & an example of the choice scenarios

Alternatives	Attributes and levels				
Train	*In-train time* (40,50,55)	*Headways* (15,30)	*PT Walk time* (5,10,15)	*Monthly cost SEK* (1600, 2000,2200)	*Ticket integration* (0,1,2)
Car	*In-car time* (55,60,65)	-	-	*Monthly cost SEK* (2000, 3000,4000)	-

Scenario 4 of 9	**Train**	**Car**
Time spend in the vehicle	50 min	60 min
A train departs every	15 min	---
Travel time to train station	15 min	---
Monthly cost (SEK)	2 200	4 000
Monthly ticket gives you	Access to all SL & UL lines + fast Regional train (SJ) between Stockholm & Uppsala	---
In this scenario, I will choose (please tick train or car)	**[ ]**	**[ ]**

The SP survey was designed with the help of Ngene, a state-of-the-art tool for discrete choice survey design (ChoiceMetrics, 2011). Nine binary, labelled and efficiently designed SP choice scenarios were generated based on different combinations of the attributes and levels presented in Table 6 - 2. Labelled choice set compared to unlabelled ones are less abstract and can thus increase the validity of the results (de Bekker-Grob et al., 2010). Also, the use of prior parameters in experimental design (i.e. efficient design) always outperforms the traditional orthogonal design, even if only the parameter signs are known or can be logically assumed (ChoiceMetrics, 2011). Efficient design focuses more on improving the statistical efficiency of the experimental design as opposed to orthogonal design that focuses on creating uncorrelated attributes. A significant advantage of an efficient design over orthogonal design is that it produces parameter estimates with smaller standard errors with a relatively small sample size (Rose and Bliemer, 2004). An example of the choice scenarios, the attributes and their level are presented in Table 6 - 2. The cost of commuting by car per month is calculated based on travel distance given the Swedish tax department's rate of 1.85 SEK/Km for work trips. Monthly train cost equals to the price of a 30-day season ticket.

6.3.3 Model specification and estimation

A binary logit (BNL) and binary mixed logit (ML) were specified and estimated using the cross-sectional dataset presented in the preceding section. The logit family of models provides a useful toolkit for analysing and understanding discrete choice behaviours. The standard logit model, even though easy to estimate, does not consider random taste variation and has restricted substitution pattern (Train, 2009). The mixed logit model solves these problems. This model currently represents the state-of-the-art method in discrete choice modelling since it is a very flexible model that approximate any random utility model (Train, 2009; Ortúzar and Willumsen, 2011). For a detail description of the mathematical formulations and applications of these methods, the reader is referred to (Train, 2009; Ortúzar and Willumsen, 2011; Ben-Akiva and Lerman, 1985; Koppelman and Bhat, 2006; Hensher and Green, 2003).

Given the research proposition that commuting is primarily a derived demand and that the decisions to commute and to choose commuting mode are rational decisions, the utility that a commuter assigns to train or car for intercity commuting between Stockholm, s, and Uppsala, u, is given by equation 6-1.

$$U_{su} = V_{su} + \mathcal{E}_{su} \tag{6-1}$$

Where U = Utility, V and $\mathcal{E}$ are respectively the deterministic and random parts of the utility. Given our sampled dataset, equation 6-1 is transformed into equation 6-2.

$$U_{su} = \beta_1 t_{su}^{v} + \beta_2 t^{a} + \beta_3 F_{su} + \beta_4 H_{su} + \beta_5 ETI + \cdots + \beta_z X_{cz} + \alpha_k \tag{6-2}$$

Where; t_{su}^{v} = In vehicle time between Stockholm and Uppsala, t^{a} = Access time, F_{su} = Fare charged for the trip between Stockholm and Uppsala, H_{su} = Service frequency, ETI = a dummy coded variable for ticketing integration, X_{cz} = a socio-economic characteristic, z, of an individual commuter, c, β1…z are the marginal effects of each specified attribute and socioeconomic characteristic on travel utility and α_k = a parameter representing unobserved part of the utility.

In the standard logit model estimation, the probability that a commuter chooses commuting mode *i*, for commuting between Stockholm and Uppsala given our binary choice set *C*, is given by equation 6-3.

$$\mathrm{P}(\mathrm{i} \mid C) = \mathrm{P}\,(U_{isu} \geq U_{jsu}, \forall \mathrm{j} \in \mathrm{C}, \mathrm{j} \neq \mathrm{i}\,) = \frac{\mathrm{e}^{U_{su}}}{\sum_j \mathrm{e}^{U_{su}}} \tag{6-3}$$

The probabilities in the mixed logit estimation are given by the integrals of the standard logit model provided in equation 6-3.

Several software packages have been developed for estimating these models. The R package, Apollo, developed by the Choice Modelling Centre at the University of Leeds, was used in this study (Hess and Palma, 2019). In estimating the ML model, all random parameters were assumed to be normally distributed and 500 Halton draws were used.

6.4 Empirical results and discussion

Table 6-3 presents the results of the estimated logit models. Except for the coefficient for access time in the binary logit model, which had the expected sign but was not statistically significant (statistically significant at 90% confidence level in the mixed logit), all the estimated mean coefficients for the included mode-specific attributes, i.e. in-vehicle-travel-times, monthly PT cost, headway, integrated ticket, and the monthly cost for the car, had the expected signs and were statistically significant, at least 95% confidence level. Assuming none-linearity, the effect of a season ticket was analysed by dummy coding it as an integrated monthly ticket and an unintegrated monthly ticket. The overall model fitness statistics presented in Table 6-3 indicate that both estimated models explained the choice behaviour in the samples relatively well. Since the two models are related and that the mixed logit model can collapse back into the standard logit model, the likelihood ratio test was applied to compare the overall statistical performance of the models. The mixed logit, as expected, explains the choice behaviour better than the standard logit model, the interpretation of the results is hence based on mixed logit’s estimates.

As anticipated by EPTG's (2009) review report on the benefits of PT integrated ticketing, the results suggest that the effect of integrated season tickets on mode choice is positive and statistically significant. Previous works confirmed a positive relationship between car ownership and season ticket ownership (Chlond et al. 2014; Scott and Axhausen; 2006; Simma and

Axhausen, 2010). However, in contrast to unintegrated season tickets, integrated season tickets generally tend to offer more users benefits as it produces a combine positive effect on travel across different service providers and beyond city and regional boundaries such as increased convenience of travelling across service providers, increased geographic accessibility, cost savings and time savings, thereby making PT more attractive to cross-county car commuters by reducing the generalised travel cost for them (PTEG, 2009; Alhassan et al., 2020; White, 2009). Some major observed benefits of integrated ticketing in the case study area that could have contributed to the positive association between integrated ticketing and mode choice include:

- In the case of the SL-UL combined line, there is at least 5 minutes reduction in travel time as passengers do no longer need to change trains at the border of the two counties at Upplands Väsby station. With the SL-UL-SJ ticket (Movingo), users have the option to choose direct service between Stockholm and Uppsala with about 15 minutes reduction in in-vehicle time, compared to taking a snail train line that services every station between the two cities.
- In terms of service frequency, users of the integrated tickets enjoy a combined headway of 20 minutes compared to users of unintegrated, which has a headway of 30 minutes or 60 minutes depending on the service their ticket can access.
- The integration also eases transfer across the three service providers for users of the integrated tickets.
- The integration further offers users access to the entire SL and UL services as well as SJ's service between Stockholm and Uppsala. Unlimited trips within and between the two counties for the season ticket's validity period.

The results also highlight the importance of user characteristics such as income, frequency of commuting by car, gender, and access to company car as significant explanatory factors for mode choice.

Consistent with the literature on the influence of income on travel mode choice behaviour, the study indicated the commuters' monthly income is positively correlated with the choice of car for commuting. I.e., commuters of the high-income category are less likely to shift to PT given integrated monthly tickets. This implies that integrated ticketing alone may not be policy effective in attracting car commuters in high-income class to PT, instead, it needs to be combined with other policy measures to achieve the desired mode shift.

Table 6-3: Model estimation results

	Binary Logit	*Mixed Logit*
Number of individuals	*84*	*84*
Number of observations	*756*	*756*
Estimated parameters	*14*	*21*
LL(final)	*-350.4572*	*-296.7679*
Rho-sq (0)	*0.33*	*0.43*
Adj. rho-sq (0)	*0.3*	*0.39*
Likelihood test statistics $\{-2(LL_R \text{ of MNL} - LL_U \text{ of MMNL})\}$	*107.3786 (df = 7, p-value = 000)*	

	Binary Logit			**Mixed Logit**					
Variables	***Mean***	***Std. err.***	***t-stat***	***Mean***	***Std error***	***t-stat***	***Std dev***	***Std error***	***t-stat***
Alternative specific constants (ASC)									
ASC train	1.1260	1.6698	0.67	1.0609	2.6694	0.40			
ASC car is normalized to zero									
Attributes of the alternatives									
In-train travel time (min)	-0.0973	0.0153	-6.37***	-0.1635	0.0272	-6.00***	0.0062	0.0156	0.40
Monthly fare, train (SEK)	-0.0010	0.0004	-2.58***	-0.0017	0.0006	-2.67***	-0.0002	0.0002	-0.92
Headway (min)	-0.0397	0.0145	-2.74***	-0.0725	0.0247	-2.93***	0.0433	0.0324	1.34
Access time	-0.0482	0.0299	-1.61	-0.0905	0.510	-1.77*	0.0974	0.0473	2.06**
Ticket, integrated	0.4864	0.2205	2.21**	0.7660	0.3776	2.03**	-1.6084	0.3583	-4.49***
Ticket, Not integrated (base level)									
In-car travel time (min)	-0.0722	0.0283	-2.55**	-0.1204	0.0479	-2.51**	-0.0105	0.0084	-1.24
Monthly cost, car (SEK)	-0.0009	0.0002	-3.72**	-0.0015	0.0004	-3.56***	0.0004	0.0002	1.68*
User characteristics									
Monthly gross income (SEK)									
00000–30000 (Base level)									
30001–60000	-2.0308	0.5940	-3.42***	-2.6622	1.0204	-2.61***			
Over 60000	-2.4269	0.6809	-3.56***	-2.6195	1.2189	-2.15**			
Gender									
Female	-0.9223	*0.3630*	*-2.54***	-1.0946	0.6022	-1.82**			
Male (Base level)									
Commuting Frequency by car									
Rarely	-3.8225	0.5057	-7.56***	-6.5553	1.0405	-6.30***			
1 - 4 days/week	-2.2389	0.3659	-6.12**	-4.2162	0.8744	-4.82***			
≥ 5 days/week (Base level)									
Use of company car for commuting trips									
Yes	1.7243	0.5774	2.99***	2.5208	1.4351	1.76*			
No (Base level)									

*Significant codes: * Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level*

Also, frequency of commuting influences mode choice as more frequent car commuters are less likely to change to PT compare to less frequent car commuters considering the availability of integrated monthly tickets. This supports the line of argument of the habitual nature of a given behaviour, such as commuting by car, is an important determinant of actual behaviour (Gärling and Axhausen, 2003).

Males and females tend to generally differ in their travel behaviours. Beck and Hess (2016) confirmed that the decision to commute is less uniform for males and female and that these two gender groups differ in their preferences for commuting. While gender difference was expected in this study, it was astonishing that female car commuters compared to males were less likely to switch to PT for commuting given integrated monthly tickets. This finding was least expected as females in Sweden generally tend to patronise PT services more than males (Johansson-Stenman, 2002; Polk, 2004), and are more willing to reduce the use of car (Matthies et al., 2002). On the other hand, using a similar dataset, Patterson et al. (2005) also found that females were less likely to choose PT in suburban Montreal. There is also a line of reasoning that habit affects travel behaviour by making a choice action more or less automatic (Gärling and Axhausen, 2003). Since commuting by car is habitual in nature, a possible explanation for this observed behaviour may be that females are more reluctant to change this habitual behaviour compared to males. Since the observed behaviour implied that regional integrated ticketing has the potential to make PT more attractive to male commuters relative to female commuters, it is policy relevant as males tend to car commute more and on average commute longer distances than females in Sweden (Figure 6-2 and Figure 6-3).

Intuitively, and as confirmed by Johansson-Stenman (2002), the results further suggest that access to a company car for work trips affects mode choice behaviour. That is, people commuting with a car owned by their employer have the tendency to stick to commuting by car. A possible explanation of this behaviour is the fact that the marginal cost of using a company car to the individual is nearly zero. Again, this finding also suggests that integrated ticketing alone may not be policy effective in attracting car commuters with access to company car to PT, instead, it has to be combined with policy measures that are geared towards changing organisational transport policies to realise the desired mode shift.

6.5 Conclusions

In this study, the hypothesis that integrated ticketing is an important factor in explaining and predicting intercounty commuting mode choice was examined. A stated preference survey was conducted, and binary and mixed logits were estimated based on that survey data. The analysis focused on modelling and comparing the choice behaviour of people who commute by car between Stockholm and Uppsala given the introduction of integrated monthly tickets.

The findings suggest that integrated ticketing has a statistically significant positive effect on mode choice for commuting due to its synergistic effects of increased convenience, increased geographic accessibility, cost and time savings. Methodologically, as most mode choice analysis excludes the effects of integrated ticketing, this insight draws our attention to the importance of including the effects of planned integrated ticketing schemes in travel demand analysis to improve mode choice measurements, particularly at regional and national levels. In terms of policy, transport planners and policymakers can draw from this evidence when developing integrated transport policies as integrated ticketing makes commuting by PT more attractive to intercounty car commuters.

Since the study focused on two scenarios, integrated and unintegrated monthly tickets, it could not provide evidence on the marginal effects of the number of operators involved in a specific integrated ticketing scheme, further research hence is recommended on this.

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Part III: Final Discussions, Conclusions and Recommendations

Chapter 7
Final Discussions and Conclusions

7.1 Introduction

An effective and well-integrated public transport (PT) system that serves a substantial share of the travel market is vital for the future of sustainable mobility. Sustainable development and transportation systems are inherently linked and compared to the automobile, PT has generally been argued to have a more positive relationship with sustainability due to its significant economic, social and environmental contributions to society (Stjernborg and Mattisson, 2016; White, 2009; Kol-TRAST, 2012; FHWA, 2014; Miller et al., 2016; Enoch, 2012).

The market share of PT, largely determined by its service quality (SQ) and fare, is key to its sustainability benefits. Ticketing as a means of operationalising PT fare policy is a vital part of an effective PT system. It pervasively affects the quality of a PT system and consequently PT demand.

The ease of obtaining PT tickets or simply, access to tickets, which gives people the legal right and opportunity to use a PT service, is an integral part of the broader concept of accessible PT systems, which aims at enabling people to easily reach opportunities such as goods, services and destinations by PT.

Evidently, access to tickets is one of the most critical components of an attractive PT service since if the PT service is not reachable, then travel time, fare and other PT service quality dimensions would be meaningless for users. As summarised in Figure 1-1, there is evidence that PT ticketing has a pervasive effect on all the major elements a quality PT system such as accessibility, service frequency, user information needs, safety and security, convenience, travel time, reliability, aesthetics and fare. Consequently, PT ticketing and its improvements affect the goals of all major PT actors - passengers, Service providers (companies and regulatory bodies) and transport policymakers.

In this thesis, I have argued that PT ticketing is not an end in itself but a means of accessing the PT service. It thus reduces PT SQ and adds to the generalised cost of the PT service compared to, for instance, the private automobile.

Four perspectives emerged upon an extensive review of the current state of the knowledge in PT ticketing in section 1.4 - technological, policy, operational and behavioural perspectives. As justified in section 1.3., this doctoral research was motivated by the need for new empirical research on the user perspective of PT ticketing. More specifically, this study, characterised by five related research papers distinguished itself from prior studies on the subject by empirically investigating and improving our understanding on users' attitudes towards the PT ticketing system as well as their behavioural response to newer ticketing innovations such as integrated ticketing and seamless ticket inspection solutions. The five specific objectives that have been addressed are:

- To explore commuters' attitudes and perceptions to the PT ticketing system (fare collection and inspection)
- To explore users' possible response to newer innovations such as seamless ticket inspection solutions
- To estimate PT users' willingness-to-pay for multi-region and multi-operator integrated ticketing
- To measure the effect of integrated ticketing on mode choice for commuting
- To examine the impact of integrated ticketing on PT ridership, user satisfaction and the perceived quality of ticketing.

This final chapter is organised as follows. Section 7.2 discusses the findings of the research in relation to the above five research objectives and their implications for the actors of the PT ticketing system as well as some methodological reflections. Section 7.3 is dedicated to the final concluding remarks. Section 7.4 covers policy implication. Section 7.5 Presents the limitations of the work and, section 7.6 covers some recommendations for future work.

7.2 Final Discussion

Attitude is a major determinant of human behaviour according to the theory of planned behaviour (Ajzen, 1991). At the same time, the perceived quality of an attitude object (i.e. a PT ticketing system in the present research) is best conceptualised as an attitude (Cronin and Taylor (1992). This implies that attitudes, behaviour and perceived quality are related concepts that are central to the analysis of the behavioural perspective of PT ticketing and its improvements such as integrated ticketing and newer ticket innovations. Consequently, two theoretical frameworks, SERVPERF (Service Performance) and RUT (Random Utility Theory), based on attitudes and rational behaviour respectively, were modified and applied to address the research objectives.

The main findings and some methodological reflections of the research are discussed in this section from the broader theoretical and policy perspectives. Section 7.2.1 discusses users' attitudes to ticketing (i.e. research objectives 1 & 2). Section 7.2.2 covers integrated ticketing (i.e. research objectives 3, 4 & 5) and section 7.2.3 focuses on methodological reflections.

7.2.1 Understanding PT users' attitudes towards the PT ticketing system

The lack of knowledge of commuters' attitudes to the PT ticketing system and its improvements is one main weakness of the body of travel behaviour knowledge. Based on the conceptualisation of perceived quality as an attitude (Cronin and Taylor, 1992), attitudes towards ticketing and the perceived quality of ticketing systems were analysed in chapter two through to chapter four.

Explicitly, peoples' attitudes are heterogeneous based on many factors. Identifying factors that can influence users' attitudes and perceived quality (PQ) of the PT ticketing system is both theoretical and policy-relevant for understanding and improving users' ticketing needs. Hence, in chapter 2, nineteen factors were hypothesised to be sources of heterogeneity in commuter's attitudes towards ticketing.

The findings showed that PT commuters' attitudes to ticketing were influenced by four factors – their income, commuting route, ticket type and ticket purchase channel. A further 15 factors were tested but were found to be statistically insignificant. These four factors have also been confirmed by earlier research works to have an effect on some aspects of travel behaviour such as mode choice and attitudes (Buehler, 2011; Schwanen and Mokhtarian, 2005; Scheiner and Holz-Rau, 2013; Graham and Mulley, 2011; Allen et al., 2019) but not on users' attitudes to PT ticketing.

With regards to the commuter's attitudes towards ticketing systems, the results further indicated that the commuters somewhat accept ticketing in general. That is, in their evaluation of the attitude object under study, ticketing, the mean score for the overall ticketing system was 4.4 on a scale of 1 to 7. They however, evaluated fare payment and fare inspection differently. They accepted fare payment more than fare inspection. That is, the mean score for fare payment was 4.7 and that for fare inspection as neutral (i.e. a mean score of 4). While we are yet to find previous studies relating to attitudes to PT fare payment and inspection systems, this observed attitude of the commuters follows the utility maximisation behaviour of human beings. The reason being that ticket payment can be linked to the direct user benefit of getting access to the PT service. At the same time, there is no such direct user benefit in relation to ticket inspection, even though high fare evasion rates can potentially damage the PT SQ or even collapse PT services, particularly commercial PT services, due to lack of funding. Moreover, the commuters' evaluation suggests that PT users care about the quality of all aspects of the PT ticketing system, instead of just fares. Yet, the fare has until now been used by both researchers and practitioners to capture the effects of ticketing in the overall evaluation of quality of PT systems. The main policy implication of this current evidence is that service providers need to pay more attention to ticket inspection improvements as this is perceived as a disutility by users. That is, if we assume that a score of 7, the highest possible score on a scale of 1-7 represents the absence of disutility, then the difference in disutility between fare payment and fare verification with reference to this no disutility (7) is about 11 %.

In view of their attitudes towards current ticket inspection options, the results suggested that the commuters' attitudes were surprisingly slightly positive to automatic ticket inspection by turnstiles but react negatively to manual ticket inspection by staff. Similarly, with reference to the reference of no disutility in ticketing (i.e. 7), the disutility difference between automatic ticket inspection by turnstiles and manual ticket inspection by staff is about 21%. This was very surprising as ticket inspection by turnstiles is associated with issues such as barrier effects while ticket inspection by staff encourages staff presence, which has benefits such as enhanced security and easy access services such as travel information. This finding is similar to the case of

Madrid’s Metro system as PT users evaluated turnstiles more positively than the kindness of security staff (Allen et al., 2019).

These ticket inspection preferences were further examined in chapter 3, by extending the ticket inspection choice set in the follow-up survey to include a “seamless ticket inspection” option. Most of the respondents, particularly young people and females, showed a preference for this option over current options. As younger adults are more likely to use technology than older adults (Czaja et al., 2006), their choice for seamless ticket inspection was expected. It was, however, surprising that people of 55 years and above also preferred this option. This may however be due to their general need for convenience and calmness.

Given that more females patronise PT services than males in Sweden (Johansson-Stenman, 2002; Polk, 2004), the results imply that Sweden has good potential for further research and implementation of a “seamless ticket inspection”. Finally, the preference of the commuters for “seamless ticket inspection” over existing options generally points out the need for service providers, policymakers and researchers to re-think PT ticket inspection.

7.2.2 Understanding integrated ticketing

There is a general lack of practical evidence on the successes of integrated transport policies (Preston, 2012) and integrated ticketing in particular (PTEG, 2009). In chapter 4, the regional integrated ticketing scheme, Movingo (described in section 1.6), was evaluated with respect to its impacts on major transport policy goals in Sweden – increase ridership, user satisfaction and improved quality of ticketing. The findings, which are discussed below, serve as a good lesson for supporting policymakers’ decisions about future integrated ticketing investments.

The impact of integrated ticketing on ridership

From the ridership perspective, there was an overall increase of about 24% in ticket sales. This was despite limitations on access to the Movingo integrated ticket implied by it only being available from one operator (SJ), and not from any of the six participating PTAs.

The three possible sources of the increase in ticket sales following the implementation of the Movingo scheme are new commuters, some existing car and PT commuters. Unfortunately, with the current dataset, the present study cannot directly disaggregate the 24% increase in ticket sales into these three sources.

The proportion of the surveyed car commuters who reported that they began to patronise rail services along the studied corridor after implementing the Movingo scheme was about 9%. While the study lacks enough data to relate this 9% to the 24% increase in ticket sales, the findings suggest that the integrated ticket was effective in encouraging public transport use amongst car commuters along the corridor who lack free parking at work and access to a company car for trips to/from work, have no need to drive children to school on their way to work, have no need to use a car during work and whose perceived mean door-to-door travel time to or from work is not statistically different from that of PT commuters.

While the study reveals that car commuters of the above characteristics found PT attractive given multicounty integrated ticketing, it could not estimate the number of car commuters along the studied corridor that switched to Movingo. This is because of the lack of sufficient data on total number of commuters and their characteristics per travel mode between Stockholm county and Uppsala municipality. For example, Statistics Sweden reported that the total number of work-commuters between Stockholm county (all municipalities) and the Uppsala municipality is 23297 (SCB, 2018). Similar data for other trip purposes such as educational trips is, however, not currently available.

Similar ridership proportions concerning integrated ticketing were reported from different parts of the world (PTEG, 2009; Kamargianni et al., 2016). This provides further evidence to PT actors that integrated ticketing positively impacts ridership, which is usually a primary PT policy goal.

The impact of integrated ticketing on user satisfaction

User satisfaction is an essential gauge of perceived quality. The findings showed that 70% of the integrated season ticket users were satisfied. This finding is similar to that found in previous works. In the case of Rotterdam, the proportion of satisfied users was 5% higher compared to the Movingo case (Cheung, 2007). In the case of Greater Manchester, West Midlands and Bristol, 70% of satisfied users was anticipated by the UK Department for Transport (2010) and this is similar to the Movingo case.

Most of the users of Movingo ranked increased accessibility to a wide range of destinations, time savings and cost savings as the three top reasons for their choice of Movingo as a mobility tool. This confirms previous work highlighting the importance of these three factors (Balcombe et al., 2004;

Ortúzar and Willumsen, 2011) in travel demand analysis. Accessibility, which is one of the main dimensions of the Swedish national transport policy, may be argued to be the main purpose of travelling. Surprisingly, ticketing improvements are normally associated with convenience and comfort in both research and practice. This is not in agreement with the current evidence as fewer respondents rather associated their choice of integrated tickets with convenience and comfort.

Also, even though females generally tend to have higher trip chaining tendencies compared to males (Susilo et al., 2019), being a male commuter astonishingly increased the likelihood of being satisfied with integrated ticketing. This may be the case because even though high trip chaining may imply a high demand for integrated tickets, males tend to commute longer distances relative to females in Sweden (SCB, 2020a).

With regards to commuting frequency, people commuting five or more days per week were less likely to be satisfied with multicounty integrated ticketing relative to those commuting four or fewer days per week. This is likely to be the case because people who commute four or fewer days per week will generally have more time to make non-commuting trips such as recreational trips with their season tickets. Since users do not need to purchase separate tickets for their non-commuting trips, it is likely to increase their satisfaction with integrated ticketing.

Commuters who rarely or never use their integrated season tickets for non-commuting trips are less likely to be satisfied with multiple-county integrated ticketing compare to those who use them for non-commuting trips.

The majority (83%) of the 23% unsatisfied users were within this group, implying that this user group do not need integrated tickets as their origin-destination choices with Movingo were mainly limited to home-work and work-home. Yet, they were forced to choose Movingo as it was the only option for intercounty commuters within the corridor who wanted to continue patronising the services of the National Swedish Railways. This confirms the need for segmented tickets to meet the needs of all commuters and a good lesson for service providers and policymakers intending to implement integrated ticketing projects.

Intuitively, commuters advocating for free PT were found to be more likely to be satisfied with integrated ticketing relative to non- advocates of free PT.

This may be explained by the cost savings associated with integrated ticketing.

Previous works focused on the proportions of satisfied users given integrated ticketing rather than how this satisfaction is associated with user characteristics. This new knowledge on the different aspects of integrated ticketing that resulted in user satisfaction and, the satisfaction among different user categories will be useful for service providers, planners and policymakers when prioritising aspects of integrated ticketing schemes. That is, the results give more insight into user needs in multi-operator integrated ticketing that can be used for the purposes of market segmentation.

The impact of integrated ticketing on improving ticketing quality

As to the impact of integrated ticketing on the perceived quality of ticketing, for all respondents, no statistically significant differences were found in the mean scores of all the ticketing aspects that were evaluated. The same is true for the Movingo users except for the aspect of automatic fare verification by turnstiles. Its perceived quality decreased by about 7.5%, mainly due to poor interoperability as users of Movingo could not directly open the turnstiles in Stockholm with either their smart cards or mobile tickets. This interoperability problem was also evident in the SL/UL integrated season ticket project in 2013 and is still an issue, as a user of this ticket is still required to keep her receipt and show it together with the SL's access card to be able to use the PT system within Uppsala county. In the Netherlands, Cheung (2004) pointed out that the technical reliability of the Tripperpas smart card technology was relevant in winning user confidence. The policy relevance of this finding is that interoperability should be made an integral part of integrated ticketing schemes since a lack of interoperability tends to significantly undermine the purpose of the integration.

The monetary value of integrated ticketing

The impact evaluation of integrated ticketing schemes such as is presented in the previous sections, is central to demonstrating the independent impact of integrated ticketing and for supporting policymakers' decisions about future investments. Yet, there is a need for the economic evaluation of integrated ticketing schemes to provide information on the extent to which their benefits balance their investment cost. This means policymakers need knowledge on the monetary value that integrated ticketing has for users.

So, the value of integrated ticketing to PT users was examined in chapter 5, based on the Random Utility Theoretical framework (McFadden, 1980; McFadden, 1997, etc.).

The findings suggested that the mean WTP estimate for all the respondents was 507 SEK/Month. This is about 26% of the average integrated monthly ticket price. The travel time equivalence of this based on the Swedish value of time (Börjesson and Eliasson, 2012) is about 10 hours for short-distance commuting with bus or about 13 hours for long-distance bus trips for all purposes. With regards to both short-distance commuting by train and long-distance train trips for all purposes, it is about 7 hours. This implies that the mean estimate of the value of integrated ticketing is approximately equal to a travel time saving of 9 hours per month per user.

The mean WTP estimate for only commuters was 390 SEK/Month, that for only non-commuters was 554 SEK/Month, that for males was 465, and that for females was 231. That is, the mean WTP value for men was about 100% higher than that of women. This was expected and may be explained by the fact that as men generally have longer commuting distances than women (SCB, 2020a) and thus, have relatively more need for multi-county integrated ticketing. Also, men's distribution of WTP is more positively skewed, indicating that a relatively high proportion of men have higher WTP values than women. This may be because men generally have higher monthly income than women in the study area (SCB, 2020b) and, hence, are relatively less sensitive to cost on average. This gender difference in WTP for integrated ticketing was expected as women and men tend to have differential travel behaviour. In policy terms, the WTP values indicate that regional level integrated ticketing may be a good strategy for meeting the needs of both female and male long-distance-commuters. This implies that a regionally integrated system has good potential for supporting a pro-PT policy. This was evident in the increase in ticket sales after the implementation of Movingo.

Very surprisingly, non-commuters had a higher mean WTP value compared to commuters. This was least expected as it contradicts the PT planners and decisionmakers belief that frequent travellers have more need for interregional integrated ticketing; hence why the Movingo scheme was designed for this user group. This contradiction may arise if the commuters compared the cost of the monthly ticket price in the SP choice scenarios to the price of their current season tickets while the non-commuters compared it to the price of a single journey ticket, which is relatively expensive.

Considering income, the findings indicated that the mean WTP estimates are not linear among income groups. The lowest income group (gross monthly income 0-15000 SEK/month) and the highest income groups have about the same mean WTP value (i.e. 13% of the average 30-days integrated season ticket price). This was also surprising as the choice of rail for interregional trips tend to be associated with increasing income level. A possible clarification for this observed behaviour may be because most of the respondents in the lowest income group are young people with low income but a relatively high need for mobility and, the studied scheme does not just provide long-distance rail services between the counties but also bus, underground and light rail services within counties. Besides, most of the respondents in this group are possible captive users of PT and thus place a high value on the increased geographic accessibility offered by regional ticketing integration. This makes integrated ticketing policy attractive in increasing accessibility for this user group.

In terms of policy, the high WTP associated with the lowest income group indicates that interregional ticketing integration of subsidised PT services has a strong potential for improving regional accessibility and for reducing transport poverty particularly in relation to long-distance trips. Thus, in contrast to MaaS that currently offer services to people who can afford it (Pangbourne et al., 2020), integrated ticketing may be made part of policy interventions that focus on reducing transport poverty.

These findings provide new information to the PT industry and researchers for the economic evaluation of these schemes.

Integrated ticketing and modal split

The effect of integrated ticketing on modal split was analysed in chapter 6. The findings showed that the effect of integrated season tickets on mode choice is positive and statistically significant. That is, integrating season tickets increases the likelihood of choosing PT for commuting. Previous works also confirmed a positive relationship between car ownership and season ticket ownership (Chlond et al. 2014; Scott and Axhausen; 2006; Simma and Axhausen, 2010). However, in contrast to non-integrated season tickets, which has been the focus of previous works, integrated season tickets generally tend to offer more users benefits as it produces a combine positive effect on travel across different service providers and beyond city and regional boundaries such as increased convenience of travelling across service providers, increased geographic accessibility, cost savings and time savings, thereby making PT more attractive to cross-county car commuters by reducing the generalised travel cost for them (PTEG, 2009; White, 2009). These benefits include increased convenience of travelling across service providers, increased geographic accessibility, cost savings and time savings, thereby making PT attractive to cross-county car commuters by reducing the generalised travel cost for them (PTEG, 2009; White, 2009).

The findings showed that income, frequency of commuting by car, gender and access to a company car correlated with the mode choice. That is:

Commuters of the high-income category are less likely to shift to PT given integrated monthly tickets. Implying that integrated ticketing alone may not be policy effective in attracting car commuters in high-income class to PT, instead, it needs to be combined with other policy measures to achieve the desired mode shift.

Furthermore, more frequent car commuters are less likely to change to PT compare to less frequent car commuters considering the availability of integrated monthly tickets. This finding supports the line of argument that the habitual nature of a given behaviour, such as commuting by car, is an important determinant of actual behaviour (Gärling and Axhausen, 2003).

Besides, it was astonishing that female car commuters in the sample compared to males were less likely to switch to PT for commuting given integrated monthly tickets. This was unexpected as females in Sweden tend to patronise PT services more than males (Johansson-Stenman, 2002; Polk, 2004), and are also more willing to reduce the use of the car (Matthies et al., 2002). It could be that most women who can switch to PT have already done so, leading to a kind of diminishing marginal returns effect and hence, making it more difficult to further increase the proportion of women using PT. This observed behaviour implied that regional integrated ticketing has a potential for making PT more attractive to male commuters relative to female commuters, making it policy relevant as males tend to car commute more and on average commute longer distances than females in Sweden

Intuitively, and as confirmed by Johansson-Stenman (2002), people commuting with a car owned by their employer, have the tendency to stick to commuting by car. A possible explanation of this behaviour is the fact that the marginal cost of using a company car to the individual is nearly zero. Again, this finding also suggests that integrated ticketing may not be policy effective in attracting car commuters with access to a company car to PT. Instead, it has to be combined with policy measures that are geared towards changing organisational transport policies to realise the desired mode shift.

Integrated fare and ticket and the effect of location

Fare structure and ticketing are the two major elements of a PT fare policy. The spatial extent of a fare zone has effect on the correlation between fare and trip length. Fare structures are normally based on the same fare for all (flat fare, a constant amount of money regardless of the trip length) or differentiated fares based on journey charateristics or passenger segments. The later correlates with travel distance and may therefore be considered to be more cost-effective than flat fares, which induces fare inequities due to the lack of correlation between fare and trip length.

Differentiated fares are normally zonal or sectional based. Considering the level one of the five levels of integrated ticketing defined in section 1.2.2, an integrated ticketing scheme covers a whole city/county. This means that all the fare zones within a city/county collapse into one flat and integrated fare zone. In this case, people with high proportion of shorter trip lengths, for instance, integrated season users who live close to a Central Business District (CDB) and commute to the CBD, will generally pay more compared with people with longer trip lengths. In cases such as smaller cities, where travel distances are comparatively uniform, the convenience of a flat fare structure may compensate its fare inequities. However, the fare inequities overshadow the convenience of a flat fare structure in bigger cities where trip lengths vary considerably (Vuchic, 2005).

Consequently, the inequity associated with flat and integrated fare structures increases with increasing geographic coverage area (i.e. from level 1 to level 4). In the case of the Movingo integrated season ticket, which is a level 2 ticketing integration, many counties are involved, and the pricing strategy relates fares to travel distances by combining a zonal and sectional fare structure. That is, each county serves as a flat fare zone and the distance between the central stations of any two cities, mostly outside the same county, is combined with this zonal flat fare in pricing the service. The sectional component of the Movingo pricing strategy ensures, to a significant extent, price equity by capturing the variability of trip lengths between intercity nodes. Yet, the zonal component does not necessarily ensure fare equity given the relatively large sizes of the counties, with potentially non-uniform trip lengths.

One way of handling this fare equity issue in integrated ticketing schemes like Movingo could be to further divide each fare zone (i.e. county) into smaller zones. However, this could also negatively affect the convenience and simplicity offered by the simplified fare zone system. This implies that the policy objectives of a given integrated ticketing scheme determines it’s fare structure.

The Movingo commuter ticket and Covid-19 disruption

The Covid-19 pandemic is most likely to impact the demand for Movingo in its current form. The original design of the scheme may need to be changed after the pandemic as it has only three options - 30 days, 90 days and 365 days. This means that its success hovers around the proportion of frequent intercounty commuting trips within the Mälardalen region. Monthly seasons are the most popular type of tickets in Sweden and, the monthly option of Movingo has especially been successful in terms of patronage before the pandemic. Mobility has generally decreased significantly during the pandemic and, preliminary analysis of the post Covid-19 demand for PT suggested that about 70% of PT users will continue to use PT after the pandemic (SKT, 2020; Oliver Wyman; HSL, 2020). A recent study by Uppsala count authority confirms significant negative relationship between PT usage and telecommuting after the pandemic. That is, given that most people and firms have tested telecommuting, the frequency of PT usage is likely to decrease for some people compared to before the pandemic. With regards to the specific case of Movingo, this implies the need for more flexible tickets instead of the current three options. This lack of flexible tickets was the main reason why some users were unsatisfied with the Movingo scheme and needs to be reviewed by the implementing policy makers and practitioners. Suggesting that PT service providers generally need to make ticketing more flexible to accommodate the anticipated increase in telecommuting.

7.2.3 Methodological reflections

Whereas developing a new method was not part of the objectives addressed by this research, the research has some methodological implications and contributions. As covered in section 1.7, an interdisciplinary approach (economics and social psychology) and quantitative research methods were considered more useful and suitable for achieving the research objectives. More specifically, in response to the empirical nature of the research objectives, attitudinal and discrete choice modelling theoretical frameworks were used to guide the research design, data collection, analysis, interpretation of the findings and conclusions. My reflections on the applied theoretical framework, data collection and analysis methods are discussed below.

Given the PT ticketing system as the attitude object in chapter 2 through to 4, the SERVPERF theoretical model that conceptualises PQ as an attitude was used to both analyse the PQ of the ticketing system before and the implementation of the integrated ticketing scheme. While the SERVPERF theoretical framework is relatively simple, robust and cost-effective for analysing the quality of PT ticketing systems, it does not incorporate a means of analysing variability in PQ as a function of external variables such as socio-demographic, location, route, ticket type, travel frequency, service provider, access mode, ticket sales outlet, interpersonal factors such as shared tickets. Hence, by extending this model to a "PT ticketing system SERVPERF", to include the analysis of the sources of variability in the perceived quality of ticketing, the existing SERVPERF has been made more theoretically sound for understanding external factors that can affect the PQ of ticketing systems. The extended model thus provides a good framework for PT service providers not just to measure the PQ of ticketing systems but also to identify the main external influencing factors. A two-way ANOVA, together with a follow-up statistical test (the Tukey HSD -Tukey Honest Significant Differences, Post-hoc pair comparison), were used to test for variability among the different commuter segments' perceived quality of ticketing. While ANOVA is argued to be the most commonly quoted advanced research method in the professional business and economic literature (Aczel and Sounderpandian, 2006) and not new to the analysis of variance in travellers' attitudes and perceptions (Soltani et al., 2019; Beck and Rose, 2016; Dütschke et al., 2016; Fraszczyk and Mulley, 2017; Malhotra et al., 2017; Pantouvakis and Renzi, 2016; Pedersen and Friman, 2011), it only provided information on the factors that affected the attitudes of the surveyed respondents, but not the extent to which these factors affected the attitudes. The use of, for instance, linear regression, Structural equation modelling or similar could have enrich the results.

On the other hand, the RUT framework was modified for the analysis of commuters' behavioural response to integrated ticketing in chapter 5 and 6. This customised RUT framework provides a good theoretical framework for PT service providers and researchers to analyse integrated ticketing. That is, PT ticketing-related research works that have applied discrete choice analysis are largely based on the standard multinomial logit model (MNL), the most popular discrete choice model. Yet, the MNL is based on the I.I.D assumptions. That is, it has a restricted substitution pattern, does not allow for random taste variation and does not account for correlation in unobserved factors over time (Train, 2009). The Mixed Logit (ML) is a very flexible model that can approximate any random utility model (Train, 2009). It was uncommon to find previous works that applied the ML in PT ticketing analysis. The ML, which is the state-of-the-art analysis method in discrete choice modelling (Ortúzar and Willumsen, 2011; Henser et al., 2015), can handle all the limitations of the standard MNL model and was used to make the analysis more robust. It was used to analysed users' WTP for integrated ticketing as well as the association between integrated ticketing and mode choice for commuting. The ML model clearly outperformed the standard multinomial logit model (MNL) in both instances.

In terms of data collection, mixed survey methods, including an on-board survey with paper and pencil, an on-board survey with tablets, web and post-and-mail-back surveys methods, were used. A test on the effect of the survey response method on the variability of the attitudinal scores was statistically insignificant. Some observations were, however, made regarding the effectiveness of these survey methods in terms of cost, ease of application and response rate.

The web survey was the easiest and cheapest. It resulted in a response rate higher than that of the mail-back survey but very much less than that of the on-board paper-and-pencil survey. Even though the mail-back was the most expensive, it resulted in the lowest response rate. It was, however, the most appropriate and easy survey method for the car commuters as we had access to only their car registration numbers and the post addresses linked to these numbers. While the traditional paper-and-pencil survey was medium in terms of cost-effectiveness, it was the most effective on-board survey method as it produced the most positive effect on the response rate. The surveyors on-board the trains had a paper-and-pencil survey as well as five tablets for respondents who wished to answer the on-board survey online.

Most of the respondents preferred the paper-and-pencil options, and, this made the survey very effective as a broader range of respondents could be reached. At some point, no respondents were using the tablets to answer the survey partly due to poor internet connection. The surveyors were then instructed to keep the tablets aside and focused on the paper survey. In addition to increasing the response rate, this helped reduced fatigue on the surveyors as they no longer needed to worry about the possibility of a survey respondent exiting the train with a tablet. With the paper survey, respondents that were exiting the train left the pencil and answered paper on their seats for later collection by the respondents.

The data collected in the survey included attitudinal, RP, SP and background information. The existing literature comparing the relative strengths and weaknesses of RP and SP methods tend to be silent about the resource-effectiveness of these methods.

Intuitively, the design of the SP scenarios in this study took the most effort and time. Efficient SP design is argued to always outperform traditional orthogonal design, even if only the parameter signs are known or can be logically assumed (ChoiceMetrics, 2011). Both methods were tried in the PT commuters' survey and the orthogonal design was found to be more time-efficient and appropriate. This is because there was time limitation as the SP scenarios needed to be included in the first wave of the PT survey, before the launch of the Movingo scheme. On the other hand, the efficient design was relatively easy and did not demand as much time when applied in the car commuter SP survey as this survey was less complex.

As to data analysis methods, quantitative analyses methods such as ANOVA, One-way chi-square test, t-test and McNemar's test were used to analyse the attitudinal dataset, i.e. chapter 2 and 3. On the other hand, binary, multinomial, nested and mixed logit models were used to analyse the choice dataset. The application of these quantitative analysis methods was considered most appropriate and most useful in addressing the study objectives, by allowing the quantification and explanation of how the survey respondents behaved. This approach did not, however, provide a direct explanation of the survey respondents behaviour, for instance, why they hold the attitudes they held such as: why the respondents' attitude towards ticket payment was more favourable than that of ticket inspection, why most respondents prefer fare inspection by turnstiles over that by staff, why certain respondents groups choose seamless fare inspection over conventional fare inspection approaches, and why women car commuters are less likely to change travel mode to PT for commuting given integrated ticketing. A combination of these quantitative methods and qualitative methods such as in-depth interviews and focus discussion could help if these questions were part of the research questions.

The next section (7.3) presents the final conclusions of the thesis based on the above final discussions.

7.3 Final Conclusions

The PT ticketing system forms the interface between the user and the PT service making it an integral part of accessibility to the PT service and, subsequently, access to opportunities for many people. Interestingly, there is limited research on PT users' attitudes towards the PT ticketing system and on their behavioural response to improvements to the ticketing system such as integrated ticketing, which is a current PT policy focus area globally due to highly deregulated PT markets, multimodalism, fast urbanisation and regionalisation of PT systems. This doctoral research, characterised by five related research papers, was undertaken with the overall aim of advancing understanding of users' attitudes to PT fare payment and inspection as well as their behavioural response to multi-regional integrated ticketing.

Two existing theoretical frameworks, SERVPERF and RUT, were modified in the light of this research aim. Then, using the Movingo multi-region and multi-operator integrated ticketing scheme in Sweden as a case study, I designed and conducted three travel surveys along the corridor with the largest proportion of cross-county commuting in Sweden, Stockholm – Uppsala.

Subsequently, the samples were analysed using inferential statistical methods including two-way ANOVA, One-way chi-square test, t-test, correlated t-test and McNemar's test as well as discrete choice modelling methods including binary, multinomial, nested and mixed logit models.

The following conclusions have been drawn based on the main findings of the research:

Attitudes towards the PT ticketing system

The extension of SERVPERF to "PT Ticketing system SERVPERF" in the analysis of commuters' PQ of ticketing demonstrates that the modified framework provides an easy-to-apply framework to service providers and other stakeholders for evaluating the PQ of PT ticketing systems.

PT commuters on average accept ticketing. That is, the mean score of their evaluation of ticketing in general was 4.4 on a scale of 1 to 7. However, they evaluated ticket payment more positively than ticket inspection, confirming our hypothesis that users care about the quality of all aspects of the PT ticketing system, instead of just fares. Interestingly, PT fare is commonly used by both researchers and policymakers to represent the effects of ticketing when evaluating the overall quality of PT systems. The main policy implication of this is that service providers need to pay more attention to ticketing aspects during the analysis of PT quality. Ticket inspection needs particular attention as it is perceived as the most disutility aspect of ticketing by the commuters.

User' attitudes to ticketing were generally affected by income, commuting route/location, ticket type and ticket purchase channel, implying that these are relevant variables to be considered by service providers, policymakers and researchers when evaluating the quality of ticketing systems.

Response to newer ticket inspection innovations

Fare inspection has a high perceived disutility than fare payment to users. Most of the commuters prefer automatic ticket inspection to that by staff and digitally automated ticket inspection (seamless ticket inspection) to mechanically automated (turnstiles). This suggests a policy direction for improving fare verification. As PT systems are increasingly being automated, a smarter fare verification approach, where fare verification is done passively without the active participation of the user, maybe a suitable future option for reducing the burden of fare verification on commuters and service providers. With regards to policy, users' preference for ticket inspection alternatives correlates with their socio-economic characteristics. Suggesting that as PT users generally have the freedom to choose how to purchase their tickets, most of them will embrace the freedom to choose how their tickets should be inspected. This means a need for service providers, policymakers and researchers to rethink how ticket inspection is currently undertaken.

Impact of integrated ticketing on PT ridership

Integrated ticketing increases PT ridership. The Movingo integrated scheme, which was the case study in this research, was largely successful in terms of increased ridership as ticket sales went up by 24%. Increase in ridership is usually a primary PT policy goal. This, thus practical evidence to PT actors intending to implement in integrated ticketing.

Impact of integrated ticketing on user satisfaction

Integrated ticketing generally has positive impact on user satisfaction. About 70% of Movingo users are satisfied mainly due to increased geographic accessibility, cost savings and time savings. Being a male commuter, or a commuter who uses an integrated season ticket for non-commuting trips or an advocate for PT to be made free have positive effects on satisfaction with multicounty integrated ticketing. This new knowledge on the aspects of integrated ticketing that users found to be more satisfying and, the satisfaction among different user categories is useful for service providers, planners and policymakers in understanding the needs of different user groups and in prioritising integrated ticketing aspects when planning these schemes.

Impacts of integrated ticketing on the quality of ticketing

Integrated ticketing potentially increases the perceived quality of ticketing. Yet, the overall perceived quality of the studies ticketing system did not improve after the ticketing integration. This was mainly due to interoperability issues such as the inability of users to open turnstiles with smart cards or mobile tickets, suggesting that complete integration of all relevant aspects of ticketing is crucial for realising the full benefits of integrated ticketing schemes.

Also, service providers' uncertainty about equity in revenue distribution among the participating organisations and the lack of interest among most of the participating agencies to sell Movingo tickets were significant challenges that policymakers can learn from. To solve these issues, the development of a transparent and acceptable revenue sharing formula as well as a requirement for all participating agencies to promote and sell the integrated tickets should be made part of the collaboration conditions in integrated ticketing schemes.

Willingness-to-pay for integrated ticketing

There is a positive relationship between WTP and integrated ticketing. The application of the modified RUT framework in analysing users' behavioural response to integrated ticketing showed strong evidence of users WTP for regional ticketing integration.

Users' valuation of the integration is at least 10% of the average integrated monthly ticket price. Due to the pervasive and synergistic nature of integrated ticketing, users valued it higher than travel time savings, cost savings and high service frequency. While this finding may be associated with the characteristics of the case study, it is plausible to expect that an integrated platform will provide a higher value to users than its individual service attributes. This implies that integrated ticketing can be considered as a multipurpose policy intervention strategy for policymakers seeking to improve seamless mobility across PT operators in deregulated PT markets.

The integration of subsidised transport services reduced transport poverty. Passengers belonging to the lowest income group have the highest mean WTP value for a multi-county integrated ticketing system, suggesting that integrated ticketing has strong potential for improving accessibility and reducing transport poverty particularly in relation to long-distance trips.

There significant heterogeneity in the WTP for integrated ticketing. Commuters differ less in their preference for integrated ticketing compared to non-commuters. Yet, non-commuters' mean WTP is about 3% higher than that of commuters. The policy implication of this is that interregional integrated ticketing platforms will achieve higher impacts if they are designed to meet the needs of both frequent and non-frequent travellers.

Women have a higher mean WTP value and showed less variability in their WTP compared to men. Yet, a higher proportion of men are willing to pay over 50% of the average integrated season ticket price for the benefits of an intercounty integrated ticketing system. This gender difference in WPT for integrated ticketing confirms differential travel needs among women and men and, intercounty integrated ticketing could thus be made part of policy measures that focus on addressing gender disparities in long-distance commuting and increasing PT patronage.

In terms of the wider policy implications, the findings provide a quantitative summary of our knowledge of the marginal effect of multi-county integrated ticketing and the resulting range of WTP values could be used as a starting point in cost-benefit-analysis to infer policy conclusions about the value of interregional integrated ticketing for users and society.

Effect of integrated ticketing on mode choice

The finding supports the Public Transport Executive Group of UK speculation that integrated ticketing increases the attractiveness of PT for car users. The application of the modified RUT framework in analysing users mode choice given integrated ticketing indicates that the integration of season tickets increases the likelihood of choosing PT for commuting due to its synergistic effects of increased convenience, increased geographic accessibility, cost and time savings.

Methodologically, as most mode choice analysis currently excludes the effects of integrated ticketing, this insight draws our attention to the importance of including the effects of planned integrated ticketing schemes in travel demand analysis to improve mode choice measurements, particularly at regional and national levels. In terms of policy, transport planners and policymakers can draw from this evidence when developing integrated transport policies as integrated ticketing makes commuting by PT more attractive to intercounty car commuters.

The applied methodology

It was novel to modify two well-established theoretical frameworks for the analysis of PT ticketing and the application the state-of-art mixed logit model, thereby making a methodological contribution in the application of the service quality theoretical framework and discrete choice analysis framework in PT ticketing studies.

Traditional paper-and-pencil survey was the most effective on-board survey approach compared to that of web with the help of tablets and mail-back surveys.

The expected effect of the Covid-19 disruption on the Movingo scheme

Service providers need to make PT ticking more flexible to accommodate the increase in telecommuting due to Covid-19. The Movingo scheme targets frequent passengers in the Mälardalen region by limiting its ticket options to 30 days, 90 days and 365 days season tickets. However, telecommuting is likely to increase after the Covid-19 pandemic, at least in the short term, meaning a reduction in commuting frequency for some people. Hence, to maintain the attractiveness of Movingo, its ticket choice set needs to be extended to include more flexible tickets. This evidence generally implied that PT service providers need to make ticking more flexible to accommodate the increase in telecommuting due to Covid-19.

7.4 Policy Implications

PT is a strategic sustainable transport tool for improving mobility and accessibility. PT ticketing system improvements, which aim at enhancing PT accessibility and user convenience is thus, a significant transport policy focus area for governments, service providers and other stakeholders. A substantial challenge for PT policymakers is obtaining better insight into user needs. The findings of this research can help these PT players understand and meet PT users' ticketing needs. The broader policy context of the thesis is informed by:

- The participating service providers' goals on increased PT usage, improved user satisfaction, increased accessibility and attractiveness or quality of the PT service.
- The national Swedish transport policy goals on accessibility
- Nationwide integrated ticketing system

The benefits of improved PT ticketing contribute to achieving these local and national policy goals. Consequently, the following policy implications are inferred from the findings and conclusions of this thesis.

The policy implication of the evidence on attitudes to the PT ticketing system
In policy terms, the differences in the commuters' evaluation of fare payment generally call for a balance in PT ticketing system development policies to reduce the perceived disutility of ticket inspection. PT commuters perceived disutility of fare inspection is 29 % higher than that of fare payment, suggesting a policy direction for improving the PT ticketing system as current PT ticketing development policies tend to focus more on fare payment improvements compared to fare inspection improvements.

Furthermore, the commuters preference for digital ticket inspection prompts the need for a paradigm shift in PT ticketing system development policies from conventional ticket inspection to seamless ticket inspection. Most of the commuters prefer automatic ticket inspection to that by staff and then, followed by digitally automated or seamless ticket inspection to mechanically automated or turnstiles. Such a solution would have been timely in the currently Covid-19 pandemic situation where distancing restrictions have made ticket inspection via direct contact with passengers almost impossible. This, for instance, in the case of the Stockholm and Uppsala county PTAs, is negatively impacting service providers revenue generation as PT ridership is gradually increasing after a massive decline due to the pandemic, without a corresponding increase in revenue.

Also, as highlighted in chapter 3 (section 3.1), conventional ticket inspection has many disadvantages that a shift to a seamless fare inspection policy can help improve.

The policy implication of the evidence on integrated ticketing

The following paragraphs summarise the policy implications of the findings on integrated ticketing, focusing on five areas - PT ridership, user satisfaction and perceived quality of ticketing; WTP for integrated ticketing; mode choice and integrated ticketing; Movingo and user needs; and Movingo and the Covid-19 disruption.

Firstly, the policy implication of the results relating to the integrated ticketing aspects that generated positive effects on PT ridership and user satisfaction is that it provides planners and policymakers with essential knowledge for prioritising integrated ticketing aspects based on user group needs. Besides ridership and user satisfaction, integrating ticketing is expected to improve ticketing quality. However, this is not often the case, as evidenced in this study due to interoperability issues. Cheung (2004) pointed out a similar challenge in the Netherlands. In policy terms, this finding is timely as the Swedish government is investigating the feasibility and benefits of a country-wide smart and integrated ticketing scheme. It is therefore recommended that technical reliability is included as one of the objectives of the proposed nationwide scheme to increase the perceived quality of the current ticketing system.

Secondly, the estimates of WTP for integrated ticketing in chapter 5 provide timely and novel evidence that policymakers and planners can draw from with regards to different user groups' WTP and the potential that integrated ticketing may have in reducing transport poverty by improving accessibility and user convenience. Besides, as CBA is widely applied for analysing transport investments in Sweden and elsewhere, the WTP values can be used as a basis for further analysis on PT users' WTP for the proposed national integrated ticketing scheme.

Thirdly, the policy implication of the evidence on the relationship between mode choice and integrated ticketing presented in chapter 6 calls for the need for transport planners and policymakers to include integrated ticketing as a potential determinant of mode choice in travel demand forecasting and analysis. Mode choice may be argued to be the most important component of transport planning and policymaking. The results showed that integrated ticketing has a positive effect on mode choice for commuting. Yet, its impact on mode choice is not often included in mode choice models. Overlooking this may lead to the underestimation of PT demand in travel demand forecasting and, consequently, underestimating the resulting implications for travel demand such as congestion, emissions and poor accessibility.

Fourthly, there is a policy lesson to be drawn (by service providers and policymakers intending to implement integrated ticketing projects) from the finding that commuters who rarely or never use their integrated season tickets for non-commuting trips, but who had only Movingo as the only available commuting ticket, were less satisfied with the Movingo scheme. It also prompts the need to segment the Movingo ticket to meet user needs effectively.

Finally, a policy change that makes the Movingo ticket more flexible is required to enable the service providers to properly manage the increase in telecommuting that is expected after the Covid-19 disruption.

7.5 Limitations of the Research

While the research unearthed some new facts and perspectives about the PT ticketing system, understanding PT users and attitudes and behavioural response to ticketing and its improvements, as discussed in section 1.6, covers a wide field. Consequently, this study has been scoped from five main dimensions: geographic or spatial coverage, handling of time (or temporal variations), unit of analysis, behavioural responses (or social), and finally, the level and extent of integrated ticketing. This scoping imposes the following limitations in terms of the generalisability of the findings:

- Even though it improves our understanding of users' attitudes to the PT ticketing system, the study focused on commuters with a daily commuting time of more than one hour. This means that since the ticketing needs of noncommuters may differ from that of these commuters, the findings cannot, therefore, be used to infer the general attitude of PT users to the PT ticketing system.
- While the findings on seamless ticketing provide a novel perspective for improving PT ticket inspection, it is based on a corridor and, it is

uncertain if the findings will remain stable when extended to a broader geographic setting and broader user group.

- The derived WTP values are based on inter-county integrated ticketing, reflecting regional PT characteristics. It may thus need some scaling to make the results transferable to city, county, nation, or international levels of integrated ticketing. Besides this spatial limitation, the WTP analysis focused on individual users. Yet, some firms and organisations patronise integrated season tickets, and their WTP values may differ from that of the individual.
- The primary forms of integrated mobility platforms are the integration of conventional PT services and Mobility-as-a-service (MaaS) that include more personalised services and travel modes such as car rental, car sharing, taxi and bicycles. The focus of the thesis was the integration of conventional PT services, and hence, the analysis of the behavioural response to integrated ticketing cannot be directly generalised to the MaaS model.
- Whereas the analysis of the effect of integrated ticketing on mode choice surely provided empirical evidence on the need to include the effects of integrated ticketing in travel demand modelling and forecasting, it aggregately considered the impact of integrated and unintegrated ticketing on mode choice. This implies that the study is limited in providing evidence on the marginal effect of the number of operators involved in a specific integrated ticketing scheme on mode choice.
- Even though the application of only quantitative analysis methods was appropriate for addressing the research objectives, it could not provide a direct explanation for the respondents' behaviours and attitudes, such as: why their attitude towards ticket payment was more positive than that of ticket inspection, why most respondents prefer fare inspection by turnstiles over that by staff, why certain respondents groups choose seamless fare inspection over conventional fare inspection approaches, etc.

7.6 Recommendations for Future Work

On the basis of the limitations discussed in section 7.5, the research envisaged the need for further study in the following areas:

- The analysis of users attitudes PT ticketing needs to be extended to a wider area and wider PT users. That is, further research on how non-commuters react to fare collection and verification is recommended. A national or international survey will provide more rich evidence on PT users attitudes to the PT ticketing system
- Given that the study focused on a corridor, it is recommended that the analysis of users' response to seamless ticket inspection be extended to a broader area and broader PT users for further validation of the findings.
- Since "seamless ticket inspection" is still hypothetical, research on its technical feasibility would be central to its implementation.
- Aggressive behaviour towards ticket inspectors by fare evaders has been reported in previous works and, this study thus sees the need for research on the potential for seamless ticket inspection to reduce or prevent hostilities between users and ticket inspectors.
- Since the frequency of encounter with ticket inspectors is a potential source of disturbance for PT users, knowledge on the acceptable number of ticket inspections users expect per trip or per time interval such per day, will help service providers in making their ticket inspection operations more convenient for users.
- Developing a transparent and effective method for optimal distribution of revenue among participating PTAs in integrated ticketing could reduce or eliminate PTAs' uncertainty about equity in revenue distribution, hence, making integrated ticketing attractive to service providers.
- Due to the lack of a framework for the systematic evaluation of integrated ticketing schemes, a standardised evaluation framework for these schemes is a potential research area.
- Further studies are needed in deriving the WTP values for integrated ticketing at city, county and nationwide levels.
- It will be relevant to examine the WTP values for a multi-region integrated ticketing system for businesses and organisations that patronise integrated tickets.
- As the MaaS model is gradually gaining acceptance at least in urban mobility, it will be policy-relevant to examine users' WTP for a regionally integrated ticketing system where many service providers (PT operators and so-called mobility operators) work together under the Mobility as a Service (MaaS) model.

- Further research is recommended on the marginal effect of the number of operators involved in a specific integrated ticketing scheme on mode choice. Making this knowledge available to policymakers will help them in making decisions about the optimal number of service providers that may go into an integrated ticketing scheme.
- Finally, there is the need to understand a bit more about what drives people's attitudes using qualitative methods such as in-depth interviews and focus discussion. This may help provide a more direct explanation to the respondents behaviours and attitudes to the PT ticketing system such as: why their attitude towards ticket payment was more positive than that of ticket inspection, why most respondents prefer fare inspection by turnstiles over that by staff, why certain respondents groups choose seamless fare inspection over conventional fare inspection approaches, etc.

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Appendix A
Survey Questionnaires

A.1 Rail Commuter Survey

Public Transport Ticketing Survey

Dear citizen/traveller,

Public transport service providers in the Mälardalen region are making effort to ease your commuting via integrated ticketing under the name **MOVINGO** (www.movingo.se). MOVINGO is a season ticket that gives a passenger access to all local and regional public transport lines within the region.

I work for the Uppsala County Public Transport Authority and this survey is part of my doctoral research at the university of Leeds in collaboration with the Royal Institute of Technology and the Public Transport Authorities in Mälardalen region. The survey takes about 15 min to answer.

Please note that all data collected will be held anonymously and no personal data is retained.

How to answer the survey

*You may complete the questionnaire and return directly to us or complete it online using the link: **https://leeds.onlinesurveys.ac.uk/movingo1**. You may also take it with you, complete it at your convenience and then post it back to us using the attached paid-reply envelope within one week but latest 10th October.*

Prize draw for monthly ticket and lunch coupon.

To thank you for your involvement, all respondents who complete the survey can entre into a prize draw to either win a free one month Movingo ticket, a free one-month SL/UL ticket or one free lunch coupon.

Winners of the prize draw will be notified by Friday 29th October 2017 and published on Movingo's website (www.movingo.se).

If you have further questions or if you would like to get a copy of the report of the survey results, please contact:

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Please proceed to complete the survey.

Thank you for your cooperation.

Part A: About your travel

1. Which of these applies to you now?
   Employed: ☐ Full-time, ☐ Part-time,
   Self-employed: ☐ Full-time, ☐ Part-time,
   Student: ☐ Full-time, ☐ Part-time,
   Other: ☐ If Other, *please go to part C (Page 6)*

2. How many days in a week, do you **usually** take a *commuter train* to and from work or school?
   ☐5 or more days a week, ☐3-4 days a week, ☐1-2 days a week,
   ☐Rarely, ☐Never, *If Never, please go to part C (Page 6)*

3. How many days in a week, do you **usually** *travel by car* to and from work or school?
   ☐5 or more days a week, ☐3-4 days a week, ☐1-2 days a week,
   ☐Rarely, ☐Never.

4. How **long** have you been taking the commuter train to and from work or school?
   ☐Less than one year, ☐1-2 years, ☐3-4 years, ☐5 or more years.

5. I **usually** go *from home* to the commuter train station by:
   ☐Walk, ☐Bike, ☐Bus, ☐Subway,
   ☐Commuter train, ☐Tram ☐Car, ☐Other.

6. I **usually** go from my *work place or school* to the commuter train station in my trip back home by:
   ☐Walk, ☐Bike, ☐Bus, ☐Subway,
   ☐Commuter train, ☐Tram ☐Car, ☐Other.

7. My **typical travel time** *from my home* to work or school is _______ minutes.

8. My **typical travel time** *from work or school* back to my home is ________ minutes.

9. In addition to my work or school trips, I use my season ticket for **other visits**:
   ☐5 times a week or more, ☐3-4 times a week, ☐1-2 times a week,
   ☐Rarely, ☐Never, ☐ I do not have season ticket.

10. I received **tax reduction** for my travels to and from work in my last tax declaration:
    ☐Yes, ☐No.

11. My employer pays for my **travel cost** to and from work: ☐Fully, ☐Partly, ☐No.

Please you have finished part A. Thank you! Go to part B (Below).

Part B: About your future Public Transport ticket choice

Below are **ten (10) monthly ticket scenarios** with the purpose of analysing your preferences in the choice of season ticket and travel mode. Choose only one alternative in each scenario by ticking it.

1. I travel **more often** between **Stockholm and Uppsala:** ☐Yes, if Yes – *please go to Section 1 (below);* if No – *please go to part C (p. 6)*

Section 1: Stockholm Central ↔ Uppsala Central

Note: ***Alternative A*** is the train that stands at all stations along the corridor and ***Alternative B*** is the train that stands at a few stations. ***Alternative C*** gives you access to both ***Alternative A*** and ***Alternative B***.

1.

Scenario 1	Alternative A	Alternative B	Alternative C
In-train-time	55 min	40 min	40 min
Train departs every	15 min	30 min	15 min
Monthly ticket price (SEK)	1600	2170	2300
Monthly ticket is valid for	All SL & UL lines	All SL & UL lines	All SL & UL lines
In this scenario, I will choose (please tick one):	**[ ]**	**[ ]**	**[ ]**

2.

Scenario 2	Alternative A	Alternative B	Alternative C
In-train-time	50 min	45 min	40 min
Train departs every	30 min	60 min	10 min
Monthly ticket price (SEK)	1600	2170	2200
Monthly ticket is valid for	Only regional train (SJ) Stockholm ↔ Uppsala	Only regional train (SJ) Stockholm ↔ Uppsala	Only regional train (SJ) Stockholm ↔ Uppsala
In this scenario, I will choose (please tick one):	**[ ]**	**[ ]**	**[ ]**

3.

Scenario 3	Alternative A	Alternative B	Alternative C
In-train-time	55 min	45 min	50 min
Train departs every	15 min	30 min	15 min
Monthly ticket price (SEK)	1530	2170	2200
Monthly ticket is valid for	All SL & UL lines	Only regional train (SJ) Stockholm ↔ Uppsala	Only regional train (SJ) Stockholm ↔ Uppsala
In this scenario, I will choose (please tick one):	[ ]	[ ]	[ ]

4.

Scenario 4	Alternative A	Alternative B	Alternative C
In-train-time	50 min	45 min	50 min
Train departs every	15 min	60 min	15 min
Monthly ticket price (SEK)	1600	2070	2300
Monthly ticket is valid for	All SL & UL lines + Regional train (SJ) Stockholm ↔ Uppsala	All SL & UL lines + Regional train (SJ) Stockholm ↔ Uppsala	All SL & UL lines + Regional train (SJ) Stockholm ↔ Uppsala
In this scenario, I will choose (please tick one):	[ ]	[ ]	[ ]

5.

Scenario 5	Alternative A	Alternative B	Alternative C
In-train-time	50 min	40 min	50 min
Train departs every	30 min	60 min	10 min
Monthly ticket price (SEK)	1600	2170	2300
Monthly ticket is valid for	All SL & UL lines + Regional train (SJ) Stockholm ↔ Uppsala	Only regional train (SJ) Stockholm ↔ Uppsala	Only regional train (SJ) Stockholm ↔ Uppsala
In this scenario, I will choose (please tick one):	[ ]	[ ]	[ ]

6.

Scenario 6	Alternative A	Alternative B	Alternative C
In-train-time	55 min	45 min	50 min
Train departs every	15 min	60 min	10 min
Monthly ticket price (SEK)	1600	2170	2300
Monthly ticket is valid for	Only regional train (SJ) Stockholm ↔ Uppsala	All SL & UL lines	All SL & UL lines
In this scenario, I will choose (please tick one):	[ ]	[ ]	[ ]

7.

Scenario 7	Alternative A	Alternative B	Alternative C
In-train-time	50 min	40 min	40 min
Train departs every	15 min	60 min	15 min
Monthly ticket price (SEK)	1600	2170	2200
Monthly ticket is valid for	All SL & UL lines + Regional train (SJ) Stockholm ↔ Uppsala	Only regional train (SJ) Stockholm ↔ Uppsala	All SL & UL lines + Regional train (SJ) Stockholm ↔ Uppsala
In this scenario, I will choose (please tick one):	[ ]	[ ]	[ ]

8.

Scenario 8	Alternative A	Alternative B	Alternative C
In-train-time	55 min	40 min	40 min
Train departs every	30 min	30 min	15 min
Monthly ticket price (SEK)	1600	2070	2200
Monthly ticket is valid for	All SL & UL lines	All SL & UL lines	Only regional train (SJ) Stockholm ↔ Uppsala
In this scenario, I will choose (please tick one):	[ ]	[ ]	[ ]

9.

Scenario 9	Alternative A	Alternative B	Alternative C
In-train-time	55 min	45 min	40 min
Train departs every	30 min	30 min	10 min
Monthly ticket price (SEK)	1530	2070	2200
Monthly ticket is valid for	Only regional train (SJ) Stockholm ↔ Uppsala	Only regional train (SJ) Stockholm ↔ Uppsala	All SL & UL lines + Regional train (SJ) Stockholm ↔ Uppsala
In this scenario, I will choose (please tick one):	[ ]	[ ]	[ ]

10.

Scenario 10	Alternative A	Alternative B	Alternative C
In-train-time	55 min	45 min	50 min
Train departs every	30 min	60 min	10 min
Monthly ticket price (SEK)	1530	2 170	2200
Monthly ticket is valid for	All SL & UL lines	Only regional train (SJ) Stockholm ↔ Uppsala	Only regional train (SJ) Stockholm ↔ Uppsala
In this scenario, I will choose (please tick one):	[ ]	[ ]	[ ]

Please you have finished part B. Thank you! Go to part C (Page 6)

Part C: About your current Public Transport ticket

This part aims at identifying the aspects of ticketing that passengers wish to be improved.

1. I **most often** travel with a ticket valid for:
   ☐SL only, ☐UL only, ☐combined SL/UL, ☐SJ only, ☐TiM, ☐Other

2. I **most often** use: ☐30 days ticket, ☐90 days ticket, ☐One year's ticket, ☐Other, please specify ________________

3. I **most often** buy my season ticket:
   ☐From service provider offices, ☐From sales agent, ☐On the internet, ☐On a mobile phone, ☐From a vending machine, ☐On-board, ☐Other channels, please specify _____________

4. How **important** are the following aspects of Public Transport ticketing to you?
   (*Please circle your response as appropriate)*

	Not important 1	*Slightly important 2*	*Fairly important 3*	*Important 4*	*Very important 5*
Easy to buy or top up ticket	1	2	3	4	5
Easy to use ticket	1	2	3	4	5
Fast to buy or top up ticket	1	2	3	4	5
Flexible to buy or top up ticket (anytime and anywhere)	1	2	3	4	5
Possible to use one ticket on lines operated by different operators	1	2	3	4	5
Possible to pay by cash on-board	1	2	3	4	5
Possible to pay with bank card on-board	1	2	3	4	5
Safe and secured to buy or top up ticket	1	2	3	4	5
Possible to recover lost ticket	1	2	3	4	5
Ticket checking by staff	1	2	3	4	5
Ticket checking by turnstiles	1	2	3	4	5

5. Please circle the response that best describes how you feel about the statement.
1 means that you **Strongly Disagree** and 7 means that you **Strongly Agree**.

	Strongly Disagree → *Strongly Agree*						
It is **convenient** for me to use my ticket	1	2	3	4	5	6	7
It is **easy** to get information about available ticket types	1	2	3	4	5	6	7
The time it takes to buy or top up ticket is **acceptable**	1	2	3	4	5	6	7
I consider it **easy** buying or toping up my ticket	1	2	3	4	5	6	7
It is fine with me that I **cannot buy** ticket on the train	1	2	3	4	5	6	7
It is fine with me that I **cannot buy** ticket on the bus	1	2	3	4	5	6	7
Using a ticket vending machine is often **easy** for me	1	2	3	4	5	6	7
I have the **flexibility** to buy or top up my ticket at any time and any where	1	2	3	4	5	6	7
It is **easy** for me to retrieve my lost ticket without extra cost	1	2	3	4	5	6	7
I find **ticket control** by staff on train disturbing	1	2	3	4	5	6	7
It is **disturbing** for me to have my ticket checked by bus driver	1	2	3	4	5	6	7
It is **smooth** for me to pass through turnstiles	1	2	3	4	5	6	7
It is **smooth** for me to pass through turnstiles when I am having luggage, pram, wheelchair or rollator	1	2	3	4	5	6	7
I do feel **safe and secured** when passing through turnstiles	1	2	3	4	5	6	7
I prefer **ticket checking** by staff to that by turnstiles	1	2	3	4	5	6	7
Congestion at turnstiles during certain periods of the day is **acceptable**	1	2	3	4	5	6	7
Delays at turnstiles during certain periods of the day are **acceptable**	1	2	3	4	5	6	7
I would like to have my season ticket on mobile application	1	2	3	4	5	6	7

Please you have finished part C. Thank you! Go to part D (Last page)

Part D: About you

Please which of these **best** describe you? *(Tick only one option in each question)*

1. What gender are you please? By gender we mean gender identity, the gender that you feel you are. ☐Female, ☐Male, ☐Other,

2. Please indicate your age group:
   ☐16 – 24 years, ☐25 – 34 years, ☐35 – 44 years,
   ☐45 – 54 years, ☐55 – 64 years, ☐65 and over.

3. Please indicate the highest level of education you completed:
   ☐ Under high school, ☐ High school graduate, ☐University less than 3 years,
   ☐ University 3 or more years, ☐ Other.

4. Please give a range for your monthly income before tax (in Swedish Crowns, SEK):
   ☐0 – 10 000, ☐10 001 – 15 000, ☐15 001 – 20 000,
   ☐20 001 – 25 000, ☐25 001 – 30 000, ☐30 001 – 35 000,
   ☐35 001 – 50 000, ☐Over 50 000 ☐ Do not want to give.

5. My home is located at: Post code, _______________

6. I work or study at (Please answer one or both):
   ☐Post code, ______________
   ☐Street address and area name, ____

Please state any other comment (s) you wish to make below:

____

____

____

Please participate in a follow-up-survey in a year's time. ☐Participate.

If you wish to take part in the prize draw please provide your contact information below. All contact information will be treated as confidential. They will only be used for the prize draw.

Name:____

Telephone Number:__________________________________

Email address:______________________________________

Please write todays date here ____________/____________/____________

THE END!

Thank you for completing this questionnaire. Your effort means a lot to us!

Please contact us if you would like to get a copy of the report of the survey results:
ilyas.alhassan@ul.se

A.2 Car Commuter Survey

Commuting Survey

Dear citizen/traveller,

Public transport service providers in the Mälardalen region are making effort to ease your commuting via integrated ticketing under the name **MOVINGO** (www.movingo.se). MOVINGO is a season ticket that gives a passenger access to all local and regional public transport lines within the region.

I work for the Uppsala County Public Transport Authority and this survey is part of my doctoral research at the university of Leeds in collaboration with the Royal Institute of Technology and the Public Transport Authorities in Mälardalen region. The survey takes about 10 min to answer.

Please note that you have been randomly select along the Stockholm - Uppsala section of the E4 motorway to take part in this survey. Your address was extracted from the Swedish car registry. All data collected will be held anonymously and no personal data is retained.

How to answer the survey

You may complete the questionnaire online using the link: https://leeds.onlinesurveys.ac.uk/bil or you may complete it and then post it back to us using the attached paid-reply envelope within one week but latest 10th May 2018.

Prize draw

To thank you for your involvement, all respondents who complete the survey can enter a prize draw to win a cinema ticket.

Winners of the prize draw will be notified by 31 May and published on Movingo's website (www.movingo.se).

If you have further questions or if you would like to get a copy of the report of the survey results, please contact:

Ilyas Alhassan
Planning engineer at UL/Research Student
Email: ilyas.alhassan@ul.se
Telephone: 018-611 19 68

Bryan Matthews
Senior Research Fellow, Leeds University
B.Matthews@its.leeds.ac.uk
+44 113 343 5341

Please proceed to complete the survey.

Thank you for your cooperation.

In cooperation with Biluppgifter
www.biluppgifter.se

Part A: About your travel

Please tick only one option in each question

1. Which of these applies to you now?
   Employed: ☐ Full-time, ☐ Part-time,
   Self-employed: ☐ Full-time, ☐ Part-time,
   Student: ☐ Full-time, ☐ Part-time,
   Other: ☐

2. How many days in a week, do you **usually** *travel by car* to and from work or school?
   ☐5 or more days a week, ☐3-4 days a week, ☐1-2 days a week,
   ☐Rarely, ☐Never.

3. How **long** have you been travelling by car to and from work or school?
   ☐Less than one year, ☐1-2 years, ☐3-4 years, ☐5 or more years

4. How many days in a week, do you **usually** take a commuter train to and from work or school? ☐5 or more days a week, ☐3-4 days a week, ☐1-2 days a week,
   ☐Rarely, ☐Never.

5. I started commuting by rail **in or after autumn 2017**: ☐Yes ☐No

6. I usually drive car to the train station and then change to train: ☐Yes ☐No

7. I travel often between **Stockholm and Uppsala:** ☐Yes ☐No

8. My **typical travel time** *from my home* to work or school is _______ minutes.

9. My **typical travel time** *from work or school* back to my home is ________ minutes.

10. I received **tax reduction** for my travels to and from work in my last tax declaration:
    ☐Yes ☐No

11. My employer pays for my **travel cost** to and from work: ☐Fully, ☐Partly, ☐No.

12. I have free parking opportunity at my work place/school: ☐Yes ☐No

13. I use company car for my trips to and from work: ☐Yes ☐No

14. I usually drive my children to school before going to work: ☐Yes ☐No

15. I usually use car as part of my work: ☐Yes ☐No

Please you have finished part A. Thank you! Go to part B (page 2)

Part B: About your choice of travel mode to work or school

Below are **nine (9) scenarios** for analysing your preferences in the choice of travel mode. Please choice train or car in each scenario by ticking it.

Note: The cost of commuting by car per month is calculated based on travel distance and fuel consumption. The Swedish tax department rate of 1.85 SEK/Km for work trips was used. Monthly train cost equals to the season ticket price. The SL/UL commuter train stops at all station between Stockholm and Uppsala while the regional train (SJ) stops at just two stations or provides direct service between Stockholm and Uppsala.

All scenarios are based on the section Stockholm ↔ Uppsala

1.

Scenario 1 of 9	**Train**	**Car**
Time spend in the vehicle	40 min	55 min
A train departs every	15 min	---
Travel time to train station	10 min	---
Monthly cost (SEK)	2 200	3 000
Monthly ticket gives you	Access to only fast Regional train (SJ)	---
In this scenario, I will choose (please tick train or car)	**[ ]**	**[ ]**

2.

Scenario 2 av 9	**Train**	**Car**
Time spend in the vehicle	40 min	60 min
A train departs every	30 min	---
Travel time to train station	10 min	---
Monthly cost (SEK)	1 600	3 000
Monthly ticket gives you	Access to all SL & UL lines including the SL/UL commuter train	---
In this scenario, I will choose (please tick train or car)	**[ ]**	**[ ]**

3.

Scenario 3 of 9	**Train**	**Car**
Time spend in the vehicle	50 min	55 min
A train departs every	30 min	---
Travel time to train station	5 min	---
Monthly cost (SEK)	2 000	4 000
Monthly ticket gives you	Access to only fast Regional train (SJ)	---
In this scenario, I will choose (please tick train or car)	**[ ]**	**[ ]**

4.

Scenario 4 of 9	Train	Car
Time spend in the vehicle	50 min	60 min
A train departs every	15 min	---
Travel time to train station	15 min	---
Monthly cost (SEK)	2 200	4 000
Monthly ticket gives you	Access to all SL & UL lines + fast Regional train (SJ)	---
In this scenario, I will choose (please tick train or car)	[ ]	[ ]

5.

Scenario 5 of 9	Train	Car
Time spend in the vehicle	40 min	65 min
A train departs every	30 min	---
Travel time to train station	5 min	---
Monthly cost (SEK)	2 000	2 000
Monthly ticket gives you	Access to all SL & UL lines + fast Regional train (SJ)	---
In this scenario, I will choose (please tick train or car)	[ ]	[ ]

6.

Scenario 6 of 9	Train	Car
Time spend in the vehicle	55 min	65 min
A train departs every	15 min	---
Travel time to train station	5 min	---
Monthly cost (SEK)	2 000	2 000
Monthly ticket gives you	Access to all SL & UL lines including the SL/UL commuter train	---
In this scenario, I will choose (please tick train or car)	[ ]	[ ]

7.

Scenario 7 of 9	Train	Car
Time spend in the vehicle	55 min	65 min
A train departs every	15 min	---
Travel time to train station	15 min	---
Monthly cost (SEK)	1 600	3 000
Monthly ticket gives you	Access to only fast Regional train (SJ)	---
In this scenario, I will choose (please tick train or car)	[ ]	[ ]

8.

Scenario 8 of 9	Train	Car
Time spend in the vehicle	55 min	60 min
A train departs every	30 min	---
Travel time to train station	15 min	---
Monthly cost (SEK)	2 200	4 000
Monthly ticket gives you	Access to all SL & UL lines including the SL/UL commuter train	---
In this scenario, I will choose (please tick train or car)	[ ]	[ ]

9.

Scenario 9 of 9	Train	Car
Time spend in the vehicle	50 min	55 min
A train departs every	15 min	---
Travel time to train station	10 min	---
Monthly cost (SEK)	1 600	2 000
Monthly ticket gives you	Access to all SL & UL lines + fast Regional train (SJ)	---
In this scenario, I will choose (please tick train or car)	[ ]	[ ]

Part C: About you

Please which of these **best** describe you? ***(Tick only one option in each question)***

1. What gender are you please? By gender we mean gender identity, the gender that you feel you are. ☐Female, ☐Male, ☐Other, ☐Do not want to give.
2. Please indicate your age group:
   ☐18 – 25 years, ☐26 – 35 years, ☐36 – 45 years,
   ☐46 – 55 years, ☐56 – 65 years, ☐66 and over.
3. Please indicate the highest level of education you completed?
   ☐ Under high school, ☐ High school graduate, ☐University less than 3 years,
   ☐ University 3 or more years, ☐ Other.
4. Please give a range for your monthly income before tax (in SEK)?
   ☐0 – 15 000, ☐15 001 – 30 000, ☐30 001 – 45 000,
   ☐45 001 – 60 000, ☐ More than 60 000 ☐ Do not want to give.
5. My home is located at: Post code, ______________
6. I work or study at (Please answer one or both):
   ☐Post code, ______________
   ☐Street address and area name, ____

Please write todays date here ____________/___________/___________

Thank you for completing this questionnaire. Your effort means a lot to us!
Please contact us if you would like to get a copy of the report of the survey results: ilyas.alhassan@ul.se

Appendix B
Survey Ethical Assessment

B.1 Ethical Review Form

University of Leeds light touch ethical review form

All research carried out by staff or students at the University of Leeds involving any of the following requires ethical approval:

- Human participants, their data or their tissue or
- Adverse environmental impact.

Ethical approval must be obtained **before** research begins and before potential participants are approached. The light touch ethical review application process is used for research where the ethical issues raised by the research are minimal and which have been adequately addressed by the researcher(s). The form may also be used to determine whether a full application for ethical approval is required.

Instructions

Please complete each section. If a question does not apply please write N/A rather than leaving it blank.

NB: Before completing the form check that your answers to C1 and C2 indicate your project is suitable for light touch ethical review.

Section A1 – Application details – to be completed by all applicants

Grant reference #	N/A	Ethics reference #	
Research title	**Commuters' behavioural response to multi-operator ticketing integration and the perceived disutility of public transport ticketing**		
Proposed start date	01/09/17	Proposed end date	30/09/17
Is the research externally funded?		Yes	
If yes, please name the funder		Uppsala County Public Transport Authority, Sweden	

Section A2 – Contact details – to be completed by all applicants

Principal Investigator	Ilyas Bandugupirah Alhassan
Position	Postgraduate Researcher
Department/ School/ Institute	Institute for Transport Studies, ITS.
Faculty	Environment
Work address	UL, Storgatan 27, Box 1400, 751 44 Uppsala, Sweden
Telephone number	+46 76 71 30 352
Email address	I.B.Alhassan1@leeds.ac.uk

Section A3 – for students only

Qualification working towards (eg Masters, PhD)	PhD
Supervisor's name	Mr. Bryan Matthews
Department/ School/ Institute	Institute for Transport Studies, ITS.
Supervisor's telephone number	+44 113 343 5341
Supervisor's email address	B.Matthews@its.leeds.ac.uk
Module name and number (if applicable)	N/A

Section A4 – to be completed by the student's supervisor

	Yes	No
The topic merits further research	X	
I believe that the student has the skills to carry out the research	X	

Section B – to be completed by all applicants

B1: Provide a brief summary of the research, outlining the aims and objectives and/or research questions and the proposed methodology. Explain how research participants will be identified, approached and recruited and what they will be asked to do. (**max 300 words**)

Public Transport (PT) fare and quality are the main service aspects that service providers manage to achieve ridership targets. Ticketing and its integration as a tool for putting a PT fare policy into action constitute the interface between a PT user and the PT service. This makes it one of the most important aspects of PT customer satisfaction and PT operational efficiency. Making PT services more attractive and effective thus requires attractive and effective ticketing. This is only possible through a clear understanding of both users' and potential users' ticketing needs and expectations by measuring their behavioural response to changes in ticketing and its integration factors. Yet, a careful review of the literature on PT ticketing suggests that little is known about: the link between multi-operator ticketing integration and mode shift; commuters' attitudes and perceived value of multi-operator ticketing integration; and the perceived disutility of PT ticketing factors to users. These are the knowledge gaps the study seeks to investigate and address through the following objectives:

1. To estimate users' perceived value of seamless travel
2. To examine PT users' choice of season tickets given a set of integrated ticketing options
3. To measure the effect of multi-operator season ticket integration on mode shift by car users
4. To examine the attitudes and perceptions of PT users to season ticket integration
5. To investigate the disutility of PT ticketing for users.

Using the Stockholm – Uppsala corridor in Sweden as a case study, the study methodology involves conducting intercept travel surveys, specifying, estimating and interpreting behavioural models base on the random utility model framework.

PT and car commuters are the research participants. The PT commuters will be identified on-board trains and asked to answer the questionnaire on-board, online or by mail-back. The car commuters will be identified by license plate recording along the corridor. The questionnaire will then be posted to their home addresses for answering and mail-back or online.

B2: Where and in what format(s) will research data and signed consent forms be retained? (**max 200 words**) Guidance is available at http://ris.leeds.ac.uk/ResearchDataManagement.

The data will be collected in Sweden, processed into digital format and then save on my M: drive through "Desktop anywhere", which I am already using. All hard copies of the survey forms will be saved in a secured place at the office of the Uppsala Public Transport Authority. They will then be destroyed after the data is processed into digital format. The online part of the survey will be carried out using the University of Leeds's online survey tool, BOS. In addition, the study does not require the use of sensitive personal data such as racial or ethnic origin; political opinions; religious beliefs; trade union membership; physical or mental health; sexual life; commission of offences or alleged offences etc.

Section C1 – High Risk Ethical Issues – to be completed by all applicants	Yes	No
Does the study involve participants who are particularly vulnerable or unable to give informed consent (eg children, people with learning disabilities, your own students)?		No
Will the study require the cooperation of a gatekeeper for initial access to groups or individuals who are taking part in the study (eg students at school, members of self-help groups, residents of a nursing home)?		No
Will participants be taking part in the research without their knowledge and consent (eg covert observation of people in non-public places)?		No
Will the study involve discussion of sensitive topics (eg sexual activity, drug use)?		No
Are drugs, placebos or other substances (eg food substances, vitamins) going to be administered to the participants or will the study involve invasive, intrusive or potentially harmful procedures of any kind?		No
Will blood or tissue samples be obtained from the participants?		No
Is pain or more than mild discomfort likely to result from the study?		No
Could the study induce psychological stress or anxiety or cause harm or have negative consequences beyond the risks encountered in normal life?		No
Will the study involve prolonged or repetitive testing?		No
Will financial inducements (other than reasonable expenses and compensation for time) be offered to participants?		No
Will the study involve research conducted outside the European Economic Area or collaborators located outside the EEA? NB: If the study involves research conducted inside the EEA please include a copy of your signed fieldwork risk assessment with your application: http://ris.leeds.ac.uk/HealthAndSafetyAdvice.		No
Will the study involve the transfer of data outside the European Economic Area?		No
Will the study involve participatory action research or members of the public in a research capacity?		No
Are there any potential conflicts of interest?		No
Does the research involve any risks to the researchers themselves, or individuals not directly involved in the research?		No
Will the study require ethical review from the NHS? (Refer to http://ris.leeds.ac.uk/NHSethicalreview for guidance in identifying circumstances which require NHS review)		No

If you have answered 'no' to all of the questions in section C1, please proceed to section C2.

If you have answered 'yes' to any of the questions in section C1 you do not need to complete the remainder of this form. Instead you must complete an application for full ethical review either by the University or the NHS.
For University applications please refer to http://ris.leeds.ac.uk/uolethicsapplication.
For NHS applications please contact the Ethics Administrator in Medicine and Health for further advice, governance-ethics@leeds.ac.uk.

Section C2 – Protocols for ethical research – to be completed by all applicants

Please indicate which of the protocols for ethical research are applicable to your study, and whether the study will be carried out in accordance with each protocol.

Protocol	**Tick if the protocol is applicable to the study**	**Will the study be carried out in accordance with this protocol?** (only answer for protocols which are appropriate to the study)	
		Yes	**No**
Data protection, anonymisation and storage and sharing of research data	√	**Yes**	
Informed consent	√	Yes	
Verbal consent			
Reimbursement for participants	√	**Yes**	
Low risk observation			

If you have answered 'no' to any of the questions in section C2 you will need to complete a full ethical review application. Please refer to http://ris.leeds.ac.uk/uolethicsapplication.

Section C3 – Other Ethical Issues – to be completed by all applicants

Does the study involve any other ethical issues outside of those covered in section C1 and C2? If yes please give details:	**Yes**	**No**
		No

To speed up the review of a light touch application it is helpful if relevant supporting documentation (ie information sheets, consent forms, interview/ questionnaire questions) is also submitted for review.

D1 Declaration – to be completed by all applicants

Applicants should read and sign the following declaration before submitting the application.

In signing this research ethics declaration I am confirming that:

- The research ethics application form is accurate to the best of my knowledge and belief.
- I have read the University's Research Ethics Policies and policies relating to ethics (available at http://ris.leeds.ac.uk/ResearchEthicsPolicies)
- I have read and agree to abide by the research ethics protocols (available at http://ris.leeds.ac.uk/downloads/download/465/light_touch_ethics_application) applicable to the project and which are listed in Section C1 of the Research Ethics Application form.
- There is no potential material interest that may, or may appear to, impair the independence and objectivity of researchers conducting this project.
- I have received authorisation from the relevant authorities to carry out the research.
- I undertake to inform the Senior Research Ethics Administrator of any significant changes to the project.
- I understand that the project, including research records and data, may be subject to inspection for audit purposes at any time in the future.
- I understand that personal data about me contained in this form will be held by those involved in the ethics review procedure (e.g. the Senior Research Ethics Administrator and/ or ethics reviewers) and that it will be managed according to Data Protection Act principles.

For supervisors of research students only:

- I have discussed the ethical issues arising from the research with the student and have read the application and agree that it has been completed accurately and fully.

Signature: ....

Print name: Ilyas B. Alhassan

Date: 30/07/2017 (dd/mm/yyyy)

Supervisor's signature (if applicable):

Print name: Bryan Matthews

Date: 30/07/2017 (dd/mm/yyyy)

Please email your completed light touch ethical review to ResearchEthics@leeds.ac.uk.

A signed application form is required and should be sent either by email or through the internal post to *Jennifer Blaikie, Senior Research Ethics Administrator, Research & Innovation Service, Level 11, Worsley Building, University of Leeds, LS2 9NL.*

B.2 Fieldwork Assessment

UNIVERSITY OF LEEDS

Fieldwork Assessment Form (Low Risk Activities)

	Fieldwork Project Details
Faculty School/Service	Institute for Transport Studies, ITS
Location of Fieldwork	Stockholm – Uppsala corridor, Sweden (59°21′N 18°4′E)
Brief description of Fieldwork activity and purpose *(Include address, area, and grid reference and map where applicable).*	Collection of primary data through questionnaire survey of commuters for studying a proposed Public Transport Ticketing Integration along the Stockholm – Uppsala corridor. The survey sites are the rail lines and motorway (E4) within the corridor shown in the map below. 
Fieldwork itinerary *E.g. flight details, hotel address, down time and personal time.*	I am a Split-site PhD student working from Sweden and I currently live near the study site. I will be staying in my home during the fieldwork and the address is: Långjärnsgatan 5, 754 20 Uppsala, Sweden
University Travel Insurance Policy Number	N/A
Organiser Details	**Contact details** *Name, email, telephone*
Fieldwork Activity Organiser / Course Leader	Supervisor: Mr. Bryan Matthew Telephone number: +44 113 343 5341 E-mail address: B.Matthews@its.leeds.ac.uk

Title:	Fieldwork Assessment Form (low risk)	Number:	PRSG17.4 v4	Issue date:	11/11/2015	Page Number:	Page 1 of 5

Departmental Co-ordinator	Mr. Bryan Matthews Telephone number: +44 113 343 5341 E-mail: B.Matthews@its.leeds.ac.uk Dr. Jeremy Toner +44 (0)113 34 36617 j.p.toner@its.leeds.ac.uk
Nature of visit *Size of Group, lone working, staff, postgraduate, undergraduate.*	The survey will be carried by myself together with the help of two of my co-workers - Ammar Korshed and My Larsson
Participant Details *Attach information as separate list if required.*	**Contact details** *Name, Address, email, telephone, gender and next of kin contact details*
	Ilyas Bandugupirah Alhassan, I.B.Alhassan@leeds.ac.uk, +46767130352, male. Next of kin: Beidaw Alhassan, biwass@outlook.com, +46722721943, Långjärnsgatan 5, 754 20 Uppsala, Sweden
	Ammar Korshed, ammar.korshed@ul.se, +46708-21 64 40, Box 1400, 751 44 Uppsala. Contact person: Stefan Adolfsson, stefan.adolfsson@ul.se, +46730-65 95 99, Box 1400, 751 44 Uppsala
	My Larsson, my.larsson@ul.se, +46721-45 34 86, Box 1400, 751 44 Uppsala. Contact person: Stefan Adolfsson, stefan.adolfsson@ul.se, +46730-65 95 99, Box 1400, 751 44 Uppsala

HAZARD IDENTIFICATION

Identify all hazards specific to fieldwork trip and activities, describe existing control measures and identify any further measures required.

HAZARD(S) IDENTIFIED	CONTROL MEASURES ***(e.g. alternative work methods, training, supervision, protective equipment)***
Nature of the site *School, college, university, remote area, laboratory, office, workshop, construction site, farm, etc.* Questionnaire distribution on-board trains and recording of license plate numbers at the Uppsala – Knivsta section of the E4 motorway	In addition to the surveyor's good knowledge of the study site, - A short training on on-board survey is to be conducted. - Car license plates will be recoded with the help of a camera mounted inside a car and drive repeated along the survey section during peak travel hours. This means that there will not be any personal interaction with motorists or direct exposure of the surveyors to vehicular traffic
Transport *Mode of transport while on site, to and from site, carriage of dangerous goods etc.* Walk and Uppsala county Public Transport Authority's office car	- Walk about 3 to 5 minutes from the Uppsala county Public Transport Authority's office to the train station where the trains will be boarded to conduct the on-board survey - Transport to the Uppsala – Knivsta section of the E4 motorway will be by the survey vehicle and it takes about 5 min.

Violence *Potential for violence in location, political and social unrest; against participants (previous incidents etc.).* Public Transport Passengers	Our investigation showed that there are no previous incidents in similar studies
Cultural Considerations *Specific to the activity or participants.*	Surveyors are natives and no cultural challenges are envisaged
Individual(s) *medical condition(s), young, inexperienced, disabilities etc.* Surveyors	N/A
Work Pattern *Time and location e.g. shift work, work at night.* Peak traffic hours between 06:00 – 09:00 and 15:00 – 18:00	We will be working during the data collection periods (3 hours in the morning and 3 hours in the afternoon) and taking rest in between
Other *E.g. temperature, humidity, confined spaces.* About 15 °C	No negative effects of weather are envisaged during the survey

Additional Control Measures	
Pre-departure Briefing *Carried out and attended.*	The field work is planned to be carried out from 11th – 22nd September 2017. There is no need for pre-departure briefing as the surveyors live near the study site
Training *Identify level and extent of information; instruction and training required consider experience of workers.* On-board survey training	I am making arrangement for a short training on on-board survey for all the three surveyors by Dr. Karl Kottenhoff of the Royal institutes of Technology, who has good experience in on-board surveys in Sweden. The training will include the purpose of the survey, safety precautions, approaching respondents, recording of problems during the survey, helping respondents who need help to be able to answer the questionnaire etc.
Supervision *Identify level of supervision required e.g. full time, Periodic telephone/radio contact.* Periodic telephone calls to two fieldworkers and daily mails to my supervisors	- I have planned to make periodic telephone calls to the surveyors at one hour intervals any time I am not personally at the site with them - My supervisors will be updated daily on the field activities - My wife will also be called once during any site visit. She will be shown the study site and contacts information of my colleagues will be provided to her.
FCO advice *Include current FCO advice for travel to the area where applicable.*	There no need for FCO advice as all of us (surveyors) live near the study area and it is safe
Other Controls *E.g. background checks for site visits.* Previous surveys	Previous surveys along the corridor have been successful.
Identify Persons at Risk *This may include more individuals than the fieldwork participants e.g. other employees of partner organisations.* *Copy of other Organisation's risk assessment attached?* Public transport passengers and fieldworks	Security officers who often monitor activities on trains and at train stations will step-in in the event of violence.
Additional Information *relevant to the one working activity including existing control measures; information instruction and training received, supervision, security, increased lighting, emergency procedures, first aid provision etc.* Emergency telephone number, first aid	Fieldworkers are already aware of the emergency telephone number 112 but will still be reminded to contact police, hospital or fire service in case of emergency.

Residual Risk *Is the residual risk acceptable with the identified controls?*	Yes	Yes
	No	

Assessment carried out by	Name:	Ilyas Bandugupirah Alhassan
	Signature:	
	Date:	11/08/2017
Names of person(s) involved in Fieldwork *N.B: This can take the form of a signed class register when large group work*	Name:	My Larsson
	Signature:	
	Date:	11/08/2017
Fieldwork Activity Organiser / Course Leader *e.g. PI, etc*	Name:	Bryan Matthews (supervisor)
	Signature:	
	Date:	08/08/2017

B.3 Ethical Approval

The Secretariat
Level 11, Worsley Building
University of Leeds
Leeds, LS2 9JT
Tel: 0113 343 4873
Email: ResearchEthics@leeds.ac.uk

UNIVERSITY OF LEEDS

Ilyas Alhassan
Institute for Transport Studies
University of Leeds
Leeds, LS2 9JT

ESSL, Environment and LUBS (AREA) Faculty Research Ethics Committee
University of Leeds

6 August 2020

Dear Ilyas

Title of study: **Commuters' behavioural response to multi-operator ticketing integration and the perceived disutility of public transport ticketing**

Ethics reference: **LTTRAN-079**

I am pleased to inform you that the above application for light touch ethical review has been reviewed by a representative of the ESSL, Environment and LUBS (AREA) Faculty Research Ethics Committee and I can confirm a favourable ethical opinion on the basis of the application form as of the date of this letter. The following documentation was considered:

Document	Version	Date
LTTRAN-079 FinalEng_PT_Stockholm_Marsta_Knivsta_Uppsala.docx	2	04/09/17
LTTRAN-079 FinalEngCar_Stockholm_Knivsta_Uppsala.docx	2	04/09/17
LTTRAN-079 further information.txt (by email)	1	04/09/17
LTTRAN-079 Ethetical_Review.pdf	1	11/08/17
LTTRAN-079 Fieldwork_Assessment.pdf	1	11/08/17

The reviewer made the following comment about your application:

- You might want to change 'Dear Customer' on the questionnaire for car drivers to 'Dear Commuter' or similar.

Please notify the committee if you intend to make any amendments to the original research as submitted at date of this approval, including changes to recruitment methodology. All changes must receive ethical approval prior to implementation. The amendment form is available at http://ris.leeds.ac.uk/EthicsAmendment.

Please note: You are expected to keep a record of all your approved documentation, as well as documents such as sample consent forms, and other documents relating to the study. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited. There is a checklist listing examples of documents to be kept which is available at http://ris.leeds.ac.uk/EthicsAudits.

We welcome feedback on your experience of the ethical review process and suggestions for improvement. Please email any comments to ResearchEthics@leeds.ac.uk.

Yours sincerely

Jennifer Blaikie
Senior Research Ethics Administrator, the Secretariat
On behalf of Dr Kahryn Hughes, Chair, AREA Faculty Research Ethics Committee
CC: Student's supervisor(s)

Appendix C
Others

C.1 Appendix to Paper III (Chapter 3)

Appendices

Appendix A: Description of the public transport commuter survey

Both survey waves included questions about the respondents' commuting habits and behaviour and socioeconomic characteristics (Table 2).

Users' socioeconomic characteristics: there was a good representation of both genders in the sample even though the number of females were slightly higher. In 2018, the population of females in both Stockholm and Uppsala municipalities is slightly higher than males (SCB 2020). The age distribution in the sample mirrors typical commuting ages. The average age in both municipalities in 2018 is 39 years (SCB 2020) and the age category 25–34 years has the highest proportion of the total. Around 20% of the respondents are in this age category. The monthly income (before tax) class 35000–50000 SEK has the widest interval and hence respondents within this class had the highest representation. In 2017, the average annual income for the subpopulation from 20 years and above in the Uppsala municipality was 311200 SEK/Year – 26000 SEK/Month and that of Stockholm municipality was 369200 SEK/Year – 31000 SEK/Month (SCB 2020). The monthly incomes of about 25% of the respondents fall within these two averages. The majority of the respondents have at least 3 years of university education and this group is the largest educational group within the population in both municipalities. 34.08% of the population in the Uppsala municipality has at least three years of university education compared to 35.48% in Stockholm municipality (SCB, 2018). As expected in a survey with commuters as the target population, full-time employed people have the highest representation in the sample followed by full-time students. Over 70% of the respondents reported that they work, reflecting the percentage of the working population in the Uppsala and Stockholm counties. 68.2% of the population in Uppsala county between 15–74 years work and the corresponding value for Stockholm county is 72.7%.

Commuting habits and behaviour: most of the respondents reported that they received an annual tax reduction for work trip expenses. Over 90% of them reported that they pay personally for their travel expenses to/from work while very few of them reported that these expenses are paid by their employers. More than half of the respondents in both survey waves reported that they commute five or more days per week and most of them have been commuting for five or more years. In terms of ticket purchase channels, ticket vending is most popular among the respondents followed by service provider offices. Most of them reported that they rarely use their season ticket for non-commuting trips.

Appendix B: Description of the car commuter survey (Table B1)

Similarly, the car commuter survey included questions about the respondents' commuting habits and behaviour, for example, whether their work assignments require regular car use, whether the travel cost to work is paid by the employer, whether they have to drive children to school, whether the car they use is a company car, whether they have free parking at the work place, whether they get tax reduction for work trips, whether they patronise park-and-ride, commuting frequency and commuting experience.

As summarised in Table B1, about one-third of the respondents reported that they need to use car in the course of work. This means that car is their default commuting mode as they need to use it as part of their work. About 90% of them reported that they pay personally for their travel expenses to/from work. 3 out of 5 respondents receive annual tax reduction for work trip expenses. This reduces their out-of-pocket annual cost for travel to work and may encourage car commuting. 1 out of 5 respondents reported that they drive their children to school and this group of car commuters may not find public transport (PT) attractive. Very few of them (7%) use cars owned by their employer for travel to/from work. Free parking at work place could be an incentive for people to drive to work and about 2 out of 5 respondents have access to free parking at work. Very few of them (6%) patronised park-and-ride services. As suggested by the sample in Table B1, there are many incentives and commitments that may make it difficult for most of the car commuter groups to change mode to PT as a result of the integrated ticketing scheme, as the benefits offered by the scheme to these groups are not large enough to let them change mode to PT. Hence, few of them (about 1 out of 10) reported they patronised PT services after the implementation of the Movingo project. Whilst 52% of the respondents reported that they never commute by PT, 46% of them reported that they commute five or more days per week and about 64% of them have been commuting for five or more years. Such long-time and high frequency commuting experiences may make it difficult for commuters to change their mode choice behaviour given integrated ticketing as the only intervention. The survey also captures the respondents' socioeconomic characteristics such as gender, age, monthly income, education level, and employment status. As shown in Table B1, there was a high representation of males in the sample. This is typical in Sweden as there are more male car drivers than females. The age distribution in the sample varies relatively little between age categories, though the age category 16–34 years has the least proportion (15%). The majority of the respondents have at least 3 years of university education and this group is the largest educational group in the PT commuter survey and within the populations in both municipalities. 34.08% of the population in Uppsala municipality has at least three years of university education compared to 35.48% in Stockholm municipality (SCB, 2018). Respondents with monthly income (before tax) over 50000 SEK have the least representation in the sample. In 2017, the average monthly income for the subpopulation aged 20 years and above was 26000 SEK/Month in the Uppsala municipality and 31000 SEK/Month in the Stockholm municipality (SCB, 2017). This implies that there are relatively few people in the population with monthly income higher than 50000 SEK/Month. As expected, full-time employed people have the highest representation (88%) in the sample since commuters were the survey population.

Of the 9.4% who reported that they currently patronise PT services: 17% were females and 83% were males. This was expected, as there are more male car users in the study compared to females. 33% were in the age group 16–34 years, 44% were in the 35–54 age group and 22% were in 55+ age group. 67% had some form of university education and 33% were high school graduates. 11% reported that they commute by train 1–2 times/week, 33% reported 3–4 times/week, 33% reported 5 or more times/week and 22% reported that they rarely commute by train.

Table B1. Descriptive analysis of the car commuter survey sample.

	Sample characteristics (Sample size, n = 96)
Gender	*Female (32%), Male (68%)*
Age (Years)	*16 – 34 (15%), 35 – 44(24%), 45 – 54 (29%), 55+ (30%)*
Monthly gross income in SEK	*00000–15000 (24%), 15001–25000 (8%), 25001–35000 (26%), 350001–50000 (26%), Over 50 0001 (6%)*
Education	*Higher education - 3 or more years (54%), Higher education-less than 3 years (25%), High school or below (22%)*
Employment status	*Full-time employed (88%), Part-time employed (7%), Other (5%)*
Car usage under work	*Yes (27%), No (74%)*
Travel cost paid by employer	*Yes (10%), No (90%)*
Drive children to school	*Yes (21%), No (79%)*
Company's car	*Yes (7%), No (93%)*
Free parking (work)	*Yes (38%), No (62%)*
Received tax reduction for work trips	*Yes (59%), No (41%)*
Park-and-ride patronage	*Yes (6%), No (94%)*
Frequent traveller (Stockholm – Uppsala)	*Yes (62%), No (38%)*
Commute by rail after Movingo project	*Yes (91%), No (9%)*
Commuting frequency (Train)	*1 - 4 days/week (11%), ≥ 5 days/week (10%), Rarely (27%), Never (52%)*
Commuting frequency (Car)	*1 - 4 days/week (31%), ≥ 5 days/week (46%), Rarely (23%)*
Commuting experience (Car)	*< 1 year (9%), 1 – 4 years (21%), ≥ 5 years (64%), N/A (6%)*