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The Movingo integrated ticket: Seamless connections across the Mälardalen region 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% 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

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 3 describes the study area and the Movingo project. Section 4 presents the data collection, analyses methods and results. Section 5 discusses some key lessons from the Movingo project, and the final section provides some concluding remarks.

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.

3 Case study area

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 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 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).

3.2 The corridor before and after the Movingo project

Commuting either by car via the E4 motorway or by train 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.

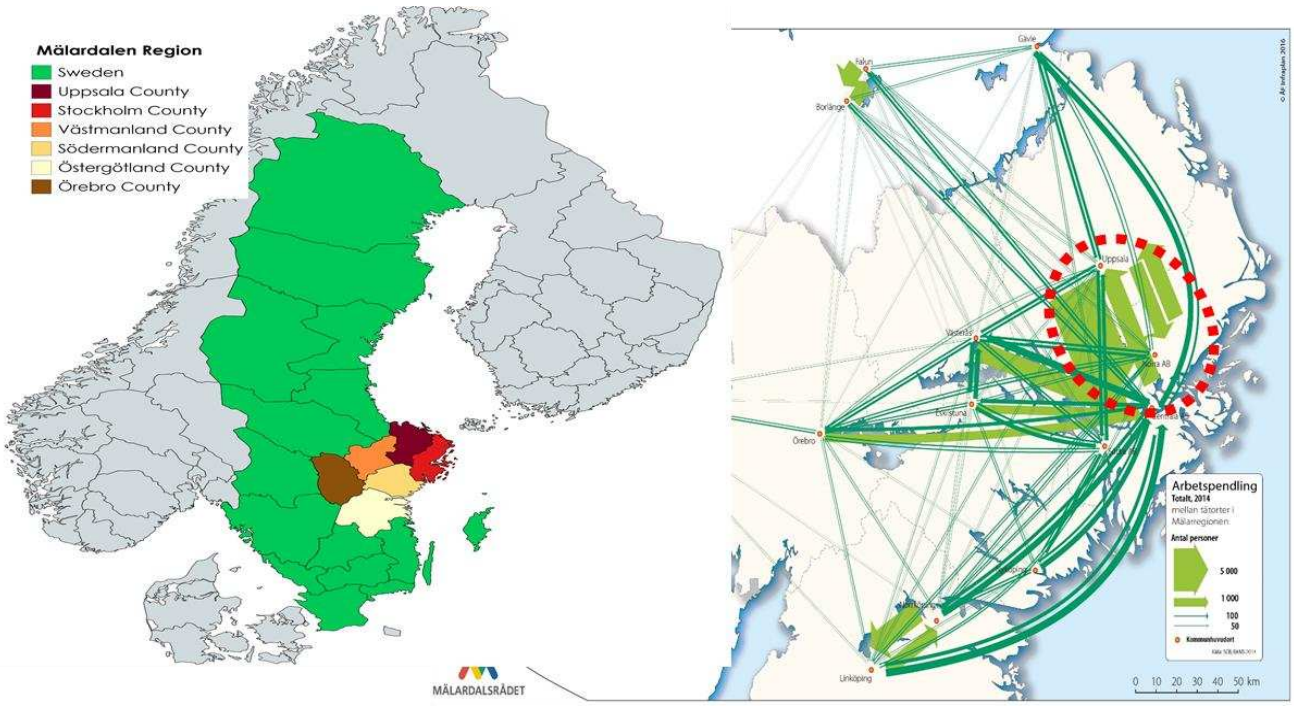

Figure 1: The Mälardalen region and the total number of work commuters among its urban areas in 2014 (Adopted from MÄLARDALSRÅDET, 2016)

4 Data collection and analysis methods

4.1 Data Collection

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** 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** 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 2** and described in appendix A, 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 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 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 2, this did not significantly affect the representativeness of the sample. The distribution in **Table** 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.

4.1.2 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 B.

4.1.3 Ticket sales data

As presented in section **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.** 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 5**, 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 1: Descriptive analysis of the survey ratings. (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 α_1 and α_2 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.

Statements	***Strongly agree 7*** ⟶						***Strongly disagree 1***	
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
I find ticket control by staff on train disturbing	8,7	5,7	6,4	10,8	10,9	15,10	42,55	3,1
I do feel safe and secured when passing through turnstiles	22,27	20,16	16,13	13,15	7,7	4,4	3,5	14,14
It is smooth to pass through turnstiles	25,29	22,17	16,15	12,7	6,4	3,10	3,11	12,7

Table 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 none-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

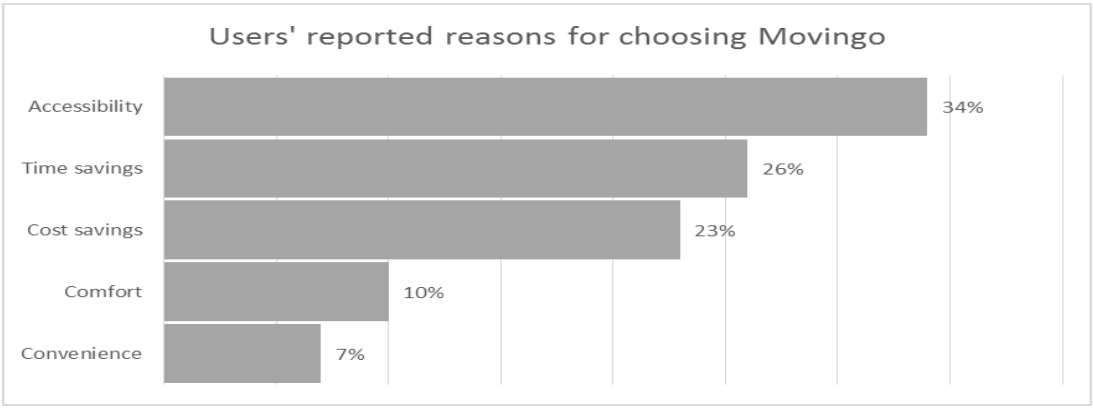

Figure 2: Users' revealed reasons for choosing Movingo

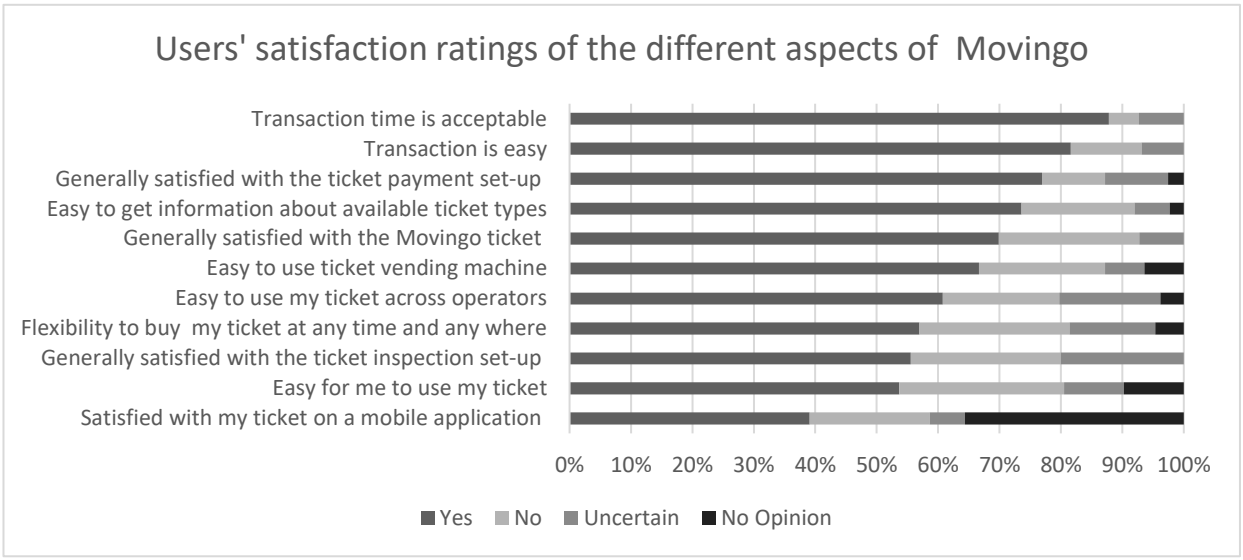

Figure 3: Satisfaction and perceived quality of the different aspects of Movingo

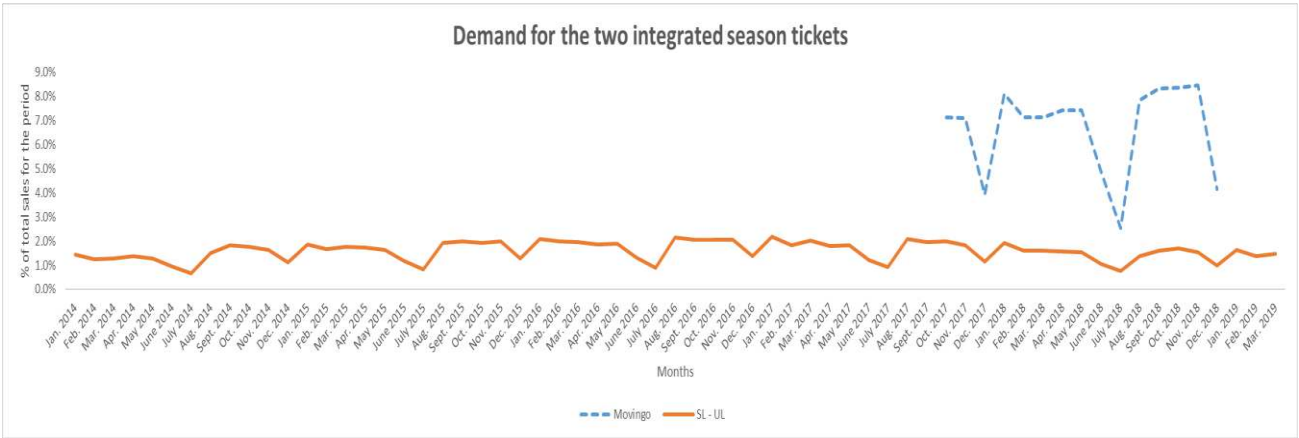

Figure 4: Monthly sale proportions of the Movingo ticket and the SL – UL season ticket over time (UL 2019)

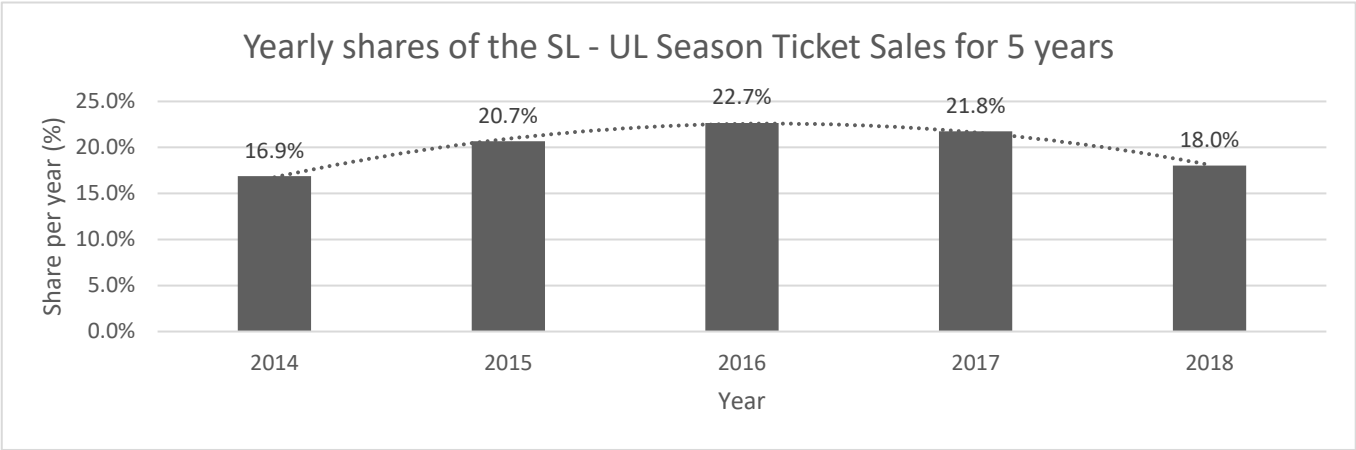

Figure 5: Annual shares of the total SL - UL season tickets sold between 2014 and 2018

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.

4.2.1 Dependent sample t-test

Fifteen out of seventeen attributes (**Table 1**) were grouped into six quality dimensions (**Table 4**) 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, H_0: $\mu_1 = \mu_2$,
- An alternative hypothesis that true difference in means is not equal to 0, H_A: $\mu_1 \neq \mu_2$.

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 ($\hat{p}$) 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 $\hat{p}$, the estimated sample proportion, is equal to the number of successes in the sample divided by the sample size, n (Washington et al, 2011).

4.2.3 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,

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

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

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

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

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

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.

(1) New commuters to the corridor: This study lacks the data needed to estimate the proportion of new commuters to the corridor.

(2) 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. While the findings of this study suggest that an

average of 9% of car commuters patronised PT services after the scheme, given the current dataset, the study could not directly relate this 9% to the 24% percent 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 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.

(3) 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 & Figure 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.

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 2** and described in section **4.1.1**, together with the explanatory variables provided in **Table 2,** were used in the modelling. Different specifications of the model were considered, as shown by the overall goodness-of-fit measures in **Table 3,** and 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.

Table 3: 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			

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 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.

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.

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**. 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.

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

Attitude dimension	**Mean**	**t value (p-val)**	**Standard Dev.**	**Coefficient of Variation**	**95% Conf. interval**
	Wave 1, Wave 2		**Wave 1, Wave 2**	**Wave 1, Wave 2**	**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

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**). 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-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.

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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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 age category 25 – 34 years has the highest proportion. The average age in both municipalities in 2018 is 39 years (SCB, 2020) and about 20% of the respondents are in this age group. 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 highest 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 to 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 fully 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 none-commuting trips

Appendix B: Description of the car commuter survey (Table 5)

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

As summarised in **Table 5**, about one-third of the respondents reported that they need to use car under 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 fully 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 car 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 5**, 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 then change mode to PT. Hence, few of them (about 1 out of 10) reported they patronised PT service 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. This long-time and high frequent commuting experiences may make difficult for the 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 5**, there was a high representation of males in the sample. This is typical in Sweden as there are more males car drivers than females. Besides the age category 16 – 34 years which has the least proportion (15%), the age distribution in the sample did not vary that much. Majority of the respondents have at least 3 years of university education and this group is the highest 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 has the least representation in the sample. In 2017, the average monthly income for the subpopulation 20 years and above in the Uppsala municipality 26000 SEK/Month and 31000 SEK/Month for Stockholm municipality (SCB, 2017). Implying that there are only 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 males 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 5: 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%)*