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Examining the effect of integrated ticketing on mode choice for interregional commuting: Studies among car commuters

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ABSTRACT
Increasing sustainable travel patterns necessitates a considerable amount of research aimed at the detail measurement and understanding of travel mode choice. Most Public transport (PT) service quality improvements are 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. Considering the widespread implementation of integrated ticketing schemes globally and some evidence confirming the positive substitution effects between car and season ticket ownerships, the objective of this study was to examine the correlation between mode choice for commuting and multi-regional integrated ticketing. A stated preference (SP) survey was conducted along the E4 motorway between Stockholm and Uppsala, Sweden. 84 out of the 96 respondents answered the SP questions, resulting in 756 SP observations. Subsequently, binary and mixed logit models were estimated. The results suggested that integrated ticketing has an overall positive effect on promoting greater public transport use; in particular, male car commuters compared to females are more likely to switch to PT for commuting. The methodological and policy implication of this positive association is that the effects of integrated ticketing should be included in demand modeling to improve both the accuracy of the estimates and the policy decisions that are based on these estimates.

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Commuters; integrated ticketing; mode choice; public transport; season tickets

1. Introduction

Sustainable development and transportation systems are inherently linked and compared to the automobile, Public Transport (PT) has generally been argued to have a more positive relationship with sustainability due to its significant economic, social and environmental contributions to society (Enoch, 2012; FHWA, 2014; Patrick Miller et al., 2016). Consequently, 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 behavior (Ortúzar et al., 2011, Ben-Akiva & Lerman, 1985).

This research hypothesizes 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 generalized cost of public transport (PT) usage. These are some of the reasons why the worldwide implementation of integrated ticketing schemes 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 worldwide (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 & Wilson, 2010). Interestingly, there is currently limited knowledge on the extent to which integrated ticketing influences mode choice behavior. 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 (Trafikverket & Sveriges Kommuner och

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Landsting, 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 (Statistics 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 has to be included as a potential determinant of mode choice in travel demand analysis.

The rest of the paper proceeds as follows. Section 2 covers a review of the literature on PT ticketing and mode choice. Section 3 describes the study approach. Section 4 presents the findings and discussions. Section 5 provides conclusions and recommendations for further research.

2. Literature review

The literature on travel mode choice behavior has increasingly recognized 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 (Johansson-Stenman, 2002; Klein & Smart, 2017; Matthies et al., 2002; Polk, 2004; Schmöcker et al., 2007; Smart, 2015; Zhou, 2012)
- Transport mode-specific factors such as travel cost, travel time, safety, security, parking facilities, service frequency, comfort level and convenience (Chlond et al., 2014; Larsen & Rekdal, 2010; Limtanakool et al., 2006)
- Natural environment-specific factors such as topography, environmentalism and weather conditions (Liu et al., 2015, Johansson et al., 2006; Müller et al., 2008; Rieser-Schüssler & Axhausen, 2012)
- Built environment-specific factors such as spatial development patterns, urban form, workplace relocation and residential relocation (Buehler, 2011; Scheiner & Holz-Rau, 2013; Schwanen & Mokhtarian, 2005)
- 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 et al., 2011)
- Psychological factors such as attitudes, subjective norms, perceived behavioral control, intension, previous experience, habits, situation, commitments, affect, exposure (Ababio-Donkor et al., 2020; Bamberg et al., 2003; Gärling & Axhausen, 2003; Heinen et al., 2017; Heinen & Chatterjee, 2015; Johansson et al., 2006; Lanzini & Khan, 2017; Nerhagen, 2003; Simma & Axhausen, 2003).

This present study focuses on transport mode-specific factors. PTAs in countries like Sweden are separate units with different pricing and ticketing systems. Also, the economic liberalization of PT markets in many countries provides PT operators with the possibility to compete by differentiating their products and applying yield management and price discrimination to maximize revenue and to better assign customers to services (Wardman & Toner, 2003). This localization of PT service supply (often with subsidies) together with the liberalized market arrangement means a wide variety of ticket types are offered for both intraurban and interurban travel, often creating a problem for passengers who need to travel across operators 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 & Pucher, 2012; EPTG, 2009; Kamargianni et al., 2016; Alhassan et al., 2020).

Besides, most PT trips are performed with season tickets as 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 (The Association of Swedish Public Transport (SKT) Annual Report & The Public Transport Barometer, 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' behavior in Germany using panel data. They found that season ticket owners were multimodal in behavior 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

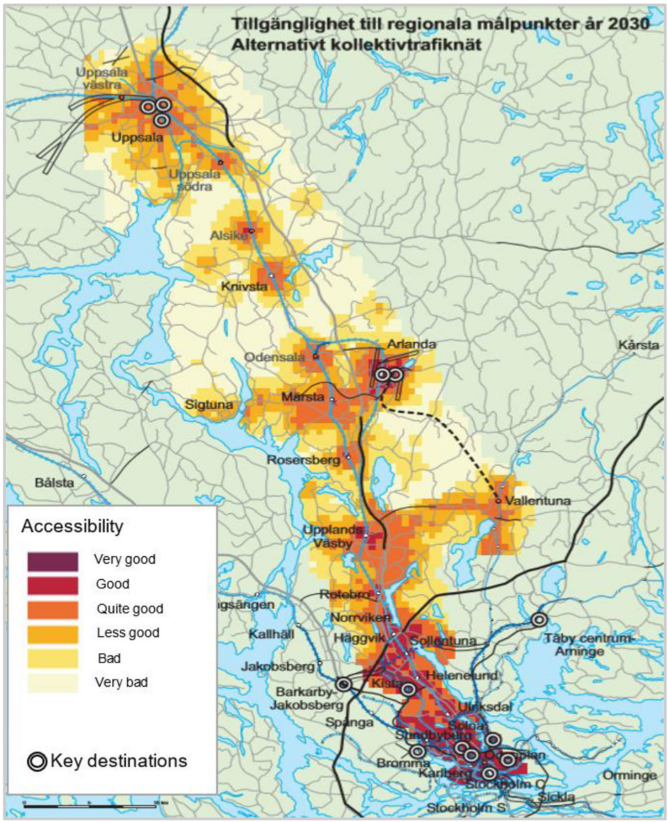

Figure 1. 2030 forecast for PT accessibility to key destinations along the ABC-Corridor (ABC-Samarbetet, 2007).

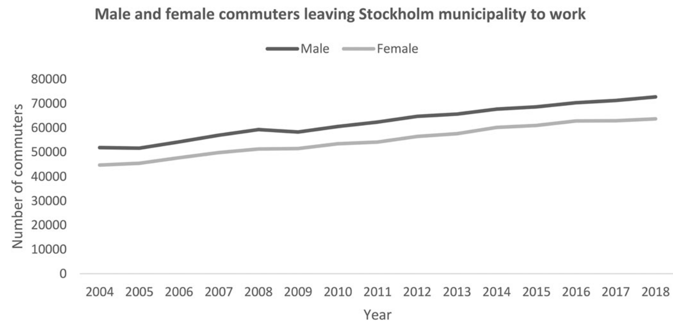

Figure 2. The number of men and women commuting outside Stockholm as their resident municipality by year (SCB data, Statistics Sweden (SCB), 2020b).

Axhausen (2003) 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 (2003) analysis of train ticket types in the UK focused on understanding the competition among train ticket types. Similarly, Mesoraca and Brakewood (2018) synthesized 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 & & European Commission, 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 analyzing the association between integrated ticketing and mode choice for cross-county commuting between Stockholm and Uppsala, Sweden.

3. Methodology

The econometric approach of discrete choice modeling and psychological methods currently dominate transportation mode choice research. Given that: commuting is primarily a derived demand toward 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 toward getting access to PT service, the discrete choice modeling framework based the random utility theory (Ortúzar et al., 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.

3.1. The Stockholm – Uppsala corridor as a case study

The corridor between Stockholm and Uppsala (Figure 1), known as ABC-corridor, an urban planning acronym in Swedish for Work, Residence and Center (Arbete, Bostäder & Centrum) in the Swedish urban planning sector, is characterized 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.

Figures 2–4 provide a summary of the data from Statistics Sweden between 2004 and 2018. The number of people traveling 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 1 shows the corridor and the 2030 estimated accessibility to major destinations along the corridor with PT. The main PT service suppliers within the corridor are the Stockholm county public transport authority (PTA), SL, the Uppsala county PTA (UL) and the Swedish National Railways (SJ).

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.

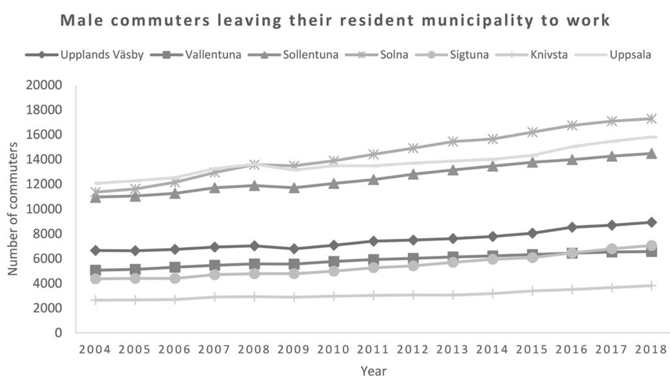

Figure 3. The number of men commuting outside their resident municipality by year (SCB data, Statistics Sweden (SCB), 2020b).

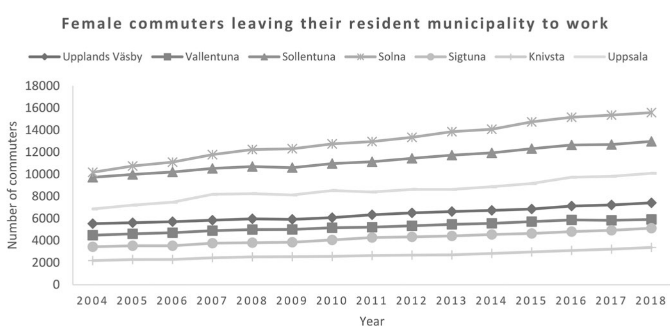

Figure 4. The number of women commuting outside their resident municipality by year (SCB data, Statistics Sweden (SCB), 2020b).

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 was ethically assessed and approved by ESSL, Environment and LUBS (AREA) Faculty Research Ethics Committee of Leeds University, with ethics reference number LTTRAN-079. The consent of the survey participants was sought by including an information sheet detailing the purpose of the survey, how and why they were selected and that all data collected will be held anonymously and no personal data will be retained.

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 behavior 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

Table 1. Descriptive statistics of the survey sample.

Sample characteristics (Sample size, n = 96)	
Gender	*Female (32%), Male (68%)*
Age (Years)	*16–34 (15%), 3001–44(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 traveler (Stockholm – Uppsala)	*Yes (62%), No (38%)*
Commute by rail after Movingo project	*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%)*

Table 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)	[ ]	[ ]

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 tradeoffs 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 traveling 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 summarized in Table 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 patronized 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% of the respondents stated that they started patronizing 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 summarized in Table 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 (Statistics Sweden (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 (Statistics Sweden (SCB), 2018). As expected of commuters as the target study group, 88% of the respondents reported that they were full-time employed.

In terms of PT usage among the respondents, 9.4% of them stated that they currently patronized 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.

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, labeled and efficiently designed SP choice scenarios were generated based on different combinations of the attributes and levels presented in Table 2. Labeled choice set compared to unlabeled 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 & Bliemer, 2004). An example of the choice scenarios, the attributes and their level are presented in Table 2. As presented in the appendix, the ticket integration attribute level 0 refers to nonintegrated monthly ticket (offered by only one operator, SJ) that gives users access to only fast Regional train services between Stockholm & Uppsala, level 1 refers to an integrated monthly ticket (offered by two operators and includes all Stockholm county and Uppsala county PT lines) and level 2 refers to an integrated monthly ticket (offered by three operators and includes all Stockholm county and Uppsala county PT lines as well as SJ's services between Stockholm and Uppsala).

The monthly incremental cost of commuting by car was included in the SP survey and in the model estimation. This was calculated based on travel distance given the Swedish tax department's rate of 1.85 SEK/Km for work trips. The monthly cost of car ownership was not included in the modeling as this is a fixed cost and is, hence, not relevant to the modeling of marginal choices. Monthly incremental train cost is equal to the price of a 30-day season ticket.

84 out of the 96 respondents answered the SP questions, resulting in 756 SP observations. Since efficient SP survey design was used, this sample size is sufficiently large to produce parameter estimates with small standard errors for the attributes of the choice alternatives (Rose & Bliemer, 2004). However, the sampling error in the parameter estimates for the user characteristics could be further reduced by increasing the sample size

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 analyzing and understanding discrete choice behaviors. 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 modeling since it is a very flexible model that approximate any random utility model (Ortúzar et al., 2011; Train, 2009). For a detail description of the mathematical formulations and applications of these methods, the reader is referred to (Ben-Akiva & Lerman, 1985; Hensher & Greene, 2003; Koppelman & Bhat, 2006; Ortúzar et al., 2011; Train, 2009).

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[1], the utility that a commuter assigns to train or car for intercity commuting between Stockholm, s, and Uppsala, u, is given by equation 1.

$$U_{su} = V_{su} + \varepsilon_{su} \tag{1}$$

Where U = Utility, V and ε are respectively the deterministic and random parts of the utility. Given our sampled dataset, equation 1 is transformed into equation 2.

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

Where; t^{v}_{su} = 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, $\beta 1 \ldots z$ 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 3.

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

The probabilities in the mixed logit estimation are given by the integrals of the standard logit model as given in equation 4.

$$\begin{aligned}\mathrm{P}(\mathrm{i} \mid C) &= \mathrm{P}\left(U_{isu} \geq U_{jsu},\ \forall \mathrm{j} \in \mathrm{C},\ \mathrm{j} \neq \mathrm{i}\right) \\ &= \int \left(\frac{\mathrm{e}^{U_{su}}}{\sum_j \mathrm{e}^{U_{su}}}\right) f(\beta \mid \theta) d\beta \end{aligned} \tag{4}$$

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

Several software packages have been developed for estimating these models. The R package, Apollo, developed by the Choice Modeling Center at the University of Leeds, was used in this study (Hess & Palma, 2019). In estimating the

[1]Travel decisions may violate the assumption of rationality and this may lead to biases in estimates.

Table 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 of MNL - LL_U of MMNL)*}					*107.3786 (df = 7, p-value = 000)*				
Variables		Binary Logit					Mixed Logit		
	Mean	*Std. err.*	*t-stat*	*Mean*	*Std error*	*t-stat*	*Std dev*	*Std error*	*t-stat*
Alternative specific constants									
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. The dependent variable is the choice between train or car for commuting.*

ML model, all random parameters were assumed to be normally distributed and 500 Halton draws were used.

4. Empirical results and discussion

Table 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 analyzed by dummy coding it as an integrated monthly ticket and a nonintegrated monthly ticket. The overall model fit statistics presented in Table 3 indicate that both estimated models explained the choice behavior 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 behavior better than the standard logit model, the interpretation of the results is hence based on mixed logit's estimates.

To validate the estimates in Table 3, we compared the value of time (VoT) derived from the mean estimates with that of the Swedish VoT values (Börjesson & Eliasson, 2014). For short distance commuting (trips < 100 Km) within the Stockholm environs, the VoT for car commuting is about 12.1 €/h and that of train is about 7.2 €/h. The respective VoT values from the estimates in Table 3[2] are 12.0 €/h and 14.4 €/h. Implying that the Swedish VoT for short distance car commuting and that from the estimates are about the same. However, since we sampled only car commuters, the VoT for train commuting given by the estimates represents the car commuters VoT for train commuting, which is about twice the Swedish VoT values for people commuting by train in the study area.

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. Thus, the estimated parameter for the ticket integration attribute as shown in Table 3 is consistent with a priori theoretical expectations.

[2]Since the estimates are based on monthly out of pocket commuting cost, we assumed 20 commuting days per month and two trips per day in the VoT calculations. 1 Euro = 10 SEK.

Specifically, the coefficient is positive, indicating that all else being equal, integrated tickets compared to nonintegrated tickets increase the likelihood of car commuters choosing PT for commuting.

Past research confirmed that collaboration among service providers to integrate PT services attracts car users to PT (Buehler et al., 2019; Evangelinos & Schütze, 2012). Concerning season tickets, previous research confirmed a positive relationship between car ownership and season ticket ownership (Chlond et al., 2014; Scott & Axhausen, 2006; Simma and Axhausen, 2003). However, in contrast to nonintegrated 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 traveling across service providers, increased geographic accessibility, cost savings and time savings, thereby making PT more attractive to cross-county car commuters by reducing the generalized travel cost for them (PTEG, 2009; Alhassan et al., 2020; White, 2009). Some major observed benefits 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 nonintegrated, 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 behavior, 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 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.

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 that the habitual nature of a given behavior, such as commuting by car, is an important determinant of actual behavior (Gärling & Axhausen, 2003).

Males and females tend to generally differ in their travel behaviors. 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 patronize 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 behavior by making a choice action more or less automatic (Gärling & Axhausen, 2003).

Since commuting by car is habitual in nature, a possible explanation for this observed behavior may be that females are more reluctant to change this habitual behavior compared to males. Since the observed behavior 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 (Figures 2 and 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 behavior. 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 behavior 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 company car to PT, instead, it has to be combined with policy measures that are geared toward changing organizational transport policies to realize the desired mode shift.

Obviously, the study examined the short term effects of integrated ticketing on mode choice but the long term effects may differ as an improved PT system may in the long term encourage people to relocate to live in the suburbs.

5. Conclusions

That Public Transport (PT) provides a more sustainable future for commuting than does the car is unarguable.

While 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. 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 modeling and comparing the choice behavior 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. This may be due to its synergistic effects such as 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. In terms of policy, transport planners and policymakers can draw from this evidence when developing sustainable 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 nonintegrated 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. Also, we see the need for further analysis in the unexpected finding on gender-based mode choice behavior in the study area.

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Appendix Car Commuter Survey

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