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Seamless public transport ticket inspection: Exploring users' reaction to next-generation ticket inspection

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ABSTRACT

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

Introduction

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

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

While ticket inspection by staff (or human-to-human ticket inspection) refers to the use of security personnel, conductors, bus drivers or other PT staff for fare verification, ticket inspection by turnstiles or fare gates refers to use of barriers for fare verification in, for instance, underground trains, surface trains, and some BRT networks. This analysis focuses on bus (with only front door boarding allowed), underground, and surface train services.

Considering the increasing digitalization and automation of PT systems globally as well as its cost effectiveness, we strongly argued that further attention be given to using established and emerging smart card and mobile ticketing technologies to develop smarter and more user-convenient ticket inspection solutions in the form of "seamless ticket inspection". Seamless travel may generally be defined as the product of a well-integrated PT service as experienced by users. Seamless ticketing as an aspect of seamless travel constitutes an arrangement among PT service providers that makes multimodal PT services accessible to users by permitting them to use the same ticket on every part of the same journey regardless of the ticketing media or geographic boundary. "Seamless ticket inspection" as a new concept used in this research is an aspect of seamless ticketing that allows

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passive and automatic (i.e., without the active participation of the users) fare verification with the help of information and communication technologies (ICT). This study, therefore, explores this "seamless ticket inspection" as the next generation ticket inspection solution. Since this is a new idea, it appears attractive to start the exploration from the demand side, analysing how different user groups will react to it. The exact form and design of the proposed seamless ticket inspection is beyond the scope of the current study.

Existing research on ticket inspection improvements tend to have focused on PT service providers' and ticket inspection service providers' benefits (Barabino et al., 2014; Barabino et al., 2019 Barabino and Salis, 2019; Sasaki, 2014; Reddy et al., 2011; Delfau et al., 2018; Delle Fave et al., 2014; Egu and Bonnel, 2020). The major advantage of the proposed "seamless ticket inspection" over existing ticket inspection approaches is that it reduces or eliminates the burden of ticket inspection on users as the requirement to invest time and effort into direct interactions with ticket inspection staff and turnstiles is mostly removed. It is also less labor-intensive compared to ticket inspection by staff and it eliminates the barrier effects imposed by turnstiles. Barabino et al. (2014) and Barabino et al. (2019) suggested that checking between 34 and 40 out every 1000 passengers is the optimal inspection level for PT service providers to maximize profit given the presence of fare evasion. Regardless of if service providers fall outside this range or not the proposed digitalized ticket inspection system which is less labor-intensive can potentially increase ticket inspection levels and subsequently decrease revenue losses from fare evasion. Additionally, seamless ticket inspection can help reduce bias in enforcement. Its major challenges are expected to be data privacy and connectivity issues.

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

Mass Transit Research Report, 2016 pointed out that fare evasion and user satisfaction as being two of the top three challenges that new ticketing technologies need to address. Similarly, the EU Commission's Urban ITS Expert Group's (2013) guidelines on smart ticketing also pointed out the need for efficient fare inspection at turnstiles and within PT networks to combat fare evasion. Yet, minimal research looked into the customer convenience and satisfaction perspectives of ticket inspection such as users' preferences and satisfaction with current ticket inspection approaches. Interestingly, we are also yet to find previous research on seamless ticket inspection in the transportation literature. TCRP Report 177, 2015 briefly mentioned smart ticket inspection with passive interaction between users' smartphone and readers located at the transit system entry points or the doors of PT vehicles. Yet, research on seamless ticketing has mainly focused on seamless ticket payment issues.

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

Inspection via turnstiles, however, has several disadvantages. Bonfanti and Wagenknecht (2010) pointed out that the use of turnstiles in metro and some BRT systems is relatively less effective in combating fare evasion; probably one of the reasons why many stations equipped with turnstiles are also staffed. Additionally, turnstiles are expensive to build and maintain; they can be visually and physically intrusive and may be impractical to implement under certain conditions (Delbosc and Currie, 2019) and, this means that they are not all-inclusive and are associated with barrier effects that may result in: the creation of queues and reduction station capacity particularly during peak hours; delays due to faulty turnstile machines; minor accidents which may cause injuries or damage to properties; fare evaders disturbing compliant users through piggy-backing or tailgating and turnstile jumping; inconveniences for travelers such as those carrying luggage or similar loads, prams, physically and visually challenged travelers (particularly wheelchair users) and older people. Turnstiles may also pose a significant risk during a stampede in the event of disaster or terror attack in crowded transit stations.

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

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

The two main contributions of the study are:

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

The rest of the paper is organized as follows. The next section describes the methods (the study area, the survey design and analysis). Section 3 presents the empirical results and discussion. Section 4 contains our conclusions and recommendations.

Methods

The case study area

The dataset used in this study was part of the data we collected along the Stockholm – Uppsala corridor, which has the largest share of

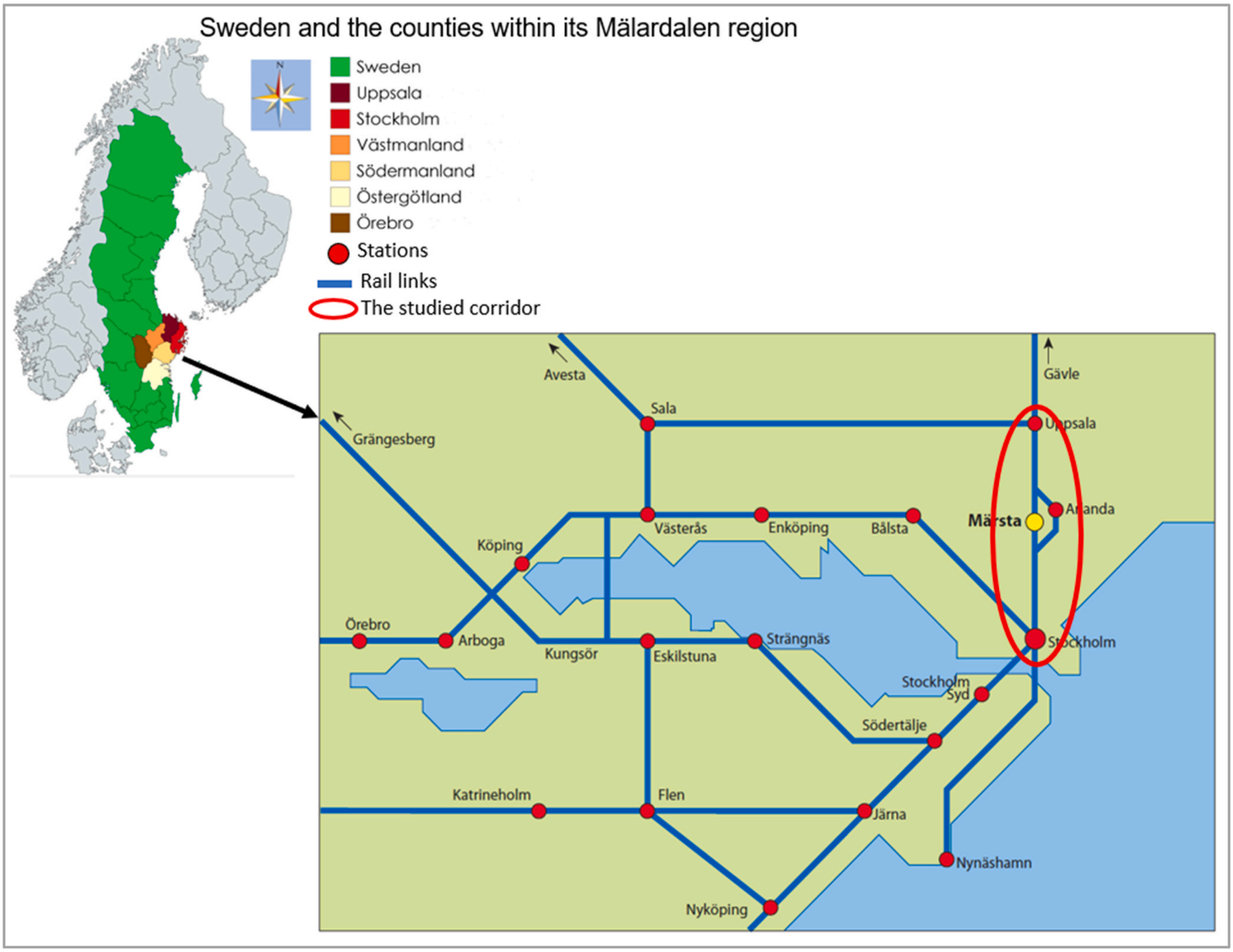

Fig. 1. Counties and the rail network within the Mälardalen region (Banverket, 2007, Modified).

cross-county commuting trips in Sweden, to evaluate the Movingo integrated ticketing scheme. Movingo is a smartcard and mobile phone-based multiple-county commuting ticket that applies to both intercity and intracity bus and train services within the Mälardalen region of Sweden (Fig. 1). The studied corridor, shown in Fig. 1, is mainly served by the National Swedish Railways (SJ), the Stockholm county public transport authority (SL) and Uppsala county public transport authority (UL).

PT fare collection in Sweden is honor-based where passengers are responsible for having a valid ticket before boarding a PT vehicle and, four main ticket inspection approaches are applied – the use of conductors on board trains, bus drivers, ticket inspectors and turnstiles. Thus, encompassing TCRP Report 80 (2002) classification PT fare collection and verification systems as Self-service barrier-free, barrier fare collection, conductor-validated and pay-on-boarding. Among the three services providers in the study area, SJ uses conductors to check tickets onboard but onboard payment is not allowed, UL relies on bus drivers, conductors onboard and ticket inspectors for ensuring that passengers have appropriate tickets, while SL applies bus drivers as well as ticket inspectors and turnstiles for both the commuter train network and subway. That is, whereas Stockholm city at one end of the corridor is heavily "turnstiled", Uppsala city at the other end is zero "turnstiled", with commuters between the two cities experiencing both systems daily. This makes this area a suitable case for analysing the demand for “seamless ticket inspection”.

Survey design

To investigate user preferences for ticket inspection options and the propensity for a seamless ticket inspection among PT users, we extended the work of Alhassan et al. (2019) that investigated commuter' preference for the two most widely used fare inspection approaches (staff and turnstiles), along the Stockholm-Uppsala corridor in relation to the Movingo integrated ticketing scheme.

That is, we designed and collected (with the cooperation of the service providers along the corridor) two panel survey datasets along the corridor, containing 450 respondents in September 2017 and 165 respondents in September 2018. Since the target group was intercounty commuters between Stockholm and Uppsala, the respondents were intercepted between the section Arlanda airport station (located at the county border of Stockholm county, about 41 Km from Stockholm city where the turnstiles are situated) and Uppsala central station. This en-route survey reduced the sampling bias towards respondents within the proximity of the turnstiles' location, Stockholm central station. Additionally, since Stockholm has more job opportunities than Uppsala, most of the commuters live in Uppsala (the city with no turnstiles) and commute to Stockholm to work. The variables included in the in the questionnaire were based on previous relevant travel behavior research (Graham and Mulley, 2011; Allen et al., 2019; Ortúzar et al., 2011). A pilot survey of 30 passengers onboard train was helped in refining the questionnaire. The first survey wave was then undertaken en-route

Table 1
Descriptive analysis of the sample.

Characteristics	Wave 1 (%), n = 450	Wave 2 (%), n = 165
Gender		
Female, Male, Other	56.9, 42.6, 0.5	54.5, 44.8, 0.6
Age (Years)		
16 – 34,35 – 44,45 – 54,55 +	47.5,38.8,13.7	29.6, 47.3, 23
Monthly gross income in SEK		
0–20,000, 20,001–35,000, Over 35,000	24, 29, 47	12.2, 23.6, 64.2
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
Other	2.5	0.6
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
Travel cost paid by employer		
No, Partly, Fully	91.5, 4.1, 4.4	94.5, 3.0, 2.4
Available tickets		
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

(both onboard trains and at stations) within a two-week period during morning and afternoon peak hours as most of the commuters travel during these times. In the second wave, the same respondents were contacted one year later via email and asked to complete the survey questionnaire again online. The resulting response rates were 63% in the first and 36.7% in the second wave. Table 1 provides summary statistics of the sample.

Fig. 2 illustrates the respondent's revealed choices in the two samples considering staff and turnstiles (the two main current ticket inspection approaches). Over 60% of the respondents preferred ticket inspection by turnstiles to that by staff in both samples. As shown in Fig. 3, with the same respondents, the ticket inspection choice set, which contains only two alternatives in the first survey wave (staff and turnstiles), was extended to five in the follow-up survey, i.e.

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

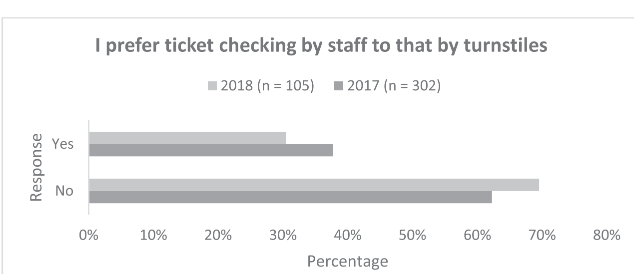

Fig. 2. Commuters' choice between ticket inspection by staff and by turnstiles in a two-wave survey.

While just 4% of the respondents in the sample opted for no ticket inspection at all, 33% of them expressed no opinion about their preferred ticket inspection option, 25% of preferred the non-existing seamless fare inspection. Behavior according to the theory of planned behavior (TPB) is largely determined by the intension to perform that behavior (Ajzen, 1991; Fishbein and Ajzen, 1975). Thus, these stated intentions provide us with some information about the potential demand for seamless ticket inspection even though the actual choices may differ as all intensions do not result in action.

In terms of gender, majority (58%) of the 33% that did not express opinion were females. With regards to age, 28%, 47% and 26% of them were in the age groups 16 – 34, 35 – 54 and 55 above respectively. Since intercity commuters were the target population, respondents of 16 years and above were surveyed as people under 16 years do not fall with the working age in Sweden and hardly study outside their resident county. Concerning income, 6%, 30% and 64% of them were in the income groups 0 – 20,000 SEK, 20,001 – 35,000 SEK and over 35,000 SEK respectively. A logistic regression analysis with a binary dependent variable that takes a value of "No Opinion" or "Opinion" (aggregated for all respondents who chose a ticket inspection option) showed that only income affected the choice at 10% significance level. Respondents of the higher income level were more likely to choose no opinion. This was expected as ticket inspection may not be associated with any direct benefits to users, and this may affect their interest in ticket inspection. Further research will be required to further understand this observation.

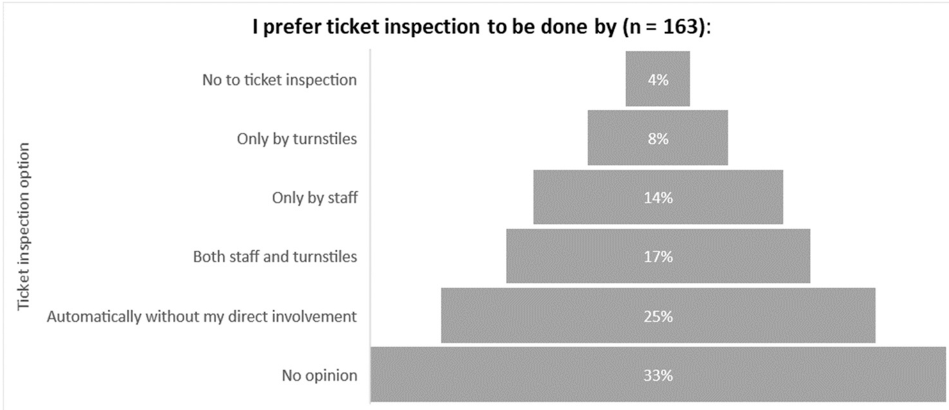

Fig. 3. Extended PT commuters' choice of ticket inspection options.

Analysis

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

By extending the choice set only in the second survey to include the hypothetical option of seamless ticket inspection, a one-way chi-squared ($\chi 2$) goodness of fit test with random expected values was conducted to determine if the respondents still showed a preference for any of the five ticket inspection ticket inspection options. I.e., the null hypothesis was H0: All the five ticket inspection options were chosen randomly (equally or 20% of the time) and that the observed values showed no preference for the options. The alternative hypothesis was that Ha: All the five ticket inspection options were not equally chosen. Note that the "No opinion" responses were removed from the analysis since the respondents were uncertain about their choice.

Using the cross-sectional dataset from the second survey as it contains all the five alternatives, we estimated one multinomial (MNL) and two nested (NL) logit models to analyse the characteristics that correlated with the users' ticket inspection choice. That is, the random utility theory (RUT) which is the most common theoretical basis for discrete choice models was applied. The fundamental assumption of the RUT is that the individual's preference for an alternative given a finite set of alternatives is captured by a latent value he places on all the alternatives called utility, and the alternative with the highest utility in the choice set is then selected. This utility function is normally represented by observable and unobservable parts. The assumption made about the distribution of the unobservable error term defines the mathematical forms of probabilistic choice models such as the logit and probit classes of models. The mathematical formulation of the MNL given our data set is as follows.

The value that an individual PT user, n, assigns to a ticket inspection alternative, i, given the choice set of ticket inspection alternatives, Cj, is given by the utility function

$$U_{in} = V_{ni} + \varepsilon_{in} \tag{1}$$

Where V_{ni} is the deterministic part of the utility, and the ε_{in} is the random part. Eq. (1) can further be expressed as:

$$U_{in} = \beta_z X_{nz} + \alpha_k \tag{2}$$

Where X_{nz} = a socioeconomic characteristic, z, of an individual PT user, n, β_z is a vector of parameters indicating the marginal effects of each specified socioeconomic characteristic on travel utility, and α_k = a parameter representing unobserved part of the utility. It implied that the probability that an individual n chooses an alternative i from a given choice set of alternatives C_j is

$$P(i\,|C) = P(U_{in} \geq U_{nj},\ \forall\ j \in C, j \neq i) = \frac{e^{U_{in}}}{\sum_j e^{U_{nj}}} \tag{3}$$

One major weakness of the MNL is its property of Independence of Irrelevant Alternative (IIA), which restricts the choice probabilities of any two pair of alternatives to be independent of the presence and characteristics of other alternatives in the choice set. Relaxing the above IIA property leads to the nested logit, NL.

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

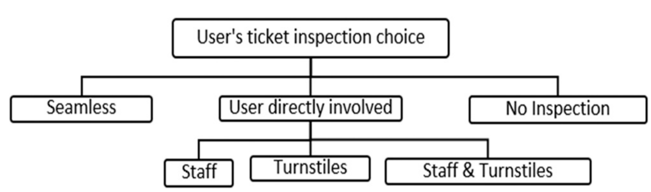

Fig. 4. Nested logit structure 1 for ticket inspection (model NL1).

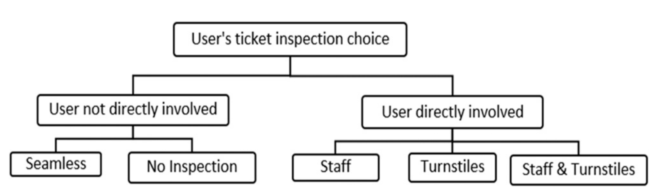

Fig. 5. Nested logit structure 2 for ticket inspection (model NL2).

Table 2
Results of the Estimated Models (The base alternative is “Both staff and turnstiles” (Status quo), Significance codes: 0.01 ‘***’, 0.05 ‘**’, 0.1‘*’).

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

	Seamless ticket inspection			**No ticket inspection**			**Only by staff**			Only by turnstiles		
Variables	**MNL** ***Value (t-stat)***	**NL1**	**NL2**	**MNL** ***Value (t-stat)***	**NL1**	**NL2**	**MNL** ***Value (t-stat)***	**NL1**	**NL2**	**MNL** ***Value(t-stat)***	**NL1**	**NL2** ***Value(t-stat)***
(Intercept)	−0.2312 (−0.61)	−0.1032 (−0.06)	−0.8176 (−2.17 **)	−1.6315 (−1.48)	1.8926 (1.15)	−1.0685 (−1.75)	0.2465 (0.76)	−2.7659 (−1.15)	0.0066 (0.34)	−2.3767 (−3.26***)	−16.76911 (−1.61)	−0.0184 (−0.38)
Logsum parameter		6.3324 (2.15 **)	−3.7078 (−1.35) 6.2028 (3.22 ***)									
Age (Years)												
16–34	2.0987 (3.82 ***)	−11.4563 (−11.97 ***)	2.1602 (4.11 ***)	−8.1648 (−7.45 ***)						−11.4491 (−14.24***)	−20.7299 (−2.48**)	
35–54 (base)												
55 +	2.4586 (3.18 ***)	6.9638 (3.36 ***)	0.6231 (1.11)	4.2729 (3.39 ***)						4.3368 (4.47***)	20.0021 (1.86*)	
Monthly gross income in SEK												
0000–20,000							−1.5665 (−1.92 *)	−4.9762 (−2.07 **)	−0.0382 (−0.39)			
20,001–35,000							−1.0110 (−1.41)	−0.6545 (−0.40)	−0.0264 (−0.35)			
Over 35,000 (base)												
Gender												
Male	−0.9280 (−2.00 **)	−1.5370 (−1.66 *)	−0.8884 (−1.95 *)									
Female (Base)												
Home to Work Door-to-door travel time (Respondents self-reported)				−0.0218 (−11.01 ***)	0.0050 (0.42)	−0.0189 (−3.27 ***)						

explanatory variables were dummy coded, assuming non-linearity in their levels.

We only used the second dataset in the estimation as it contained all the four ticket inspection alternatives and, Apollo, the R package developed by the Choice Modeling Center at the University of Leeds, was used for the estimation (Hess and Palma, 2019).

Empirical results and discussion

Preferences for ticket inspection options

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

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

Factors associated with users' choice of ticket inspection approaches

Table 2 shows the results of the estimated MNL and NL models, given ticket inspection choice as the dependent variable and a set of user characteristics as the explanatory variables. The parameter signs were generally similar in all the three models. Given the data in this study, The MNL model provides the best fit model by examining the likelihood ratio test results in Table 2. The logsum parameters for both nested models fall outside the interval [0,1], which is a precondition for the validity of nested logit models (Koppelman and Bhat, 2006). In addition to the MNL providing the best fit for the dataset, the inconsistency of the logsum parameter estimates with the NL theory further motivated the rejection of the estimated NL models.

The results suggest that PT users in the age category 16–34 years and 55 + years are more likely to accept seamless ticket inspection relative to people in the age category 35–54. As younger adults are more likely to use technology than older adults (Czaja et al., 2006), their choice for seamless ticket inspection was expected. It is, however, surprising that people who are 55 years and above also preferred seamless ticket inspection. This is worth further research as it looks promising for the adoption of the new technology. Similarly, females are more likely to choose this new approach relative to males. Given that females patronize PT services more than males in the study area (Johansson-Stenman, 2002; Polk, 2004), this implies this area has good potential for implementing seamless ticket inspection.

Concerning income, very high-income groups have a higher propensity to choose ticket inspection by staff. This could be because people with very high often travel on first-class train tickets. Thus, often getting the opportunity to enjoy services from staff.

PT users with perceived short door-to-door travel time opted for no ticket inspection. This is keeping with expectations given they have short travel distances and any encounter (s) with ticket inspectors or delays at turnstiles may increase their travel time.

Concluding remarks

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

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

The findings suggest that:

- The users generally prefer automatic ticket inspection to that by staff and digitally automated ticket inspection to mechanically automated (turnstiles). That is, given only turnstiles and staff as the only ticket inspection alternatives, the McNemar's Chi-squared test confirmed that the respondents' choice of ticket inspection by turnstiles over that by staff did not change over time (in the two survey waves). However, by extending the choice set to five alternatives, many of the respondents opted for seamless ticket inspection.
- Major PT user groups such as females and young people have a high tendency to accept seamless ticket inspection, implying that there is a potential market for its implementation.
- People in the high-income class are more likely to choose ticket inspection by staff.
- Generally, users' preference for ticket inspection alternatives correlates with their characteristics. Suggesting that as PT users generally have the freedom to choose how to purchase their tickets, most of them will embrace the freedom to choose how their tickets should be inspected.

In terms of the generalization of the findings in a wider context, it is conceivable to suggest that most younger adults are more likely to choose seamless ticket inspection due to their interest in new technologies. Yet, considering that the study focused on a corridor in Sweden, with most of the respondents being commuters, further validation is needed to be able to generalize the findings beyond the study area particularly capturing social and cultural diversity factors such as race/ethnicity as well as privacy sentiments and enforcement bias issues, which were not included in the current study. We hence recommend that the analysis be extended to a broader area and broader set of PT users. Also, the present study could not explain why the respondents chose different ticket inspection options, we hence, recommend further research in the area.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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