Quantifying individuals' trade-offs between privacy, liberty & security: The case of rail travel in U.K.

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Abstract

Public transport systems have been targets in several terrorist attacks, notably in recent years, resulting in tight security measures worldwide. However, individuals' privacy and liberty often conflict with efforts towards safety and security, making it difficult to assess the benefits of security measures balanced against the costs (e.g. citizens may be stopped, searched and asked to provide personal identification data to authorities without any particular reason). Henceforth, our research question asks, "to what extend would legitimate citizens sacrifice their privacy and liberty rights in exchange for potentially safer and more secure travel?" This paper uses a stated choice experiment to quantify individuals' trade-offs between privacy and security within a real-life context, namely rail travel in the UK. Using a nationwide sample, the empirical analysis yields the importance of improvements in the security infrastructure and identifies areas of concern with regard to privacy and liberty controlling for travel related factors. Further, trade-offs across different security improvements for rail travel are quantified in terms of individuals' willingness to pay extra on top of the average ticket price.

Keywords: Rail, Privacy, Security, Liberty, Rail Travel, Stated Choices, Discrete Choice Models

1 Introduction

Following terrorist attacks targeting public transport systems worldwide, safety and security have become a top priority in the policy agenda of many countries, and particularly the UK. Security measures for air travel have historically received a great deal of attention, but security authorities are now increasingly having to focus upon land-based mass transit systems. These have become a target for terrorist groups due to their vulnerability and ease of access arising from their intrinsically open nature. Additionally, mass transit systems can be both the means and the target for the attack. Terrorists understand how the widespread use of such transportation infrastructure under the fear of terrorist attack has the potential to cause mass panic, disruption and fear.

Recent well known examples include the Madrid bombings of 11 March 2004 and the London bombings of 7th July 2005.

- In Madrid a series of bombs exploded within minutes on 4 packed commuter trains, killing 191 people and injuring 1,841 (BBC News, 2004).
- On the 7th July 2005, bombs exploded on three Tube trains and a bus in Central London. The subsequent London Assembly report from the July bombings concluded that plans, systems and processes that are intended to provide a framework for the response to major incidents in London must be revised and improved (Greater London Authority, 2006).

In responding to such targeting, the security authorities must adapt a wide range of policy measures to mitigate the risk of such events occurring, and to deal with the consequences if they do.

A range of measures may be adopted by authorities in seeking to deal with these challenges. In the UK, these have included legislation and regulations as well as other measures such as campaigns raising awareness of the risk of attacks. Additionally, the UK Department of Transport's Transport Security and Contingencies Team (TRANSEC) (UK Dept. for Transport, 2006) has an important role to play in regard to security arrangements for multi-modal transportation systems. The picture is complicated by the fact that many of these transportation systems are privately owned.

Potential compromise of individuals' privacy and liberty is a countervailing concern. It must be recognised that increased security measures - in many cases - require travellers' compliance with privacy intrusive procedures including screening, release of personal data and even an additional cost in the price of ticket and possible delays. Once implemented, there is considerable pressure to retain such measures as an intelligence gathering tool to pre-empt further attacks. Civil liberties advocates claim that the general imposition of such measures (by comparison to their short term use) negatively affects civil liberties by eroding the rights of the citizen (Crossman et al., 2007). Ultimately, they claim that the general imposition of security measures are, in the long-term, counter-productive to dealing with the terrorist threat and may actually be helping the terrorists achieve their objectives by reducing trust in the state.

In the immediate aftermath of an event, citizens often report being prepared to undergo compromises of their privacy and liberty in order to obtain security benefits. Respondents to a question in the 23rd report of the British Social Attitudes Survey indicated that they were prepared to accept some loss of privacy and liberty to provide for security. For example, 71% of respondents to this survey said that the implementation of compulsory identity cards for all adults is a price worth paying for increased security. Also, 79% thought that allowing the police to detain people for more than a week or so without charge, if the police suspect them of involvement in terrorism, is 'a price worth paying'. (Johnson and Gearty, 2007).

In this context, much of the analytical work with respect to improved security of public transport has been focusing on the costs of security improvements and to a lesser extent on the benefits of security. Quantifying the benefits of security is a difficult task, since the monetisation of benefits is difficult to achieve and the total extent of the risk can never be truly known (although with appropriate information and accurate analysis may be accurately predicted). Furthermore, some of the security benefits might be difficult to pin down, such as the deterrent effect of seeing security personnel at a station or the feelings of reassurance that the presence of security measures can provide. Indeed, the latter has been identified as a key benefit of many security measures (Clarke, 2008). In relation to certain policy measures (for example, the National Identity Register) the government has listed the stated security benefits as helping in the fight against terrorism and illegal immigration (Smith, 2008).

To date, individuals' liberty, privacy and security have been generally examined through opinion surveys. Examples include the February 2008 ICM Omnibus poll conducted for the Joseph Rowntree Reform Trust (2008) and research like the British Social Attitudes Survey 2006 (Johnson and Gearty, 2007). In the context of rail travel, in 2006 the UK Department for Transport conducted capabilities trials of various passenger screening security measures at stations as part of its London Underground and National Railway program (LUNR) programme. This also includes public attitude surveys (UK Dept. for Transport, 2008). These concluded that the public accepted the need for security measures but would not tolerate delays and invasions of privacy (UK Dept. for Transport, 2008).

An opinion questionnaire, however, would only be capable of collecting uni-dimensional opinions (e.g. yes or no, sensitive vs. non sensitive, etc.) while these would be expressed within a vague context. This is likely, however, to lead to ideologically based responses. Clearly, opinion surveys do not offer the research basis for policy-making in the context of security interventions. Hence, there is a need for an evidence-based approach that would enable policy makers to evaluate the way various security measures reflect upon behavioural, social and economic issues and, most importantly, effective resource allocation. Privacy Impact Assessments (PIAs) consist a relatively recent tool that aim to take into consideration the effect of new policy measures or initiatives upon individuals' privacy. However, current methodologies for undertaking such assessments only focus upon qualitative research methods such as direct consultation, open meetings and focus groups to gather first hand data on individual views on how certain measures or initiatives would affect their privacy (ICO, 2007).

While research on the security of public transport systems has been extensive from a public spending and benefits perspective, individuals' preferences have hardly been explored, having been focused merely on opinion surveys. To the best of our knowledge, we are not aware of any empirical research on quantifying individuals' trade-offs for a specific set of security, privacy and travel attributes concerning public transport.

The aim of this paper is to demonstrate how stated choice (SC) methods (Louviere et al.,

2000) can be used in order to empirically examine how individuals trade-off between privacy and security when they travel on the national rail system in the UK. In particular, the objectives of this paper are to determine the key factors driving individuals' choice between alternative scenarios of rail travel and to determine individuals' willingness-to-pay (WTP) for specific aspects of security and privacy. Questions that guided this study include: (i) what are the policy interventions that individuals would consider as important for their security or just intrusive when they consider travelling on the national rail system? (ii) Is there any heterogeneity in preferences among individuals? That is, do preferences vary according to socio-demographic characteristics, ideology and attitudes? And finally, (iii) what is the WTP of individuals for security related policy interventions?

Following this section, the paper is organised as follows. Firstly, we discuss the development of the stated choice experiment and the administration of the data collection. Next, we report the modelling results of this experiment, estimates of WTP and discuss the findings of the analyses. Finally, conclusions and a discussion of policy implications are summarised in the last section.

2. Methodology: Survey Design and Administration

2.1 Stated Choice Experimental Design

The rationale for using stated choice methods in this study is based on the absence of existing data (i.e., revealed preferences) that would enable the investigation of issues related to individuals' security, privacy and liberty. In particular, it was necessary to capture individuals' willingness to trade-off privacy and liberty against improved security. Moreover, stated choice methods enable the researcher to quantify these trade-offs in terms of willingness-to-pay (WTP) for a particular security improvement. The research objective in this study was to examine whether security improvements concerning rail travel would be acceptable by individuals and what factors are likely to influence individuals' decisions when privacy, liberty and security may be in conflict. Stated choice methods were therefore judged to have the potential to provide useful insights in answering such questions.

Stated choice (SC) methods are a methodological toolkit that has been used extensively in the fields of marketing, health, environmental and transport economics (Louviere and Woodworth, 1983, Louviere, 1992, Louviere et al., 2000, Ryan et al., 2001). SC methods elicit respondents' choices from hypothetical - though realistic - scenarios that describe different options using a set of attributes and their levels (values). The choices expressed indicate the relative importance of the attributes that characterise the scenarios (see, Hensher et al., 2005, Louviere et al., 2000).

Application of stated choice methods is particularly useful when alternatives or certain characteristics of these alternatives are currently not available. For example, this can be the case with alternatives that involve new technologies or new policy interventions. The objective is to replicate individuals' decision-making structures to understand the combinations of features or attributes that consumers value the most. Further, stated choice methods recognise that there are no "perfect" choices. Each alternative option has a particular set of advantages and disadvantages that an individual must explicitly trade-off when selecting between competing options. Thus, individuals are presented with competing options and are asked to jointly compare the options based on their attributes. Stated choice methods' main drawback, however, is that such data is based around what individuals state they would do in hypothetical situations, which may not exactly correspond with what they would do if faced with the same choice in real life (Arrow et al., 1993, Blackburn et al., 1994).

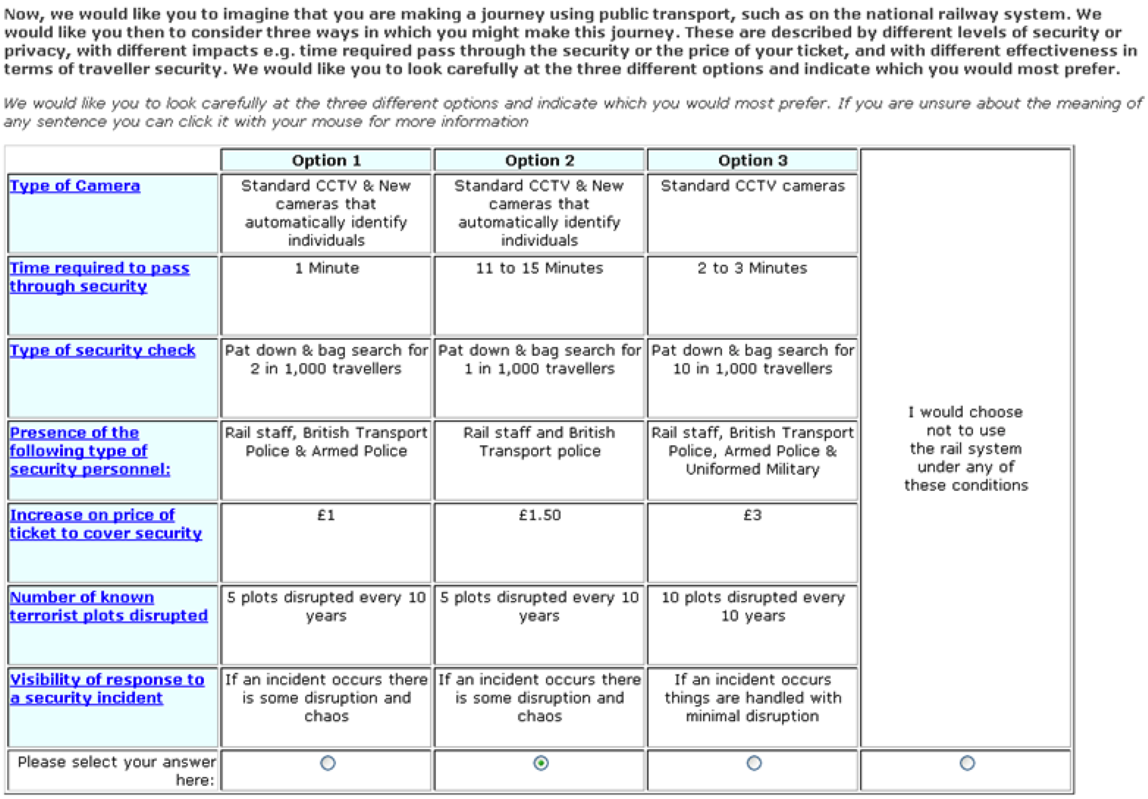
Relevant attributes and their levels were identified through in-depth interviews with data protection (Hosein, 2008) and security officials (Clarke, 2007, Clarke, 2008), press-articles (BBC, 2006) and literature review research (Cozens et al., 2002, UK Dept. for Transport, 2008, UK Dept. for Transport, 2006, Srinivasan et al., 2006). The trade-offs introduced to respondents involved three main categories of relevant attributes: security improvements in terms of surveillance equipment and presence of personnel and security checks; potential benefits such as likelihood that a terrorist plot may be disrupted and how things may be handled in case an incident occurs, and travel related characteristics such as waiting time to pass through security and additional cost to cover security improvements. The complete list of attributes and levels used in the choice experiment is shown in Table 1.

Table 1: Attributes and levels of the rail travel scenarios

Attribute	**Levels**
Type of camera	(1) None (2) Standard CCTV cameras (3) Standard CCTV and new cameras that automatically identify individuals
Time required to pass through security	(1) 1 minute (2) 2-3 minutes (3) 4-7 minutes (4) 8-10 minutes (5) 11-15 minutes
Type of security check	(1) No Checks (2) Pat down and bag search for 1 in 1000 travellers (3) Pat down and bag search for 2 in 1000 travellers (4) Pat down and bag search for 10 in 1000 travellers (5) Metal detector / X-ray for all
Presence of the following type of security personnel	(1) Rail Staff (2) Rail Staff and British transport police (3) Rail Staff, British transport police and armed police (4) Rail Staff, British transport police, armed police and uniformed military
Increase on price of ticket to cover security	(1) £0.75 (2) £1.00 (3) £1.50 (4) £3.00

Number of known terrorist plots disrupted	(1) 1 plot disrupted every 10 years (2) 1-2 plots disrupted every 10 years (3) 2-3 plots disrupted every 10 years (4) 5 plots disrupted every 10 years (5) 10 plots disrupted every 10 years (6) 20 plots disrupted every 10 years
Visibility of response to a security incident	(1) If an incident occurs you are not aware of it (2) If an incident occurs then you are aware of that when you get back home (3) If an incident occurs things are handled with minimal disruption (4) If an incident occurs there is some disruption and chaos (5) If an incident occurs there is lots of disruption and chaos

The SC experiment in this study was set in the context of choosing between three alternative options each describing situations that the respondent may experience upon travelling on UK's national rail network. In particular, respondents were asked to "Imagine that you are making a journey using public transport, such as on the national railway system. We would like you then to consider three ways in which you might make this journey. These are described by different levels of security or privacy". As shown in Figure 1, an additional fourth option in the scenario allowed respondents to opt-out from choosing one of the first three alternatives, stating, "I would choose not to use the rail system under any of these conditions". Each alternative differed in terms of security measures, potential benefits from improved security, and travel related characteristics.



Now, we would like you to imagine that you are making a journey using public transport, such as on the national railway system. We would like you then to consider three ways in which you might make this journey. These are described by different levels of security or privacy, with different impacts e.g. time required pass through the security or the price of your ticket, and with different effectiveness in terms of traveller security. We would like you to look carefully at the three different options and indicate which you would most prefer.

We would like you to look carefully at the three different options and indicate which you would most prefer. If you are unsure about the meaning of any sentence you can click it with your mouse for more information

	Option 1	Option 2	Option 3	
Type of Camera	Standard CCTV & New cameras that automatically identify individuals	Standard CCTV & New cameras that automatically identify individuals	Standard CCTV cameras	I would choose not to use the rail system under any of these conditions
Time required to pass through security	1 Minute	11 to 15 Minutes	2 to 3 Minutes	
Type of security check	Pat down & bag search for 2 in 1,000 travellers	Pat down & bag search for 1 in 1,000 travellers	Pat down & bag search for 10 in 1,000 travellers	
Presence of the following type of security personnel:	Rail staff, British Transport Police & Armed Police	Rail staff and British Transport police	Rail staff, British Transport Police, Armed Police & Uniformed Military	
Increase on price of ticket to cover security	£1	£1.50	£3	
Number of known terrorist plots disrupted	5 plots disrupted every 10 years	5 plots disrupted every 10 years	10 plots disrupted every 10 years	
Visibility of response to a security incident	If an incident occurs there is some disruption and chaos	If an incident occurs there is some disruption and chaos	If an incident occurs things are handled with minimal disruption	
Please select your answer here:	○	◉	○	○

Figure 1: A choice scenario example

The combination of all attributes and levels would result in a significantly large number of choice scenarios, which would be impractical to present as a whole to respondents. Therefore, we constructed an experimental design matrix consisting of 120 scenarios using the SAS macros for discrete choice experiments (Kuhfeld, 2009). While the combination of attributes and attribute levels in Table 1 (i.e., $3^3 * 5^9 * 4^6 * 6^3$) does not result into an absolutely orthogonal design matrix, the 120 scenarios consist a well-conditioned matrix, which would explain main effects with reasonable statistical efficiency (Bliemer and Rose, 2006, Louviere et al., 2000). Each respondent received a random sample of eight different choice scenarios.

Some additional constraints were applied to the design matrix to ensure that the scenarios were internally consistent. First, security checks could not be performed using "Metal detector - X-ray" applied to all travellers if the waiting time within an alternative option was less than four (4) minutes. Second, to allow for realistic representation of a choice scenario, when uniformed military was proposed, then other security improvements (i.e., advanced Closed Circuit Television (CCTV) cameras that enable real-time face recognition) and tighter security checks (i.e., more than 2 checks in 1,000 travellers) should be in place. Overall, we attempted to control for other cases, so that none of the choice scenarios would seem unrealistic or dominant compared to the other two options.

2.2 Background Questions

In addition to the stated choice scenarios, data were also collected on the social and economic characteristics of the respondents (e.g., age, gender, employment status, income, frequency of travel by rail, etc.) and their media preferences including newspapers and news channels. Also, respondents were asked general questions about their attitudes towards security, liberty and privacy known as the "Distrust Index" (Kumaraguru and Cranon, 2005, Louis Harris et al., 1994). Finally, the survey included a number of cognitive questions concerning the SC scenarios. The cognitive questions were designed to ensure that respondents understood and attributed meanings to the choice scenarios that were consistent both with the intent of the survey and with the interpretations of the other survey respondents.

2.3 Survey Implementation and Data

The stated choice experiment was conducted through the Internet between the 17 and 19 September 2008. Prior its official release, the survey instrument was modified in accordance with post-survey cognitive questions from pilot-surveying 260 individuals between 27 and 29 June 2008. The 2,058 participants in the final sample were recruited from a nation-wide panel of Internet users who were registered with "Research Now" (www.researchnow.co.uk), a market research agency with the largest panel of Internet users in the UK. The e-mail invitation to the survey was originally sent to 15,214 individuals yielding a response rate of approximately 24%, after excluding the number of individuals who did not meet eligibility criteria (e.g. age $<$ 18 years) (0.8%), provided incomplete information (7.9%) or the sample quota had already been collected (4.5%). Descriptive statistics of the sample are reported in Table 2.

The sample represents well the general population in terms of gender and age. As expected with Internet surveys, however, the proportion of individuals with high level of education in the sample is remarkably higher than the proportions in 2001 UK Census (www.statistics.gov.uk/census2001). In comparison with employment status of our sample (see Table 2), our data over-represents retired individuals (28% vs. 13.4%) and under-represents students compared to the 2001 UK census. Clearly, because of the use of the Internet as the data collection mode and differences in the socio-economic profiles of our sample compared to the 2001 UK census, there could be no claim that the collected sample is statistically representative of the UK population. However, one may argue that it is representative of an active segment of the population in the UK, which does match with the demographic profiles (age and gender) of the UK census.

With regard to their attitudes to privacy, liberty and security, as reported in Table 2, 95.8% of the respondents rated the statement "protecting the privacy of my personal information" as important or very important. Also, 96.3% agreed that "taking action against important security risks" was important or very important. Interestingly, a remarkably lower percentage (85.7%) of respondents - as compared with the previous statements - agreed that "defending current liberties and human rights" was important or very important. The responses of participants to the distrust index questions (Kumaraguru and Cranon, 2005, Louis Harris et al., 1994) showed that 33.8% of respondents had high levels of distrust whereas only a 4.8% had no distrust at all. Finally, based on newspaper preferences, respondents were classified ideologically into conservative (55.8%) and non-conservative (44.2%).

Table 2: Sample characteristics (Sample size: 2,058)

Variable	**Sample (%)**	**2001 UK Census (%)**
Gender: Female	52	52
Age Group		
18-24	7	16
25-34	13	16
35-44	19	19
45-54	18	16
55-64	21	14
65 and over	22	20
Education Level		
None	11	29
O level / GCSE	32	36
A level / CSE	26	8
Graduate	32	20
Other	-	7
Occupational Status		
Working full-time	42	59.6
Working part-time	16	
Student	4	7.2
Retired	28	13.4
Seeking work	3	4.5
Other	7	15.3
Annual Income		
Less than £29,000	58	-
£30,000 - £69,999	26	-
£70,000 or higher	2	-
Not reported	14	-
Rail user	80.1	-
Attitudes to Privacy, Liberty and Security		
Privacy concerned	95.8	-
Liberty Concerned	85.7	-
Security Concerned	96.3	-
Distrust Index		
High	33.8	-
Medium	37.9	-
Low	23.5	-
No Distrust	4.8	-

3. Results and Discussion

The stated preference data were first checked for accuracy. Sixty-six (66) records were discarded as these were respondents who felt that they did not understand the survey (Rouwendal and De Blaeij, 2004). Also, as in any stated preference survey, there is a risk of non-trading behaviour, that is respondents always choosing the same option, and this can have significant impact on model results (Hess et al., 2008). To alleviate these issues, the 31 respondents who consistently chose the same option across the eight scenarios were also excluded from the analysis. Thus, the analysis of the stated choice scenarios was conducted using 1,961 observations.

Prior to the analysis, the stated choice data were dummy coded according to the levels of the attributes (Hensher et al., 2005). In addition, the time required to pass through security, increase on price of ticket to cover security and the number of known terrorist plots disrupted attributes were also tested as cardinal-linear variables in the model specification. Consequently, the time required to pass though security took the levels 1, 2.5, 5.5, 9 and 13 minutes.

Similarly, the number of known terrorist plots disrupted was coded as 1, 1.5, 2.5, 5, 10, and 20. The choice experiment attributes in the "I would choose not to use the rail system under any of these conditions" option were coded with zero values for each of the attributes .

3.1 Conditional Logit Model Specification

The stated choices experiment was designed with the assumption that the observable utility function would follow a strictly additive form. The model was specified so that the probability of selecting a particular option was a function of seven attributes. Using ALOGIT (2005) and the 15,688 choices elicited from 1,961 respondents, the highest value of the log-likelihood function was found for the specification shown in the first column of Table 3. The model reported has been corrected for the interdependence of SP observations (i.e., multiple responses per individual) using the "jack-knife" procedure.

The overall fit of the model, as measured by McFadden's ρ^2 indicates a moderate fit, and the coefficients are statistically significant and intuitively correct. All the potential security attributes that may compete with privacy and liberty are significant factors in the choice of a particular scenario of travel on the national rail network in the UK. The positive signs on the majority of the coefficients related to improved security measures, including type of camera, security checks and the presence of specialised security personnel, show that these measures act to increase the probability that a particular travel situation (option) is selected.

Table 3: MNL estimation results

Variable	**Coeff.**	**t-stat**
Type of security camera		
None	Base	-
Standard CCTV	0.5523	16.2
Advanced CCTV		
x (1, if liberty unconcerned; 0 otherwise)	1.1168	10.6
x (1, if liberty concerned and education A-level or lower; 0 otherwise)	0.8856	18.5
x (1, if liberty concerned and education higher than A-level; 0 otherwise)	0.6356	10.6

Type of security check		
No checks	Base	-
Pat down and bag search for 1 in 1,000 travellers	0.2341	6.5
Pat down and bag search for 2 in 1,000 travellers	0.2341	6.5
Pat down and bag search for 10 in 1,000 travellers		
x (1, if white collar worker; 0 otherwise)	0.2341	6.5
x (1, if blue collar worker; 0 otherwise)	0.4454	8.9
Metal detector and X-rays for all		
x (1, if female; 0, otherwise)	0.83	11.2
x (1, if male and education level is A-level or higher; 0 otherwise)	0.2341	6.5
x (1, if male and education level is lower than A-level; 0 otherwise)	0.83	11.2
Presence of the following type of security personnel		
Rail staff	Base	-
Rail staff and British transport police	0.1974	8.1
Rail staff, British transport police and armed police		
x (1, if white collar conservative or blue collar; 0 otherwise)	0.1974	8.1
Rail staff, British transport police, armed police and uniformed military		
x (1 if blue collar worker; 0 otherwise)	0.1974	8.1
x (1 if white collar worker and conservative; 0 otherwise)	0.163	2.8
x (1 if white collar worker and non conservative; 0 otherwise)	-0.1992	-3.7
Increase on price of ticket to cover security		
x (1, annual income is less than £20,000; 0 otherwise)	-0.3321	-12.6
x (1, annual income is £20,000 or higher ; 0 otherwise)	-0.2245	-8.6
x (1, annual income is not reported; 0 otherwise)	-0.459	-8.7
Time required to pass through security	-0.0732	-25.6
Number of known terrorist plots disrupted (the three following terms are additive)		
x (1)	0.2963	13
x (1, if plots greater than 2.5; 0 otherwise)	-0.2285	-9.0
x (1, if plots greater than 10; 0 otherwise)	-0.0433	-5.7
Visibility of response to a security incident		
If an incident occurs you are not aware of it	Base	-
If an incident occurs then you are aware of that when you get back home	0	0
If an incident occurs things are handled with minimal disruption	0	0
If an incident occurs there is some disruption and chaos	-0.3555	-13.6
If an incident occurs there is lots of disruption and chaos	-0.6502	-13.5
Variables in the "I would choose not to use the rail system under any of these conditions"		
Male	0.3129	3.3
Individual is highly distrustful (1, if Distrust Index = High; 0 otherwise)	-0.2308	-2.3
Individual lives in Southern UK (1, if yes; 0 otherwise)	0.4144	3.5
Age 18 - 24 (1, if yes; 0 otherwise)	-0.714	-3.2
Individual is security concerned (1, if yes; 0 otherwise)	-1.2336	-4.9
Individual travels by rail at least twice a year (1, if yes; 0 otherwise)	-0.3481	-2.9
Individual attends public events more than once per year (1 if yes; 0 otherwise)	-0.2694	-2.6
Constant, Option 1	-1.5768	-6.2
Constant, Option 2	-1.5555	-6.1
Constant, Option 3	-1.7689	-6.8
No. of observations	1961* 8 = 15,688	
Log-likelihood function: sample shares (constants only), L(c)		-21,386.10
Log-likelihood function: model, L(b)		-19,150.00
Rho-square (0) [ρ^2 = 1 - [L(b)/L(0)]		0.105
Rho-square (c) [ρ^2 = 1 - [L(b)/L(c)]		0.119

Following an initial phase of model development that used generic coefficients for all respondents in the sample, we tested whether different groups of respondents placed different valuations on any of the attributes in the choice experiment. To identify possible differences we examined cross tables that summarised the in-the-sample predictive ability of the model.

These tests were conducted on a comprehensive list of respondent's attitudes (e.g. the Distrust Index) and background variables including age group, gender, socio-economic group, income band and education level.

The negative signs on the price and time required to pass through security coefficients indicate that respondents made rational choices and prefer alternatives that are less costly and require shorter times to pass through security checks. Also, the valuation on the increase of ticket price was different across income bands. As expected, respondents in the lowest income band (<£20,000 per year) placed a higher value on the potential extra cost of the ticket to cover security than respondents belonging in the higher income band (>£20,000 per year). Interestingly, respondents who refused to report their income placed an even higher value on the cost of the ticket. General trends regarding the acceptability of related fare increases and time delays are in line with previous opinion surveys undertaken in the UK (UK Dept. for Transport, 2005, UK Dept. for Transport, 2006, UK Dept. for Transport, 2008).

Overall, respondents would prefer travel situations that offer some type of monitoring system, being either standard CCTV cameras or advanced CCTV cameras that enable real-time face recognition. The value placed on improving CCTV cameras to advanced CCTV cameras differed if respondents were identified as liberty concerned and also, according to respondents' education level. In particular, respondents with higher education level placed a lower value on the presence of advanced CCTV cameras compared to individuals with lower education level (i.e., A-level or lower). These results agree with previous opinion surveys and focus-group research findings. For example, respondents in the Crime Concern/Transport and Travel Research (1997) felt that a broad range of measures including more staff, improved levels of lighting, CCTV and help points might enhance security and perceptions of personal security for a wide variety of public transport settings. Also, the UK Department of Transport (2006) opinion poll found that respondents were in general comfortable with the presence of CCTV cameras at rail stations.

With regard to the type of security check, respondents would generally prefer travel situations that involve some type of security check. This finding agrees with findings from the UK Department for Transport (2005) study where the majority (71%) of respondents supported the use of body searches at least twice a week or more. It is worth noting, however, that our study findings indicate that, on average, respondents would prefer less intrusive security checks (i.e., X-ray imaging) than hand searching. Moreover, different segments of respondents in the sample (white vs. blue collar workers) placed different values on pat down and bag search for 10 in 1,000 travellers whereas preferences for metal detector and x-rays for all were different across gender and education level.

Concerning the different levels of security personnel, the estimation results highlight that respondents would prefer travel situations where more specialised security personnel - other than rail staff only - are present at rail stations. Evidence from previous research has shown that more uniformed staff has been found to enhance security awareness (Collins, 1993, quoted from Cozens et al., 2002). As shown in Table 3, blue-collar and conservative white-collar workers placed higher value to the presence of more specialised personnel even for the presence of uniformed military. In contrast, non-conservative white-collar workers were less likely to choose a situation where uniformed military were present over situations with rail staff only. The number of known terrorist plots disrupted attribute was considered as a potential benefit of improved security measures. While the true number of plots is unbounded and could not be easily quantified nor even defined, we used as the baseline of 30 terrorist plots known to the authorities as defined from statements from the Head of MI5, Jonathan Evans in (2007) and also, Dame Eliza Manningham-Buller (2006) former Head of MI5 to define the range of the number of known terrorist plots disrupted attribute.

One of our hypotheses here was that respondents would trade-off security improvements that would allow more terrorist plots to be disrupted against intrusions on liberty or privacy . In line with a priori expectations, as shown in Table 3, respondents would prefer situations where more terrorist plots are disrupted. The estimated coefficients are the result of a piecewise-linear specification with two points of inflection at 2.5 and10 plots every 10 years, which show that the marginal utility of this attribute increases as the number of plots increases.

Also, the results show that respondents found no different between levels one and two of the visibility of response to a security incident attribute. However, there were less likely to choose options where an incident would cause some disruption or lots of disruption and chaos.

Finally, the estimation results provided an indication of the respondents who were more or less likely to opt-out and choose the forth option offered, i.e. indicate that they would not travel on the rail network under any of the situations offered. As shown in Table 3, males, respondents who scored high values of the Distrust Index and those living in the southern parts of Great Britain were more likely to opt-out. In contrast, individuals aged between 18-24 years, security concerned, frequent rail travellers and people who attend public events were more likely to choose one of the first three options.

3.2 Willingness to Pay Estimates

The Stated Choices method is consistent with utility maximisation and demand theory (Louviere et al., 2000, Ortuzar and Willumsen, 2001). Once parameter estimates are obtained by the use of the most appropriate model, a willingness-to-pay (WTP) measure for changes in the level of a given attribute can be derived (Hensher et al., 2005). Let represents the utility of the base level (e.g., no cameras) for a segment in the sample i (e.g. males) with proportion αi; and represents the utility of the same segment i for a security improvement (e.g., advanced CCTV cameras) compared to base level. The coefficient of the price increase on ticket to cover security, βprice, gives the marginal utility of price:

$$WTP = -\beta_{price}^{-1} ln \frac{\sum_i \alpha_i * exp(V_1^1)}{\sum_i \alpha_i * exp(V_i^0)} \tag{1}$$

In a simple linear model each attribute in the utility expression and price are associated with one coefficient each. In that case, equation [1] can be simplified for any individual to the ratio of two utility parameters and provide an estimate of WTP:

$$WTP = -1(\frac{\beta_{securityintervention}}{\beta price}) \tag{2}$$

The best fitting model in this study describes utility functions with segmentation with respect to some of the interventions with the respondents' characteristics and also segmentation on the cost coefficient βprice, across three income bands (see Table 3). Estimates can be used to calculate the value assigned by the respondents to each of the security improvements, potential benefits and the time delay to go through security.

Table 4 presents a weighted average measure of willingness-to-pay (WTPwa) over income groups is given as:

$$WTP_{wa} = \sum_j \delta_j * WTP_j \tag{3}$$

where δj is the proportion of respondents in the sample under income band j (i.e., less than £20,000; more than £20,000; unknown). WTP_j is the willingness-to-pay of individuals belonging to income band j and can be calculated by applying equation [1] to each of the j income bands:

$$WTP_j = -\beta_{j_{price}} ln(\frac{\sum_i \alpha_i * exp(V_i^1)}{\sum_i(\alpha * exp(V_i^0))} \tag{4}$$

The results show that on average respondents derive significant values from improved security measures. The highest (weighted average) valuations, £4.44 and £3.54 on top of the average price of a ticket, were placed on the efforts to increase the effectiveness of security authorities, namely to able to disrupt terrorist plots - i.e., 20 plots and 10 plots per 10 years, respectively. The next highest valuation of £3.13 was placed for reducing waiting times to pass through security from 13 minutes to 1 minute. With regard to CCTV cameras at rail stations, respondents perceived security benefits of the more privacy intrusive cameras to outweigh their possible concerns about privacy, and therefore, place a value of £3.10 for advanced CCTV cameras that enable face recognition to be installed at rail stations. Also, respondents placed an average willingness to pay value of £2.41 for improving security checks to measures involving metal detectors and X-rays for all. Finally, respondents perceived that more specialised security personnel would be necessary. However, the presence of uniformed military was valued less than other types of security personnel.

Table 4: WTP estimates in British Pounds

Base level	**Change level**	**<£20,000**	**>£20,000**	**Unknown**	WTP_wa
Type of security camera					
None	Standard CCTV	1.66 (0.34)	2.46 (0.66)	1.20 (0.31)	2.03
None	Advanced CCTV	2.55 (0.46)	3.77 (0.93)	1.84 (0.44)	3.10
Type of security check					
No checks	Pat down and bag search for 1 in 1,000 travellers	0.71 (0.23)	1.04 (0.37)	0.51 (0.18)	0.86
No checks	Pat down and bag search for 2 in 1,000 travellers	0.71 (0.23)	1.04 (0.37)	0.51 (0.19)	0.86
No checks	Pat down and bag search for 10 in 1,000 travellers	0.95 (0.24)	1.40 (0.42)	0.69 (0.21)	1.15
No checks	Metal detector and X-rays for all	1.98 (0.43)	2.93 (0.79)	1.43 (0.39)	2.41
Presence of the following type of security personnel					
Rail staff	Rail staff and British Transport Police	0.59 (0.16)	0.88 (0.28)	0.43 (0.14)	0.72

Rail staff	Rail staff, British Transport Police and Armed Police	0.43 (0.12)	0.64 (0.20)	0.31 (0.10)	0.52
Rail staff	Rail staff, British transport police, armed police and uniformed military	0.23 (0.18)	0.34 (0.27)	0.17 (0.14)	0.28
Visibility of response to a security incident					
If an incident occurs there is lots of disruption and chaos	If an incident occurs then you are not aware of it	1.96 (0.41)	2.90 (0.78)	1.42 (0.37)	2.38
If an incident occurs there is lots of disruption and chaos	If an incident occurs then you are aware of it when you get back home	1.96 (0.41)	2.90 (0.78)	1.42 (0.37)	2.38
If an incident occurs there is lots of disruption and chaos	If an incident occurs then things are handled with minimal disruption	0.89 (0.22)	1.31 (0.40)	0.64 (0.20)	1.08
If an incident occurs there is lots of disruption and chaos	If an incident occurs then there is some disruption and chaos	0.00 (0.00)	0.00 (0.00)	0.00 0.00	
Time required to pass through security					
13 min	1 min	2.66 (0.46)	3.73 (0.94)	1.94 (0.45)	3.13
13 min	2.5 min	2.23 (0.40)	3.47 (0.82)	1.70 (0.39)	2.82
13 min	5.5 min	1.66 (0.28)	2.48 (0.59)	1.21 (0.28)	2.04
13 min	9 min	0.89 (0.15)	1.32 (0.31)	0.65 (0.15)	1.08
Number of known terrorist plots that may be disrupted					
1 plot / 10 years	20 plots / 10 years	3.63 (0.60)	5.41 (1.26)	2.65 (0.61)	4.44
1 plot / 10 years	10 plots / 10 years	2.89 (0.48)	4.30 (1.05)	2.10 (0.48)	3.54
1 plot / 10 years	5 plots / 10 years	1.86 (0.34)	2.77 (0.68)	1.36 (0.33)	2.28
1 plot / 10 years	2-3 plots / 10 years	1.35 (0.29)	2.01 (0.56)	0.98 (0.26)	1.65
1 plot / 10 years	1-2 plots / 10 years	0.45 (0.1)	0.67 (0.18)	0.33 (0.08)	0.55

4. Conclusions

This paper is a first attempt to employ Stated Preference Discrete Choice Modelling (SPDCM) methods in order to assess people's preferences across security, privacy and liberty. The case study focuses on a real-life situation under which individuals are about to travel using UK's national rail network. Estimates obtained from the development of a conditional multinomial logit model indicate the respondents' characteristics to the valuation of security, privacy and liberty issues in the context of rail travel are statistically significant. Also, the results indicate that on average, respondents are willing to pay for security improvements implying that potential concerns about privacy and security are outweighed by their preferences for security. However, we do identify segments in the sample that are against measures that involve for example, presence of uniformed military at rail stations.

Throughout this paper, it is shown that application of SPDCM methods can be a comprehensive toolkit for risk assessment that enables researchers to address these issues in a systematic way. In particular, it allows researchers to obtain views of citizens subject to varying levels of security infrastructure and measures, and quantify the trade-offs in monetary terms (i.e., WTP). For example, within the context of privacy impact assessments, the application of such methods would allow researchers to identify the gap between policy and preferences and respond to cases where security runs counter to popular preferences, or where there is a need to adjust policy without losing security benefits.

In terms of lessons learnt for further research, we identify three main factors. Firstly, the experiment was based on an Internet panel. Although this panel was statistically consistent with UK's 2001 Census, the long-term validity of conclusions based on a panel of Internet users remains open to further discussion. Were this study to be carried out in a formal policy context prior to the implementation of certain measures, then greater consideration of a different approach to fieldwork would be given. Secondly, greater preliminary research focus could be placed on the definitions (of what constitutes privacy and liberty). A pragmatic approach was taken in interpretation as to how individuals' rights might be affected by each of the policy measures being considered in the context of travel on the national rail network, but to permit broader analysis, further consideration might be given to selecting the measures on the basis of their impact upon privacy or liberty in order to maximize the possibilities for further analysis. Finally, in order to maximize understanding and accessibility of the stated preference discrete choice element to the experiment, some attributes were shortened or concatenated. An example of this can clearly be seen in the absence of an indication of what constitutes the average ticket price. This rendered comparisons of relative WTP difficult and open to interpretation. There is a great deal of variation in ticket prices ranging from £14.90 for a Greater London Day Travelcard to £179.00 for a return Inter-city ticket. Explaining, identifying and characterizing such information prior to the stated preferences experiment was deemed to be too complex and would further confuse respondents. Further refinement of the methodology might include a focus or greater consideration being given to this attribute, in order to arrive at a robust definition of WTP given relative ticket prices.

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References

- ALOGIT (2005) HCG Software, `http://www.alogit.com`, London.
- Arrow, K., Solow, R., Portney, P.R., Leamer, E.E., Radner, R. & Shuman, H. (1993) Report of the NOAA panel on contingent valuation. Federal Register, 58, 4601-4614.
- BBC (2006) Extracts from MI5 chief's speech (Interview of Eliza Manningham-Buller), `http://news.bbc.co.uk/2/hi/uk_news/6135000.stm`, London.
- BBC News (2004) BBC News Special Reports: Madrid Train Attacks, `http://news.bbc.co.uk/2/hi/in_depth/europe/2004/madrid_train_attacks/default.stm`, BBC

News, London.

- Blackburn, M., Harrison, G.W. & Rutstrom, E.E. (1994) Statistical bias functions and informative hypothetical surveys. American Journal of Agricultural Economics, 76, 1084-1088.

- Bliemer, M. & Rose, J. (2006) Designing stated choice experiments: The state of the art. 11th International Conference on Travel Behaviour Research. Kyoto, Japan.

- Clarke, P. (2007) DAC Peter Clark's speech on counter terrorism, `http://cms.met.police.uk/news/major_operational_announcements/terrorism/dac_peter_clark_s_speech_on_counter_terrorism`, Metropolitan Police, London.

- Clarke, P. (2008) Benefits and disbenefits of security initiatives. London (personal communication).

- Collins, M. (1993) Strathclyde PTE focuses on safety of women passengers. Modern Railways, 50, 141.

- Cozens, P.M., Neale, R.H., Whitaker, J. & Hillier, D. (2002) Investigating perceptions of personal security on the valley lines network in South Wales. World Transport Policy & Practice, 8, 19-29.

- Crime Concern/Transport and Travel Research (1997) Perceptions of safety from crime public transport. Research report for the Department of Environment, Transport and Regions. Department of Transport, London.

- Crossman, G., Kitchin, H., Kuna, R., Skrein, M. & Russell, J. (2007) Overlooked: Surveillance and personal privacy in modern Britain. Liberty & The Nuffield Foundation, London.

- Dame Eliza Manningham-Buller (2006) Official: Britain Tracks Terrorist Plots, `http://www.cbsnews.com/stories/2006/11/10/ap/world/mainD8LADAJ02.shtml`, CBS News, New York.

- Evans, J. (2007) Speech: counter-terrorism and public trust, `http://www.timesonline.co.uk/tol/news/uk/article2810794.ece`, Times Online, London.

- Greater London Authority (2006) Report of the 7 July Review Committee, `http://www.london.gov.uk/assembly/reports/7july/report.pdf`, Greater London Authority, London.

- Hensher, D.A., Rose, J.M. & Greene, W.H. (2005) Applied Choice Analysis - A Primer, New York, Cambridge University Press, New York.

- Hess, S., Rose, J. & Polak, J. (2008) Non-trading lexicographic and inconsistent behaviour in SP choice data. 87th Annual Meeting of the Transportation Research Board,. January 13-17, Washington D.C.

- Hosein, G. (2008) National Identity Register, National DNA Databank, Data protection law. London (personal communication).
- ICO (2007) Information Commissioner's Office: Privacy impact assessment handbook. London.
- Johnson, M. & Gearty, C. (2007) A Price worth paying? Changing public attitudes to civil liberties under the threat of terrorism. British Social Attitudes: the 23rd Report - Perspectives on a changing society. Sage Publications for NatCen, London.
- Joseph Rowntree Reform Trust (2008) ICM omnibus poll on ID cards and the government's handling of personal information, http://www.jrrt.org.uk/ICM%20Omnibus%20poll%20-%203%20February%202008.pdf
- Kuhfeld, W. (2009) Marketing Research Methods in SAS: Experimental Design, Choice, Conjoint and Graphical Techniques, Cary, NC, USA, SAS Institute Inc., Cary, NC, USA.
- Kumaraguru, P. & Cranon, L.F. (2005) Privacy indexes: A survey of Westin's studies, Institute for Software Research International, Pittsburgh.
- Louis Harris, & Associates & Westin, A.F. (1994) Equifax-Harris Consumer Privacy Survey. Technical Report Conducted for Equifax Inc. 1,005 adults of the U.S. public., Louis Harris & Associates, New York.
- Louviere, J. (1992) Experimental choice analysis: introduction and overview. Journal of Business Research, 24, 89-96.
- Louviere, J. & Woodworth, G. (1983) Design and analysis of simulated consumer choice or allocation experiments: an approach based on aggregated data. Journal of Marketing Research, 20, 350-367.
- Louviere, J.J., Hensher, D.A. & Swait, J.D. (2000) Stated Choice Methods: Analysis and Application, Cambridge, Cambridge Press, Cambridge.
- Ortuzar, J.D. & Willumsen, L.G. (2001) Modelling Transport, Chichester, John Wiley & Sons, Ltd, Chichester.
- Rouwendal, J. & De Blaeij, T.A. (2004) Inconsistent and lexicographic choices in stated preference analysis. Tinbergen Institute Discussion Paper, Dept. of Economics. Free University of Amsterdam, Amsterdam, Netherlands.
- Ryan, M., Bate, A., Eastmond, C.J. & Ludbrook, A. (2001) Use of discrete choice experiment to elicit preferences. Quality in Health Care, 10, i55-i60. Smith, J. (2008) The future of the National Identity Scheme to Demos on 6th March 2008, http://press.homeoffice.gov.uk/Speeches/Speech-HS-Identity-Scheme1
- Srinivasan, S., Bhat, C.R. & Holguin-Veras, J. (2006) Empirical analysis of the impact of security perception on intercity mode choice. Transportation Research Record, 2006, 9-15.

- UK Dept. for Transport (2005) Research findings: Attitudes to transport security after July 2005 London bombings. London.
- UK Dept. for Transport (2006) Responsibilities of Transport Security's Land Transport Division,
`http://www.dft.gov.uk/pgr/security/land/responsibilitiesoftransports4898`
- UK Dept. for Transport (2008) Summary report of the 'LUNR' passenger screening trials, `http://www.dft.gov.uk/pgr/security/land/lunr`, London.