Deal or no deal: Can incentives encourage widespread adoption of Intelligent Speed Adaptation devices?

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Abstract

Given the burden of injury, economic, environmental and social consequences associated with speeding, reducing road traffic speed remains a major priority. Intelligent speed adaptation (ISA) is a promising but controversial new in-vehicle system that provides drivers with support on the speed-control task. In order to model potential system uptake, this paper explores drivers' preferences for two different types of ISA given a number of alternative fiscal incentives and non-fiscal measures, using a stated preference approach. As would be expected with such a contentious issue, the analysis revealed the presence of significant variations in sensitivities and preferences in the sample. While a non-negligible part of the sample population has such strong opposition to ISA that no reasonable discounts or incentives would lead to them buying or accepting such a system, there is also a large part of the population that, if given the right incentives, would be willing or even keen to equip their vehicle with an ISA device.

Introduction

Intelligent speed adaptation (ISA) is a system that provides information on the local speed limit to the driver, demonstrated to produce substantial savings in accidents and small reductions in fuel consumption and subsequent CO_2 emissions (Carsten et al., 2008). As such, this new technology offers one of the most promising strategies for combating the major economic, environmental, societal and public health impacts of road traffic speed. Since the safety effects of ISA are directly dependent on the number of equipped vehicles on the road (Carsten et al., 2008) the benefits of ISA will not be realised without widespread adoption and use by members of the public and fleets. In the absence of fiscal incentives, the market penetration of ISA amongst private drivers will depend on the extent to which consumer buying behaviour relates to the benefits associated with ISA (increased safety, lower emissions). But whilst these benefits are known to influence drivers' purchasing decision, attributes such as price, styling and reliability remain drivers' primary considerations when buying a new vehicle (see Koppel et al., 2005). A recent survey of European drivers also noted that whilst drivers recognise some active safety systems as indispensible, those that monitor driving behaviour are clearly rejected (European Commission, 2006). In the case of ISA, this rejection is a likely consequence of private good characteristics of speed outweighing the public good characteristic of safety. Given the positive beliefs associated with speeding, such as reduced journey time (Warner and Aberg, 2008), promoting ISA with less obvious private benefits presents a difficult problem. Beyond this, the deployment of many Intelligent Vehicle Safety Systems (IVS), such as ISA, is often limited by the publics' poor understanding, and lack of experience with the technology. Borrowing from cognitive psychology and advertising and marketing research, Zwijnenberg et al. (2007) therefore propose that the key to enhancing market penetration of any IVS lies in promotional activities and deployment initiatives. Promotional activities such as demonstrations, campaigns and field operational tests serve to enhance consumers' awareness and understanding of systems, whereas deployment initiatives are designed to increase a consumer's willingness to buy. Together, successful promotion and deployment activities should lead to increased sales of ISA equipped vehicles.

To date, the U.K. has achieved considerable success in raising awareness amongst stakeholders through research, but little attention has been paid to deployment initiatives. Zwijnenberg et al. (2007) report, however, that over half of drivers' reasons for *not* buying an IVS system relate to willingness to buy (e.g. too expensive to buy/service, undermines freedom). Thus whilst drivers state reasons related to willingness-to-buy for not purchasing IVS systems, stakeholders are engaging in very few activities to address this. Since only a strategic approach, where activities are aimed at increasing awareness, understanding and willingness to buy, will guarantee accelerated market penetration, ensuring that the appropriate deployment initiatives are in place may be the key to encouraging take-up of ISA. The research reported here explored this issue by examining drivers' preferences for ISA given a number of alternative fiscal incentives, alongside non-fiscal measures, using a stated preference (SP) approach. Two variants of ISA were examined; (1) mandatory ISA, a system which permanently limits the speed of the vehicle to the current speed limit and (2) voluntary ISA, a system which limits the speed of the vehicle to the speed limit but allows the driver to disengage the system.

Incentivising purchase

It is well known that financial considerations influence vehicle purchase and use decisions (e.g. Mohammadian & Miller, 2003). Financial encouragement to purchase ISA systems may be delivered by various means. In Italy, the government provided 250 Euros (£213 approx) to encourage the purchase of motorcycles whose emissions complied with the EURO-2 standards (Carrotta, 2007). Insurance discounts provide an alternative means of providing a financial remuneration to the buyer. Lindberg et al. (2005) observed that the number of young drivers agreeing to the installation of a warning ISA system was influenced by the offer of an unconditional monthly insurance remuneration of SEK 150 (approx £12). Reduced taxation schemes have also been shown to increase sales of safety systems (Bansgaard, 2007) and environmentally friendly vehicles (Carrotta, 2007). We have in our SP experiments explored each of these mechanisms since we accept that each is likely to vary in popularity and influence. The impact of an insurance incentive, for example, may have little effect on mid to highly experienced drivers who already enjoy significant bonuses. This incentive is liable to have its largest effect on younger new vehicle purchasers who are more likely to identify insurance as an important cost (DfT, 2004). Consequently, an important part of the current research was to explore not only the magnitude of discount required to encourage ISA take-up but also the most influential means of delivering that discount.

This paper focuses solely on the relative preference between the two systems as well as the stated intention to buy a given system and does not look at the extent of use for the voluntary system. From this perspective, *one-off* installation costs or incentives are likely to play the largest role in the behaviour observed in our survey. However, it should be recognised that incentives to use an ISA system (i.e. *marginal* benefits), where the system is voluntary and has to be activated by the driver, will also affect the relative preferences as well as stated purchase intentions, and as such these incentives will also need to be incorporated in our models. Here, we considered two variants in order to determine the most influential mechanism, namely fuel rebates or cash back on a driver's insurance premium if they used the system for a certain proportion of their driving.

Beyond this, four non-fiscal features were considered that might potentially influence an individual's propensity to purchase an ISA equipped vehicle. Changes in policy can be expected to play an important role in accelerating market penetration of ISA. Broughton (2008) noted that drivers changed their behaviour according to the number of speeding convictions they have accrued where these would increase the risk of disqualification from driving under the U.K. penalty point system. Given that the threat of disqualification has been shown to change behaviour, we predicted that an increase in the fixed penalty points for speeding or the length of time for which points remain on a driver's license may create demand for speed limiting technologies. As the safety benefits associated with ISA increase in line with the number of other ISA equipped vehicles on the road (at least to a certain threshold), we also hypothesised that the penetration rate of ISA would influence drivers' tendency to purchase an ISA vehicle. Finally, since drivers show little willingness to pay extra for intrusive safety features, combining ISA with attractive 'add on' packages (such as entertainment packages) was also considered. Emphasizing the saving made on the purchase of these combined safety and optional packages is believed to make the extra costs easier to accept (European Commission, 2006).

Methodology

Survey design

The SP survey involved presenting drivers with a set of hypothetical scenarios, each time involving a vehicle fitted with a mandatory ISA system (i.e. a system which permanently limits the speed of the vehicle to speed limit) or a vehicle fitted with an voluntary ISA system (i.e. a system which limits the speed of the vehicle to the speed limit but allows the driver to disengage the system). These two options were described using a range of attributes that are discussed below.

Our a priori assumption, which was confirmed by focus groups and piloting, was that there would be considerable heterogeneity of preferences towards safety and speed related devices in the population. On this basis, separate survey designs were created for three types of vehicle purchaser:

Group 1: Those who would buy a mandatory ISA system — these drivers received an SP survey where both systems were offered at a cost to the driver (490 respondents).

Group 2: Those who would only buy a voluntary system — here drivers were required to pay for a voluntary system but received incentives to acquire a mandatory system (503 respondents).

Group 3: Those who like neither system — both systems were offered with discounts and incentives to encourage drivers to purchase an ISA vehicle (466 respondents).

The segmentation of respondents into these three groups was based on an initial screening question which determined a preference for ISA in the absence of incentives. Anyone willing to buy a mandatory ISA equipped vehicle was assigned to group 1, those only willing to buy a voluntary equipped ISA vehicle were assigned to group 2, whilst those showing no willingness to buy either system formed group 3. The question used to inform allocation into groups was not accompanied by any information on costs and discounts. Nevertheless, the allocation of respondents into these initial groups provided an early indication that 64% of the sample was willing, in principle, to consider purchasing an ISA-equipped vehicle.

Core attributes

The SP design included two core attributes. These core attributes reflected *purchase incentives/costs* and *incentives to use* a voluntary ISA system, as discussed above.

In Group 1, respondents had to pay for both systems, with the price for the system being a function of the average amount respondents would spend on their next vehicle, using a range between 0% and 9% for the mandatory system and between 4% and 9% for the voluntary system (5 levels). To ensure that in the majority of cases the mandatory ISA system represented the 'best' deal when comparing the incentives to buy and use, the minimum and maximum value of the amount spent on the next vehicle used in the calculations was capped at £5,000 and £15,000. Additionally, respondents were given an incentive to use the voluntary system, ranging from no incentive to 2 pence per mile up to a maximum of 20,000 miles[1] (4 levels).

In Group 2, which contained respondents who expressed a preference for the voluntary system, a discount on vehicle price was offered in return for choosing the mandatory system (ranging from 5% to 50% of vehicle price), while the respondents still had to pay for the voluntary system (ranging from 0.5% to 8% of the vehicle price)(5 levels). Again the price offered was a function of the amount respondents were willing to spend on their next vehicle (with cut off points of £5,000 and £15,000). The same incentives to use the voluntary system were again offered.

In Group 3, which contained respondents who expressed a dislike for both systems, two approaches were used. In the first approach, discounts on vehicle price were offered in return for choosing either system, ranging from 15% to 40% for the mandatory system, and from 0% to 20% for the voluntary system (5 levels). In the second approach, these discounts were replaced by tax rebates, ranging from £750 to £950 for the mandatory system and from £0 to £200 for the voluntary system. Finally, incentives to use the voluntary system were again offered, but these have now increased, with a range between 1 penny per mile to 2.5 pence per mile (4 levels with an upper limit of 20,000 miles).

Additional attributes

While the core attributes were included with a view to testing for the relative preference for either system, the additional attributes were included with a view to influencing the overall attractiveness of ISA systems. For this reason, the four additional attributes included here were common to both ISA systems and groups. These comprise:

1. *Penetration rate*: percentage of other vehicles equipped with the speed limiter system on U.K. roads (5 levels: 0%, 20%, 40%, 60%, 80%);

[1] An upper limit of 20,000 miles was set so as not to create a reward system which encouraged drivers to increase their annual mileage for financial gain.

2. *Free add-ons*: packages offered with a speed limiter equipped vehicle at no extra cost to driver (4 levels: free safety add on (e.g. additional airbags); free entertainment add-on (e.g. in-car dvd player); free styling add-on (e.g. leather seats); no free add-on);

3. Penalty points: penalty administered for committing a speeding offence (2 levels: 3 points; 6 points) and

4. Endorsement period: the length of time speeding endorsements remain on a driver's licence (3 levels: remain on license for 3 years; remain on license for 4 years; remain on license for 5 years).

SP design

In order to limit the information presented within each scenario, each respondent was presented with four attributes. All were presented with the two core attributes and two extra attributes (either "penalty points" and "penetration rate" *or* "free add-ons" and "endorsement period"). The attributes were combined depending on purchaser group to create 16 SP surveys, each making use of 12 separate scenarios. An overview of the survey design is presented in Table 1.

[insert table 1 here]

The field of SP experimental design has evolved significantly over recent years, with growing interest in efficient designs (cf. Rose & Bliemer, 2008). However, efficient designs require a priori information on the likely values of the coefficients for the model to be estimated on the data resulting from the survey. With the innovative nature of the study presented here, such prior information was not available, and we consequently relied on the use of an orthogonal design.

An example of a typical choice scenario for a group 3 respondent is present in Figure 1. Respondents were also provided with a show card detailing the definitions of each attribute.

[insert figure 1 here]

Stated choice and stated intention

In each SP scenario, two separate pieces of information were collected from a respondent. We first collected information on which of the two ISA equipped vehicles a driver would prefer under given scenarios. This stated choice or stated preference information provided the majority of the input for the modelling analysis. This however equates to a *forced* choice, and while it allows us to gauge the relative preference, it does not provide us with any information on actual or absolute preferences. For this reason, in each scenario respondents were also asked which vehicle, if any, they would consider buying. In this stated purchase intention, respondents also had the option of indicating that they would, in principle, be willing to buy either vehicle, or neither vehicle.

Participants

The survey was administered using Computer Aided Personal Interviewing (CAPI) to allow customisation of the SP scenarios to each individual's responses and random presentation of the SP designs. Interviews were conducted with 1,487 drivers at their homes (1,459 of the interviews were used in the analysis). The interviews were carried out across Great Britain in randomly selected census output areas across 11 regions and at addresses randomly selected within each area. The number of interviews conducted in each region was proportionate to the population. Only one driver was interviewed per household.

Modelling methodology

Mathematical structures belonging to the family of Random Utility Models (RUM) were used in the analysis of both the stated choice (SC) and stated intention (SI) components of the SP data. We specifically make use of discrete choice models that are used to analyse one choice at a time (see Train, 2003). These models can be used directly for the choice between the two systems, while for the SI data, the choice was formulated as being between the decision to buy and the decision not to buy. This leads to three different model structures, one choice model for the SC data, and two models for the decision to buy the mandatory and voluntary systems respectively.

In a discrete choice model, a respondent is faced with a choice between a finite set of mutually exclusive options, referred to as alternatives. Each alternative in this choice set is characterised by a number of attributes, e.g. price and cost of use. The underlying reasoning is that each alternative has an associated *utility*, where this is a function of the *attributes* of the alternatives and the associated *sensitivities* of a respondent, possibly interacting with socio-demographic characteristics of the respondent. The aim of a choice modelling analysis is to provide estimates of the sensitivities of respondents to changes in the attributes of the alternatives.

A rational decision maker is expected to choose the alternative with the highest utility (or lowest disutility). With the utility of an alternative not being observed by the analyst, we move to a random utility framework in which the probability of choosing an alternative increases with the *modelled* utility for that alternative. In the present analysis, we relied on two different model structures. The base model in each case was a Multinomial Logit (MNL) model in which the sensitivities (and hence preferences) are kept constant across all respondents in the sample. While the MNL model remains the starting (and reference) point of almost all discrete choice studies, the assumption of taste homogeneity (other than in terms of interactions and segmentations) is not generally justified, especially in the context of a topic as divisive as the one at the heart of this paper.

To move away from the restrictive homogeneity assumption, we also estimated Latent Class (LC) choice models (see e.g. Greene & Hensher, 2003). In these models, the sample population is divided into different classes with variations in sensitivities across classes. In the absence of information on which class a specific respondent belongs to, a *class allocation model* is used that allocates a respondent into a specific class with a certain probability, where this probability is a function of socio-demographic attributes of the respondent. A LC model could thus for example lead to two classes with different cost sensitivities, and respondents with higher income might have a higher probability of falling into the low cost sensitivity class[2]. LC models are not used as widely in transportation as their continuous Mixed Multinomial Logit (MMNL) counterparts, yet posses a number of crucial advantages not just in terms of linking sensitivities to socio-demographics but also in terms of breaking free from restrictive a priori shape assumptions in the specification of this heterogeneity (cf. Hess et al, 2009). In the present paper, an exploratory (rather than confirmatory) approach was used, such that the classes were *retrieved* during model estimation, rather than being *imposed* during model specification.

Results

The results from the modelling analysis are presented in two parts. We first look at the models estimated on the stated choice between the two ISA options before turning to the models estimated on the stated purchase intention data.

Choice between different ISA options

This section presents the models estimated on the stated choice information, i.e. respondents' preferences between the two systems in given settings. For each of the three segments, we first estimated MNL models before turning our attention to the LC models. Here, it quickly became clear that the level of heterogeneity in the data was so pronounced that MNL models were not

[2] Another crucial advantage of this model in the present context is that it can recognise the repeated choice nature of the data, i.e. the fact that each respondent is faced with multiple choice tasks.

appropriate, with the LC models obtaining far superior fit and more reasonable results. For the sake of brevity, we limit our presentation here to the findings from the more advanced LC models [3]. These models only include the incentive to buy (either cost or discount) as well as the incentive to use (voluntary only) as attributes[4]. The remaining attributes (i.e. the *extras*) were common to the two systems and were not observed to have a differential effect on the probability of choosing either system so they were not included in these models.

Group 1

The final sample from the SC survey in group 1 contains 5,695 responses from 490 respondents. In the specification search, we gradually increased the number of classes in the model, where the model with a single class corresponds to the MNL structure. As expected, each additional class leads to increases in model fit, where these are especially dramatic early on (e.g. when moving from MNL[5] to a LC model with two classes), but the improvements obtained beyond four classes were not statistically significant.

In each class, five parameters explaining the choices were estimated, namely a constant for the mandatory system, system specific cost coefficients (associated with purchase price), and coefficients associated with fuel rebates and insurance cash backs offered as an incentive to use the voluntary system. The marginal utility coefficients give the change in utility resulting from an increase by one unit in the associated attribute, with any constant giving a baseline value for that alternative's utility.

In the class allocation model, a class-specific constant was estimated, along with parameters associated with five different socio-demographic attributes. In each case, a summation to zero constraint was used across classes for the sake of normalisation. The five socio-demographic attributes used were sex, age, income, driving experience and annual mileage. We also made attempts to include various other socio-demographic attributes in the class-allocation models, relating to employment status, occupation, penalty points on a respondent's license, value of the vehicle, marital status and current fuel, insurance and road tax costs. None of these additional terms

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[3] MNL models are available from the second author on request.

[4] In the final specification, the actual per mile discount was used in the utility functions as this was found to lead to more robust results than using the respondent-specific discount as a function of miles driven.

[5] As a comparison with the model from Table 2, the log-likelihood for the MNL model was -2,617.77, with 5 estimated parameters, giving an adjusted ρ^2 measure of 0.34

had any consistent effects such that they were dropped from the models. Finally, for multi-level attributes (e.g. different age groups), summation to zero constraints were used to allow model identification.

The estimation results for the model with four classes are summarised in Table 2. Looking first at the class specific choice models, we can see that the four marginal utility coefficients[6] are of the expected sign and statistically significant in classes one, two and three. However, in the fourth class, there are issues with significance for all four coefficients, along with a sign issue for the coefficient associated with the fuel rebates. This class is characterised by a large negative constant for the mandatory system, while this constant was positive in the remaining three classes. These results would suggest that this fourth class captures respondents who have a strong opposition to the mandatory system, independently of the attributes of either system. This is an interesting observation in its own right. The subclass of population used for this model were respondents who had previously indicated an interest in the mandatory system. The results would thus suggest that the scenarios presented in the SP did not correspond with the a priori expectations of these respondents.

Turning our attention next to the class allocation model, we observe that apart from the constant and the experience parameters, the estimates are not significantly different across classes on the basis of the Wald test. Additionally, and again apart from the constants, few of the estimates in the class allocation model are significantly different from zero. This would suggest that while there are some significant differences in sensitivities (and hence behaviour) in the sample population (looking at the choice model rather than the class allocation model), these cannot be explained on the basis of the socio-demographic information.

[Insert Table 2 here]

In terms of actual differences, the model identifies two classes with a strong preference for the mandatory system (class 1 and especially class 2), a third class with relatively even probabilities across the presented choices, and the above mentioned fourth class with the strong preference for the voluntary system. The first two classes and to some extent also the third class get much higher weight, resulting in the sample market shares of 76.5% and 23.5% for the two systems. Here, it is interesting to note that male respondents are less likely to fall into the class with a strong preference for the mandatory system (class 1).

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[6] Cost of mandatory system (£), Cost of voluntary system (£), Fuel rebate for voluntary system (pence/mile), Insurance cash back for voluntary system (pence/mile)

On the basis of the estimation results, it is straightforward to work out a point at which the mandatory system and the voluntary system have equal probability of being chosen. We undertake this calculation on the basis of a price of £600 for the voluntary system along with a 1p per mile fuel rebate. Here, we can see that this equilibrium would be achieved with a price of £423 in the first class. In the second class, which is characterised by a high preference for the mandatory system along with low cost sensitivity, the mandatory system could cost £1,296 to get the same probability as the voluntary system with £600 and a 1 penny fuel rebate. In the third class, which shows much more even preferences, the mandatory system would again have to be cheaper than the voluntary system, at £323, while in the fourth class, even a free mandatory system would have a lower probability than the voluntary system, even at prices higher than £600. This comparison illustrates the major differences between different respondents in their attitudes towards the two systems.

Group 2

The final sample for the second group contains 5,836 responses collected from 503 individuals. In the second group of SP surveys, respondents obtained a discount for choosing the mandatory system while still paying to buy the voluntary system. The models thus still make use of five main parameters, but the cost coefficient for the mandatory system is replaced by a discount coefficient, where we would expect positive estimates.

In the specification search for the second group, we observed comparatively very poor fit for the MNL model (giving an adjusted ρ^2 measure of 0.06), suggesting that the extent of heterogeneity is so high that no reliable results can be obtained with a model making a taste homogeneity assumption. Significant improvements were obtained with the LC structures, where once again we settled on a structure using four classes.

The estimation results for the model with four classes are summarised in Table 3. Looking first at the class specific choice models, we can see that the four marginal utility coefficients are of the expected sign and statistically significant in classes one and four. In the second class, the coefficient associated with fuel rebates is negative, but not significantly different from zero, while in the third class, the cost coefficient for the voluntary alternative is positive, but again not significantly different from zero. There are differences across classes in the relative sensitivities to fuel rebates and insurance cash backs. Additionally, in three classes, respondents react more positively to discounts in the cost of the mandatory system than they do negatively to increases in the cost of the voluntary system, although these differences are small.

The constant for the mandatory alternative is negative and significant in the second and fourth class, while it is positive in the second class. On the basis of the Wald test, the results also show us that all estimates, and especially the constant for the mandatory alternative, vary significantly across classes, highlighting the presence of significant differences in sensitivities within this sample.

Turning our attention next to the class allocation model, we observe that the constant, the age and the experience parameters vary significantly across classes on the basis of the Wald test. Again, like in group 1, few of the estimates in the class allocation model are significantly different from zero. This would again suggest that while there are some significant differences in sensitivities (and hence behaviour) in the sample population, these cannot easily be explained on the basis of the socio-demographic information.

[insert Table 3 here]

In terms of actual differences, the model identifies a single class with a very strong preference for the mandatory system (class 1), where the models show that male respondents are less likely to fall into this class. The second class shows a strong preference for the voluntary system, with respondents aged over sixty being more likely to fall into this class. The remaining two classes show a slight preference for the mandatory system, but differ significantly for example in terms of the higher sensitivity to incentives to use in the third class. The first two classes, i.e. those with more extreme preferences for one of the two systems, get a higher weight, again highlighting the strong differences in attitudes in the population.

As a comparison with the models from group 1, we again look at points at which the two systems would have equal probability of being chosen. Here, we can calculate that, in the first class, a discount for the mandatory system is only required if the voluntary system is sold at less than £530 with a 1 penny per mile fuel discount. In the second class, the dislike of the mandatory system is so extreme that any realistic levels for the discount would not be sufficient for the mandatory system to be as likely to be chosen as the voluntary system. In the third class, this calculation is not possible due to the insignificant cost coefficient for the voluntary system, while in the fourth class, we see that, with a cost of the voluntary system at £600, a discount of £1,450 on the mandatory system is needed to obtain equal probabilities for the two systems. As in the group 1 models, this comparison again illustrates the major differences between different respondents in their attitudes to the two systems.

Group 3

The final sample for the third group contains 5,412 observations collected from 466 respondents. Some differences in the model specification arise in that discounts are now offered for both systems, with two types of discount depending on the specific survey, either in terms of a reduced price or a discount on vehicle tax. This leads to seven parameters in each class in the choice model.

Just as in group 2, the MNL model again produced comparatively very poor performance (with an adjusted ρ^2 measure of 0.07), with dramatic improvements when moving to the LC models, where the recommended model in this group makes use of three classes.

The estimation results for the model with three classes are summarised in Table 4. Looking first at the class specific choice models, we can see that the six marginal utility coefficients are of the expected sign (positive) in all three classes. However, there are some problems with parameter significance in class 1, which suggests that in this class, the large negative constant dominates, along with the discount on the mandatory system. On the basis of the Wald test, the results also show us that all estimates with the exception of the sensitivity to the tax discount for the voluntary system vary significantly across classes.

Turning our attention next to the class allocation model, we observe that only the effect of age varies significantly across classes. Here, we note that younger respondents are less likely to fall into the first two classes with older respondents less likely to fall into the third class. This suggests that younger respondents have less extreme preferences for the two systems (class 3 has a more even distribution of sensitivities).

In terms of actual differences, the model identifies one class with a strong preference for the mandatory system (class 1), one class with a strong preference for the voluntary system (class 2), and a final class (class 3) with relatively even probabilities across the presented choices. The preferences in the first class are so extreme that no reasonable shift in discounts will lead to equal probabilities for the two systems. In the second class, the preference for the mandatory system is so large that with no discount for that system, a discount of £769 for the voluntary system along with a 1 penny per mile fuel discount is required to obtain equal probabilities. Finally, in the third class, with no discount on the voluntary system but a 1 penny per mile fuel discount, a discount of £2,040 is required for the mandatory system to obtain equal probabilities of choice for the two systems.

[insert Table 4 here]

Purchase intention

We next turn our attention to models estimated on respondents' stated intention to buy or not buy an ISA system. As a reminder, respondents were asked to indicate in each scenario, and for each system, whether they would be prepared to purchase that system. Here, separate models were estimated for the two systems, with the two alternatives being to buy or not to buy the system in question. However, it was recognised that the attributes of one system potentially had an effect on the stated intention to buy the other system given that the two systems were presented alongside one another. On the basis of this, the attributes of both systems were included in both sets of models (with separate coefficients). The utility of the second alternative (*not buy*) was set to zero. A constant was included in the *buy* alternative, along with the attributes of the two systems as already discussed in the context of the stated choice models. The expectation here is that e.g. increases the cost attribute for a given system have a negative effect on the utility of buying that system, while they have a positive impact on the utility of buying the alternative system. Efforts were also made to test for the effects of extra attributes, such as the free add-ons, but these were only found to have an effect in one model, namely that for buying the mandatory system in the third group.

Here, we present a comparatively brief overview of these models, with less detail than for the stated choice models. In particular, we limit ourselves to the presentation of MNL results. Indeed, while the estimation of LC results again showed the presence of significant variations in sensitivities in the sample population, the improvements over the MNL models were far less dramatic than in the models estimated on stated choice questions. Additionally, the overall findings from the MNL models were robust and consistent with those from the LC models.

Table 5 summarises the results of the MNL models estimated on the buy/not buy data. We first turn our attention to the group 1 models. The results are very much as expected. Increases in cost have a decreasing effect on the probability of buying a specific system, but have an increasing effect on the probability of buying the alternative system. Here, the cost of the mandatory system plays a much bigger role than does the cost of the voluntary system. Fuel rebates and insurance cash backs as an incentive of using the voluntary system have a positive impact on the probability of buying the voluntary system but have the opposite effect on the probability of buying the mandatory system. On the basis of these estimation results, we can work out that, if the voluntary system was free with a fuel rebate of 1p/mile, the mandatory system could cost up to £273 before the probability of buying it would drop below 50%. However, with costs of the voluntary system at £600 and £1,200, the maximum price (before the probability drops below 50%) for the mandatory system is below that of the voluntary system, at £541 and £810 respectively. This is a result of the asymmetry in the sensitivity to costs for the two systems. Looking at the probability of buying the voluntary system, again at no cost and with a fuel rebate of 1p/mile, the mandatory system would have to cost more than £775 before the probability of buying the voluntary system exceeds 50%. At costs of the voluntary system at £600 and £1,200, the minimum price for the mandatory system is at £987 and £1199 respectively. This means that up to a price of £1,200, the cost of the voluntary system needs to be below that of the mandatory system for the probability of buying it to exceed 50%.

Looking next at group 2, all parameters again have the expected sign, with increases in the discount for the mandatory system or the cost of the voluntary system having positive impacts on the probability of buying the mandatory system, and negative impacts on the probability of buying the voluntary system. Here, we can also calculate that, if the voluntary system was free with a fuel rebate of 1p/mile, the mandatory system would have to come with a discount of at least £2,818 before the probability of buying the mandatory system would drop below 50%. This drops to £1,788 and £757 when the cost of the voluntary system is increased to £600 and £1,200 respectively. On the other hand, looking at the probability of buying the voluntary system, again at no cost and with a fuel rebate of 1p/mile, the mandatory system would have to come with a discount of less than £140, above which the probability of buying the voluntary system drops below 50%. With higher costs for the voluntary system, the probability is less than 50% even without discounts for the mandatory system. At higher rates of fuel rebates, these values change significantly.

Looking finally at the models for group 3, the overall results are consistent with intuition, but there are several problems with parameter robustness. In this group, the probability to buy either system is very low (as expected), and consequently, the models are strongly dominated by the constant. The calculations of trade-offs are hampered by the insignificant parameters. However, we can see that, with no discount for the voluntary system and no fuel rebate, a discount of £7,936 would be required to have a probability of 50% or more for the mandatory system to be bought. When adding a free entertainment system, this drops to £5,566. This drop is higher than expected, and gives an indication of the high protest vote associated with the mandatory system. For the voluntary system, a discount of £2,838 would be required for the probability of buying the system to exceed 50%, where fuel rebates and insurance cash backs seemingly have no statistically significant effects.

[insert Table 5 here]

Discussion

This paper has discussed the estimation of discrete choice model structures on data from a stated preference survey looking at the potential demand for ISA. The analysis made use of two approaches, looking at respondents' stated choice between the two systems in various settings, as well as their stated buying intentions in these settings. The analysis has shown that for the latter, respondents still compare the two systems, i.e. they do not evaluate the mandatory and voluntary system independently. Nevertheless, especially in group 3, these models may be seen as more useful than the choice models as they avoid the issue of forcing upon respondents a choice between two systems neither of which they may like.

As would be expected with such a contentious issue, the analysis has revealed the presence of significant variations in sensitivities and preferences in the sample. The main differences arise between the three groups already identified prior to the administration of the survey questionnaire. However, further differences arise also within these groups, in the form of significant variations in the acceptable costs (for respondents willing to pay for ISA) respectably the required discounts (for respondents requiring incentives to have ISA installed in their vehicles) . Here, the degree of heterogeneity is so high that models making an assumption of homogeneity in tastes are unable to offer an acceptable fit to the data. Significant improvements in performance are in turn obtained by making use of models that break free from this homogeneity assumption.

The other observation that comes out of the analysis is that, while there are very significant variations in sensitivities and preferences, these cannot easily be linked to socio-demographic attributes of the respondents. As such, it is not necessarily the case that young male respondents have a strong objection to ISAs while older respondents with more expensive vehicles have a more positive attitude. This observation would suggest that people have strong inherent views on installing an ISA in their vehicle, where these are independent of their socio-demographic characteristics, and that, as a consequence, it is not easy to target one specific part of the population in a campaign to increase the uptake of such systems.

The range of retrieved valuations is extreme. While discounts of up to £8,000 may be required in group 3 to obtain a probability of 50% of buying a mandatory ISA, respondents in group 1 are willing to pay several hundred pounds for a mandatory system. Similarly extreme valuations arise in the preference models where respondents are asked to choose between the two systems. To some degree, the actual valuations discussed in this section are specific to the data at hand and are dependent on the scenarios put to respondents. However, what is clear is that there are strong underlying attitudes to ISA systems, where these attitudes are quite hostile especially in the third group. A non-negligible part of the sample population have such strong opposition especially to the mandatory system that no reasonable discounts or incentives would lead to them buying or accepting such a system. Finally, the analysis has similarly shown that there is a large part of the population that, if given the right incentives (whether in terms of lower cost or higher discounts), would be willing or even keen to equip their vehicle with an ISA device. To some extent, these results are clearly affected by strategic voting by some individuals, and a more moderate response may arise in a real life setting. Nevertheless, this paper presents useful initial insights into the potential uptake of ISA.

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Table 1: Design of stated preference survey

Group	*Group Characteristics*	*Form of SP Survey*	*Cost of ISA*	*Incentive to Use Voluntary System*
Group 1 (490)	Those who would buy a mandatory ISA system	Survey where both systems were offered at a cost to the driver	Price of system ranges from 0% to 9% of vehicle price for the mandatory system, and from 4% to 9% for the voluntary system	Ranged from 0p to 2p per mile (up to 20,000 miles). Incentive could be fuel rebates or insurance rebates.
Group 2 (503)	Those who would buy a voluntary ISA system	Requirement to pay for voluntary system but incentives to buy a mandatory system	Discount on vehicle price offered in return for choosing the mandatory system (ranging from 5% to 50% of vehicle price). Respondents had to pay for voluntary system (ranging from 0.5% to 8% of the vehicle price).	As above
Group 3 (466)	Those who like neither system	Both systems offered with discounts and incentives	Two approaches tested: (1) discounts on vehicle price offered in return for choosing either system, ranging from 15% to 40% for the mandatory system, and from 0% to 20% for the voluntary system; (2) these discounts were replaced by tax rebates, ranging from £750 to £950 for the mandatory system and from £0 to £200 for the voluntary system	Ranged from 1p per mile to 2.5p per mile (up to 20,000 miles)

Table 2: Estimation results for LC choice model with 4 classes for group 1

Number of respondents:	490
Number of observations:	5695
Number of parameters:	50
Log-likelihood (LL):	-1,922.59
adj. P^2:	0.5003

	Class 1	Class 2	Class 3	Class 4	Weighted average
class size	35.79%	34.39%	23.72%	6.11%	
av.prob. for mandatory	80.31%	95.48%	57.11%	16.27%	76.49%
av.prob. for voluntary	19.69%	4.52%	42.89%	83.73%	23.51%

	Class 1		Class 2		Class 3		Class 4		Wald test	
Choice model parameters	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.		*p*-value
Constant for mandatory system	3.6857	5.97	4.1782	9.76	0.6538	2.93	-2.2420	-3.03	201.62	0.00
Cost of mandatory system (£)	-0.0132	-10.05	-0.0035	-7.93	-0.0025	-7.01	-0.0009	-1.31	200.65	0.00
Cost of voluntary system (£)	-0.0047	-3.78	-0.0015	-2.17	-0.0019	-5.76	-0.0010	-1.87	53.89	0.00
Fuel rebate for voluntary system (pence/mile)	0.9264	3.99	0.5428	2.37	0.9865	8.26	-0.2713	-0.70	96.16	0.00
Insurance cash back for voluntary system (pence/mile)	1.0341	3.69	0.4731	2.28	0.8820	7.60	0.0098	0.02	85.30	0.00

	Class 1		Class 2		Class 3		Class 4		Wald test	
Class allocation model parameters	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.		*p*-value
Class specific constant	0.9490	3.86	0.6113	2.65	-0.3688	-1.34	-1.1915	-3.09	22.33	0.00
Dummy for male respondents	-0.4234	-2.07	0.0269	0.14	0.1404	0.59	0.2561	0.73	4.45	0.22
Aged under 24 years	-0.0750	-0.21	-0.4099	-1.15	0.4275	0.94	0.0574	0.08		
Aged between 24 and 40 years	0.2481	1.13	0.1339	0.61	0.3512	1.45	-0.7332	-1.50	12.11	0.21
Aged between 40 and 60 years	-0.1745	-0.93	-0.0373	-0.20	-0.3820	-1.68	0.5938	1.85		
Aged over 60 years	0.0014	0.01	0.3133	1.48	-0.3967	-1.64	0.0820	0.21		
Income less than £15,000	0.2259	1.20	0.2273	1.21	-0.2498	-0.96	-0.2034	-0.64		
Income between £15,000 and £45,000	-0.1649	-1.10	0.0587	0.38	0.3232	1.63	-0.2170	-0.88	7.53	0.27
Income above £45,000	-0.0610	-0.25	-0.2860	-1.15	-0.0734	-0.22	0.4204	1.20		
Less than 5 years driving experience	0.4806	1.61	0.2670	0.92	-0.4621	-1.05	-0.2855	-0.40		
Between 5 and 10 years driving experience	-0.6236	-2.35	-0.0490	-0.22	0.0100	0.03	0.6625	1.49	11.79	0.07
Over 10 years driving experience	0.1430	0.65	-0.2180	-1.06	0.4521	1.61	-0.3770	-0.90		
Annual mileage (1,000s)	-0.0271	-1.22	-0.0030	-0.17	0.0179	1.37	0.0123	0.91	2.19	0.53

Table 3: Estimation results for LC choice model with 4 classes for group 2

Number of respondents:	503
Number of observations:	5,836
Number of parameters:	50
Log-likelihood (LL):	-2,315.00
adj. P^2:	0.4154

	Class 1	Class 2	Class 3	Class 4	Weighted average
class size	0.3046	0.2845	0.2284	0.1825	
av.prob. for mandatory	0.9244	0.0343	0.6243	0.5953	0.5446
av.prob. for voluntary	0.0756	0.9657	0.3757	0.4047	0.4554

	Class 1		Class 2		Class 3		Class 4		Wald	
Choice model parameters	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	test	*p*-value
Constant for mandatory system	-0.1816	-0.59	-4.4210	-11.19	1.0080	4.46	-2.0170	-5.30	215.80	0.00
Discount for mandatory system (£)	0.0025	6.70	0.0001	1.32	0.0002	3.74	0.0011	7.86	105.38	0.00
Cost of voluntary system (£)	-0.0017	-2.96	-0.0021	-4.64	0.0000	0.15	-0.0009	-2.25	36.00	0.00
Fuel rebate for voluntary system (pence/mile)	0.7188	3.99	-0.0870	-0.39	1.1040	8.29	0.1180	0.71	84.30	0.00
Insurance cash back for voluntary system (pence/mile)	0.7794	4.43	0.3684	1.36	0.9395	7.65	0.6569	3.68	117.70	0.00

	Class 1		Class 2		Class 3		Class 4		Wald	
Class allocation model parameters	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	test	*p*-value
Class specific constant	0.4547	1.88	0.4374	1.96	-0.8631	-1.92	-0.0291	-0.10	7.0921	0.07
Dummy for male respondents	-0.3571	-2.16	-0.0207	-0.12	0.1774	0.77	0.2004	0.79	4.9705	0.17
Aged under 24 years	-0.2928	-0.75	-0.2296	-0.65	1.2810	1.93	-0.7591	-1.54		
Aged between 24 and 40 years	0.2659	1.53	-0.3859	-2.28	0.2466	0.87	-0.1266	-0.52	24.7659	0.00
Aged between 40 and 60 years	-0.0997	-0.53	-0.2002	-1.12	-0.0063	-0.02	0.3062	1.14		
Aged over 60 years	0.1265	0.48	0.8158	3.45	-1.5220	-3.17	0.5795	1.55		
Income less than £15,000	0.0329	0.13	0.0680	0.27	-0.3953	-0.81	0.2944	0.89		
Income between £15,000 and £45,000	-0.1805	-1.14	-0.0575	-0.37	0.3308	1.20	-0.0928	-0.43	2.8559	0.83
Income above £45,000	0.1476	0.72	-0.0105	-0.05	0.0645	0.19	-0.2016	-0.72		
Less than 5 years driving experience	0.4387	1.33	0.1642	0.53	-1.3640	-2.16	0.7612	2.10		
Between 5 and 10 years driving experience	-0.5371	-1.97	0.1065	0.50	0.3068	0.76	0.1238	0.45	14.0439	0.03
Over 10 years driving experience	0.0983	0.44	-0.2707	-1.21	1.0570	2.77	-0.8850	-2.88		
Annual mileage (1,000s)	0.0084	0.69	0.0194	1.71	-0.0548	-2.28	0.0270	2.05	5.8549	0.12

Table 4: Estimation results for LC choice model with 3 classes for group 3

Number of respondents:	466
Number of observations:	5,412
Number of parameters:	41
Log-likelihood (LL):	-1,839.50
adj. P^2:	0.4987

	Class 1	Class 2	Class 3	Weighted average
class size	0.4965	0.2843	0.2192	
av.prob. for mandatory	0.0161	0.8923	0.4021	0.3485
av.prob. for voluntary	0.9839	0.1077	0.5979	0.6515

	Class 1		Class 2		Class 3		Wald test	
Choice model parameters	est.	t-rat.	est.	t-rat.	est.	t-rat.		*p*-value
Constant for mandatory system	-4.8440	-6.71	1.6110	4.21	-0.6025	-1.85	69.99	0.00
Discount for mandatory system, price (£)	0.0005	3.80	0.0012	5.50	0.0004	4.32	55.27	0.00
Discount for mandatory system, tax (£)	0.0004	0.48	0.0021	4.93	0.0008	2.17	27.46	0.00
Discount for voluntary system, price (£)	0.0001	0.29	0.0016	7.21	0.0009	5.10	76.55	0.00
Discount for voluntary system, tax (£)	0.0009	0.22	0.0028	1.72	0.0016	1.42	5.33	0.15
Fuel rebate for voluntary system (pence/mile)	0.2919	0.82	0.3812	2.06	0.2136	1.73	7.29	0.06
Insurance cash back for voluntary system	0.0158	0.05	0.5141	3.02	0.1960	1.41	12.90	0.00

	Class 1		Class 2		Class 3		Wald test	
Class allocation model parameters	est.	t-rat.	est.	t-rat.	est.	t-rat.		*p*-value
Class specific constant	0.3361	1.97	-0.0692	-0.35	-0.2669	-1.21	3.93	0.14
Dummy for male respondents	-0.1089	-0.78	-0.2872	-1.82	0.3962	2.09	4.65	0.10
Aged under 24 years	-0.5083	-1.97	-0.1915	-0.65	0.6997	2.40		
Aged between 24 and 40 years	0.1265	1.00	-0.2429	-1.64	0.1164	0.76	12.07	0.06
Aged between 40 and 60 years	0.1436	1.09	0.0354	0.24	-0.1790	-1.07		
Aged over 60 years	0.2382	1.40	0.3990	2.11	-0.6372	-2.78		
Income less than £15,000	-0.0576	-0.41	-0.0524	-0.33	0.1100	0.63		
Income between £15,000 and £45,000	0.1019	0.97	0.0001	0.00	-0.1020	-0.76	1.42	0.84
Income above £45,000	-0.0443	-0.26	0.0523	0.27	-0.0080	-0.04		
Less than 5 years driving experience	0.1935	1.04	0.0032	0.01	-0.1967	-0.84		
Between 5 and 10 years driving experience	-0.0805	-0.52	-0.0713	-0.38	0.1518	0.80	1.58	0.81
Over 10 years driving experience	-0.1129	-0.84	0.0680	0.42	0.0449	0.27		
Annual mileage (1,000s)	0.0152	1.44	0.0141	1.19	-0.0294	-1.72	3.02	0.22

Table 5: Results for purchase models

	Group 1				Group 2				Group 3			
	Mandatory		Voluntary		Mandatory		Voluntary		Mandatory		Voluntary	
Log-likelihood (LL):	-3,079.82		-3,555.92		-3,761.17		-3,655.43		-2,930.32		-3,094.16	
adj. P^2:	0.2185		0.0979		0.0690		0.0951		0.2162		0.1733	
P (buy):	70.34%		33.50%		52.33%		35.47%		23.72%		26.40%	
	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.
Constant for buying	1.0400	13.38	-0.9460	-13.55	-0.6400	-10.16	-0.3380	-5.35	-1.5000	-11.68	-1.2600	-10.35
Cost of mandatory system (£)	-0.0027	-22.19	0.0009	9.66	-	-	-	-	-	-	-	-
Discount for mandatory system, price (£)	-	-	-	-	0.0003	16.41	-0.0001	-8.31	0.0002	5.38	-0.00001	-0.33
Discount for mandatory system, tax (£)	-	-	-	-	-	-	-	-	0.0003	2.1	0.0002	1.41
Cost of voluntary system (£)	0.0012	8.89	-0.0003	-3.08	0.0005	5.73	-0.0007	-6.89	-	-	-	-
Discount for voluntary system, price (£)	-	-	-	-	-	-	-	-	-0.0003	-3.99	0.0004	7.02
Discount for voluntary system, tax (£)	-	-	-	-	-	-	-	-	-0.0005	-0.91	-0.0001	-0.2
Fuel rebate for voluntary system (pence/mile)	-0.3140	-6.77	0.2320	5.25	-0.2280	-5.35	0.3580	8.37	-0.0642	-1.1	0.0014	0.03
Insurance cash back for voluntary system (pence/mile)	-0.1190	-2.6	0.2800	6.64	-0.2690	-6.66	0.3820	9.32	0.0071	0.12	0.0871	1.56
Free safety add-on	-	-	-	-	-	-	-	-	0.2620	3.22	-	-
Free styling add-on	-	-	-	-	-	-	-	-	0.3530	3.38	-	-
Free entertainment add-on	-	-	-	-	-	-	-	-	0.4480	4.31	-	-

Figure 1: Example of typical choice scenario[7]

SCENARIO 25	PERMANENT	OPT-OUT
Vehicle purchase price discount	£3500	£1000
Incentive to use: Cashback on your insurance	no incentive	For every mile the speed limiter is switched on earn 1p (max £200 per year for 20,000 miles)
Penalty for speeding	6 points	6 points
% of other equipped vehicles on road	40% equipped (60% not equipped)	40% equipped (60% not equipped)

[7] The ISA systems were referred to as permanent (mandatory) and opt-out (voluntary) speed limiters to ease understanding and avoid confusion with mandatory fitment.