ON THE IMPACTS OF SEPTEMBER 11TH ON INTERCITY PASSENGER TRAVEL BEHAVIOR AND AN ASSESSMENT OF THE IMPACTS OF INSPECTION TIME ON THE AIRLINE INDUSTRY'S MARKET SHARE AFTER 9/11

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ABSTRACT

This paper quantifies the behavioral impacts of 9/11 on intercity passenger travel as well as the significance of inspection time on airline industry's market share. The behavioral modeling is based on a sample of 214 individuals, providing stated preference data about hypothetical intercity travel mode choices. The modeling results indicate that air travel has been much more adversely affected by 9/11 compared to the other three alternatives. In addition, travel costs, travel time, and security inspection time are found to play an important role in mode choice decisions.

The paper also simulates the security screening procedures at a hypothetical commercial airport. The results show that: (1) for the base case with an average inspection time of about two hours (similar to the situation immediately after 9/11), the market share of the airline industry was about 32% for the three intercity corridors, (2) if the average inspection time reduced to about one hour, the market share would increase to about 41%, and (3) if the average inspection time reduced to about half an hour, the market share would increase to about 46%. This suggests that additional security-related investments have a significant effect on the airline industry's market share.

Keywords: Airport Security Screening; Behavioral Impacts; Discrete Choice Modeling; Extreme Events; Mixed Logit

1. INTRODUCTION

Immediately after the 9/11 attack, the North American airspace was completely shut down for four days. The airline industry faced an unprecedented decline in demand for air travel. It has been estimated that, just in the first week after 9/11, the U.S. airline industry lost $1-$2 billion (Kumar et al., 2003). Recent passenger surveys show that most travelers feel as safe flying now as they did before 9/11, but that a significant number of travelers still avoid traveling by air, either out of fear or because of the increased security and the uncertainty of passenger processing times at the airport (MIT, 2004).

Although it is clear that 9/11 impacted passengers' travel behavior, the research community has not put together a full picture of the underlying behavioral impacts, or quantitatively analyzed the significance of inspection time on the airline industry's market share. The main objective of this research is to fill this gap and contribute to our understanding of travel behavior after extreme events. Such an understanding will enable transportation and city planners to evaluate and implement alternative strategies to help a city recover after extreme events.

The data used to support the analysis in this paper are drawn from a survey conducted for a project sponsored by the National Science Foundation to assess the changes produced by 9/11 on intercity passenger travel behavior. Preliminary analyses of the data can be found in Holguín-Veras et al. (2003), which was based on the 192 surveys that had been received at the time. This paper builds upon the results of Holguín-Veras et al. (2003) in two important ways. First, more behaviorally realistic econometric models are used to provide additional insights of the behavioral impacts. Second, the behavioral models are used to estimate the impacts that the massive security investment that took place after 9/11 have had on the airline industry's market share.

The analyses in this paper are based on a sample of 214 individuals providing Stated Preference (SP) data on hypothetical intercity travel choices. The questionnaire was administered to 200 graduate and undergraduate students at the City College of New York, as well as 14 student volunteers from The University of Texas at Austin. The survey was conducted from March to May of 2002, approximately six months after 9/11. Using the SP data collected from the survey, the research undertaken here focuses on (1) estimating behavioral models based on the Random Utility Theory (RUT), (2) analyzing the modeling results, and (3) assessing the impacts of 9/11 on intercity passenger travel behavior.

The paper has five sections, including this introduction. Section 2 describes the survey instrument and provides a brief descriptive analysis of the data. Section 3 describes the model methodology used. Section 4 presents and interprets the model estimation results. Section 5 assesses the impact of security investment on market share of the airline industry. Section 6 summarizes the key findings.

2. SURVEY INSTRUMENT AND RESULTS

This section provides an overview of the survey instrument and important descriptive analyses of the data collected.

Choice Situation

The choice situation in the SP survey was framed in the context of business trips from one city to another city. A business trip was used because it eliminates the choice of not to travel that is more likely to be available for non-business trips. Thus, using business trips presents a fairly clear choice situation that minimizes misunderstandings on the part of the respondents. Another benefit of using a business trip in the choice situation is that the behavioral changes identified could be interpreted as lower bounds of the impacts, because non-business trips are likely to be more impacted than business trips.

Another relevant decision concerning the choice situation is trip distance. For long trip distances, since air transportation may be the only practical alternative, respondents may feel captive to air transportation. At the other extreme, short trips not suitable for air transportation may lead to the same type of problem because respondents may feel captive to the car alternative. Consequently, the focus here is on the mid range of trip distances, for which the decision makers have different alternatives that effectively compete with each other. In this context, the behavioral changes would reveal themselves as components of the tradeoffs among alternatives captured by the systematic component of the utility functions.

Survey Instrument

The survey focused on three different intercity corridors in the northeast part of the U.S.: (a) New York City-Washington D.C., (b) New York City-Boston, and (c) Boston-Washington D.C. The survey questionnaire starts with asking respondents if they have ever made a trip in any of the three inter-city corridors. If they have made a trip, the respondents are asked about trip frequency, trip mode, time of travel, who paid for the trip, reasons for selecting the mode, cost of the selected mode and preference, and rank of four different modes (Metroliner, Acela, air, and car). Questions were also included to obtain respondents' socio-economic characteristics.

The survey next proceeds to SP experiments, where respondents choose a preferred mode for nine hypothetical scenarios of travel in one of the three assigned corridors. About half of respondents were told that their employer would pay for the trip, while the other half were asked to assume they would pay by themselves. The choice set included four alternatives: two train alternatives (Metroliner and Acela), air, and car. The two train alternatives differed in travel time and cost in the choice scenarios to reflect the fact that trips by Acela take less time and cost more than Metroliner. The alternatives in the choice set were characterized in terms of: (a) travel time, (b) inspection/boarding time at the airport (assumed to have three factor levels of 25, 60 and 120 minutes), (c) cost of travel time, and (d) the departure and arrival times of the train alternatives and air (three factor levels each). A full factorial design was used and non-feasible combinations were removed. Throughout the experiment, the attributes of the car alternative remained constant.

The sample of individuals used in the study is a convenience sample of college students, which may lead to a biased sample. In total, 214 complete surveys were collected from 200 graduate and undergraduate students from the City College of New York, and 14 volunteers from University of Texas at Austin. Nevertheless, as shown later in the paper, the models estimated do provide insights on the impacts of 9/11 on travelers' decision process.

Descriptive Analyses of Survey Results

The majority of respondents were male (61.2%), college educated (88.8%), single (56.1%), and with no children (57.0%). A typical respondent is about 32 years old, with 2.8 individuals in the household.

The majority of respondents actually traveled from NYC to Washington D.C. (65.7% of those who were asked about this trip) and from NYC to Boston (70.7%), but a much smaller percentage (28.1%) made Boston-Washington D.C. trips. This is intuitive given that the sample comprises individuals whose primary residence is NYC.

Of the 214 total respondents, 122 respondents (or 57.0%) indicated that they had made the trip in the intercity corridor they were assigned to in the SP experiments. Out of this group, 53.3% made that trip over a year ago, 23.0% made that trip 1-6 months ago, 18.0% 6-12 months back, and only 5.7% made it less than a month ago. The distribution of frequency of trips along the intercity corridors was as follows: twice a year (84.4%), 3-5 times a year (9.8%), 3 respondents reported 6-8 times a year (2.5%), only two respondents reported more than 8 times a year (1.6%), and two respondents did not provide answers. The distribution of trip purpose was: social (59.8%), work (16.4%), education (6.6%), and other (17.2%). The majority of respondents traveled by car (59.8%), followed by air (18.0%), Amtrak (13.1%), other (8.2%), and one respondent did not provide a response. Respondents were then asked to indicate all reasons that they chose the mode they used for the last trip (they were allowed to check all that apply): 64.8% of respondents mentioned convenience, followed by cost (53.3%), comfort (36.1%), trip time (27.9%), reliability (20.5%), safety (17.2%), security (13.9%), and easy transfers (8.2%). The majority (68.9%) of respondents paid for the trip themselves, which is probably the reason why cost was important in mode choice; 18.0% of trips were paid by the employer, 5.7% by family, 4.9% by others, and 2.5% did not provide responses.

The survey also collected information about the psychological impacts of 9/11 relating to intercity travel. This was assessed based on two sets of variables derived from the questionnaire: the stated impact produced by 9/11 (*Change*) and respondents' stress level (*Stress*). These two variables are described next.

The variable *Change* was estimated using a seven point ordinal scale using the question: "How much did 9/11 change your travel choice of whether to travel or not" (1 = not at all, and 7 = significantly). The survey results show that the average *Change* score is 3.4 (standard deviation=2.0), which corresponds to moderate *Change*. Respondents were then asked how 9/11 affected their choice of travel (they were allowed to check all that apply). It was found that the majority of respondents (73.4%) mentioned *they are more conscious of security*, followed by *more aware of people traveling with them* (45.3%), *more selective in choosing travel mode*

(33.6%), *avoid traveling by air* (21.0%), *avoid traveling altogether as much as they can* (11.2%), and only 2.8% mentioned *they plan to change type of work*.

Stress was estimated using a 4-item version of the Perceived Stress Scale (PSS4) (Cohen and Williamson, 1988), which assessed the degree to which respondents appraise their life as stressful. Respondents indicated how frequently they felt unable to control the important things in life, felt unable to overcome difficulties, felt confident about handling personal problems, and felt things were going right. The first two items were rated on a 5-point scale ranging from 1 (never) to 5 (often) and the last two were reversely scored. A total stress score (PSS4) for each respondent was calculated by summing item responses. PSS4 scores could range from 4 to 20; the lowest and highest total stress scores in this sample were 4 and 14, respectively. The survey results show that the mean was 9.6, with a standard deviation of 2.1. This translates into a mean of 2.4 for each item, corresponding to “almost never” for the first two items, and “fairly often” for the last two.

3. METHODOLOGY

The methodology relies on the use of discrete choice models (DCM). The basic problem studied by DCM is the modeling of choice from a set of mutually exclusive and collectively exhaustive alternatives. The DCMs used here are based on the concept of random utility maximization (RUM), which is a behavioral/economic theory that postulates that decision makers choose the alternative that maximizes the utility derived from their choices. RUM assumes that utility has two components: (a) a systematic component, which depends upon the socio-economic characteristics of the decision maker and the alternatives’ attributes, is explained by the variables included in the model; and, (b) a random component, which recognizes that the analyst does not have full information about all relevant variables and decision processes. The random components enable the formulation of random utility models based on probability principles. Different assumptions of the distribution of the random terms lead to different models. In the case that the random terms are assumed to be independent and identically distributed Gumbel across alternatives, one obtains the familiar multinomial logit (MNL) form for the probability expressions (Ben-Akiva and Lerman, 1985).

However, in spite of its usefulness, the MNL model is not suited for modeling of the problem described in this paper. First, the MNL assumes that the coefficients of the variables to the utility functions are constant across individuals. Although this assumption could be relaxed through market segmentation techniques, it is likely that there will be a significant degree of random taste heterogeneity across individuals in choice experiments that involve subjective valuations of complex dynamics. Second, one important characteristic of the MNL model is the independence from irrelevant alternatives (IIA) property. The key assumption that leads to the IIA property is that the disturbances are mutually independent. However, this is not likely to be the case in this study. This is because there are two train alternatives, Metroliner and Acela, sharing all the unobserved characteristics of trains. Third, MNL models assume that repeated choices made by the same respondent are independent (Algers et al., 1998). Since in this study, each respondent provided attitudinal data for nine different scenarios, using responses from the same individuals is likely to introduce correlation in the data set (this is known as the repeated measurement problem, and is related to random taste heterogeneity).

On the other hand, the mixed logit (ML) model relaxes all three restrictions of the MNL models, which leads to a more realistic and flexible formulation. ML allows coefficients to vary in the population, does not exhibit the IIA property, and allows correlation in unobserved utility over alternatives and repeated choices. In the context of ML, the utility of alternative *i* for individual *n* for choice scenario *k* is,

$$U_{ink} = \beta X_{ink} + \eta_n z_{ink} + \varepsilon_{ink} \tag{1}$$

Where: X_{ink} is the systematic component, including travelers' socio-economic characteristics such as income, gender, education, and marital status, as well as trip attributes such as travel time and travel cost. β is the vector of coefficients for the system components. η_n is a vector of random terms with zero mean that varies over individuals according to the distribution $g(\eta_n | \Omega)$, where Ω are the fixed parameters of the distribution *g*. We use a normal distribution for *g*(.) in this paper. z_{ink} can share some or all elements with X_{ink}. The term $\eta_n z_{ink}$ is the error component that induces heteroscedasticity and correlation over alternatives in the unobserved portion of the utility, which relaxes the IIA property that holds for MNL (see Bhat, 2003). ε_{ink} is the Gumbel-distributed random component with zero mean and unit scale, assumed to be independently and identically distributed.

Estimation of ML entails the estimation of β and Ω. Conditional on η_n, the probability that individual *n* selects alternative *i* for choice scenario *k* is:

$$L_{nk}(i | \eta_n) = \frac{\exp(\beta X_{ink} + \eta_n z_{ink})}{\sum_{i \in I} \exp(\beta X_{ink} + \eta_n z_{ink})} \tag{2}$$

The unconditional probability of this is:

$$L_{nk}(i) = \int_{\eta_n = -\infty}^{+\infty} \frac{\exp(\beta X_{ink} + \eta_n z_{ink})}{\sum_{i \in I} \exp(\beta X_{ink} + \eta_n z_{ink})} g(\eta_n | \Omega) \partial \eta_n \tag{3}$$

Since respondents reported multiple choices for different scenarios, an expression for the probability of the string of choices made by each respondent is needed. Conditional on η_n, the probability of individual *n*'s observed sequence of choices is the product of standard logits:

$$S_n(\eta_n) = \prod_k L_{nk}(i \mid \eta_n) \tag{4}$$

The unconditional probability is:

$$S_n = \int_{\eta_n=-\infty}^{+\infty} S_n(\eta_n) g(\eta_n \mid \Omega) d\eta_n = \int_{\eta_n=-\infty}^{+\infty} \prod_k L_{nk}(i \mid \eta_n) g(\eta_n \mid \Omega) d\eta_n \tag{5}$$

However, equation (5) does not have a closed form, and it usually needs the use of simulation techniques to estimate the maximum likelihood function. In the paper, we used 200 draws per individual of the Halton sequence in a maximum simulated likelihood (MSL) estimation approach (see Bhat, 2003). The results were tested with different numbers of Halton draws, but the results clearly stabilized at 200 draws.

In this study, an individual-specific error term was introduced in the utility functions of Metroliner and Acela. This entails specifying a variable in the z_{ink} vector that takes a value 1 for the utility of alternatives corresponding to Metroliner and Acela, and 0 for the utility of other alternatives in Equation (1). The motivation for this error structure is to induce higher levels of sensitivity between the two rail modes because of such individual-specific unobserved factors as being train-inclined.

4. MODELING RESULTS

Since the analyses conducted here are related to Holguín-Veras et al. (2003), it is important to highlight some of their key findings for comparison purposes. In the previous research, the modeling results indicated that: (1) variables such as travel costs, travel time, income, gender, education level, and marital status are statistically significant explanatory variables in inter-city mode choice; (2) variables that measured the impact of 9/11 on individuals that participated in the survey, i.e., *Change* and *Stress*, were found to play a statistically significant role in affecting mode choice.

In the current study, the inter-city mode choice models were estimated using car as the base alternative for introducing alternative specific constants. Two travel cost variables were considered: *Company Costs* and *User Costs* (in U.S. dollars) that represent the actual charges incurred either by the company or the traveler (depending on who pays for the trip expenses). In the previous study (Holguín-Veras et al. 2003), it was found that the marginal disutility of *Company Costs* is approximately half the value of the marginal disutility of *User Costs*.

The role of travel time was considered using four different variables, as discussed next. *Inspection/Boarding Time* refers to the time spent at the airport checking-in and going through the security check points. *Main Travel Time* is the time spent in door-to-door travel excluding inspection/boarding time, i.e., total travel time minus inspection and boarding. Respondents were told that they had an important meeting at a certain time. Depending on the mode they chose, they arrived at the destination some time before the meeting, which varied from 5-80 minutes. *Extra Time 1 before Meeting* represents the extra time before the meeting up to the cutoff value of 30 minutes, while *Extra Time 2 before Meeting* represents the extra time in excess of 30 minutes. *Extra Time 1 and 2* create a piecewise linear approximation to nonlinear effects of the utility functions. As shown in Holguín-Veras et al. (2003), the time available in excess of 30 minutes has a negative utility.

In the previous study by Holguin-Veras (2003), the *Change* and *Stress* scores were used directly in the modeling process assuming that these two variables could be treated as if they were ratio scales, when in fact they are ordinal scales. For this study, a set of binary variables were created to indicate different levels of *Change* and *Stress*, and used as interaction terms with main travel time. For the variable *Change*, three binary variables were created to indicate if respondents reveal small, moderate or significant *Change*: if the *Change* score is 1 or 2, the binary variable *Change 1* (small *Change*) is equal to 1; if the *Change* score is from 3 to 5, the binary variable *Change 2* (moderate *Change*) is equal to 1; if the *Change* score is 6 or 7, the binary variable *Change 3* (significant *Change*) is equal to 1. Similarly, three binary variables were created for *Stress*: if the *Stress* score is from 4 to 8, the binary variable *Stress 1* (small *Stress* level) is equal to 1; if the *Stress* score is from 9 to 11, the binary variable *Stress 2* (medium *Stress* level) is equal to 1; if the *Stress* score is greater than 11 (from 12 to 14 in this case), the binary variable *Stress 3* (high *Stress* level) is equal to 1.

Table 1 presents the best estimation results for the ML model. Several different error components structures (to generate correlation and heteroscedasticity across alternatives at the individual level) as well as varying sensitivities across individuals to the time and cost variables were considered. The final specification in Table 1 was the result of retaining only the statistically significant effects. In this final specification, the standard deviation of the individual specific error term generating the higher sensitivity between the two rail modes does not appear because it turned out to be statistically insignificant. The model includes variables of trip attributes such as main travel time (total travel time minus inspection time), inspection time, extra time before meeting, interaction term between main travel time and the binary variable indicating how individuals changed their decision of travel after 9/11 (*Change 2* corresponding to *Change* scores from 3 to 5 or *Change 3* corresponding to *Change* scores from 6 to 7), as well as demographic variables indicating if the respondent is married.

In this model, the coefficient of the main travel time is random. The mean of the coefficient of main travel time is about the same as the one for inspection time. The coefficients of *CC* (travel cost if company pays/household income) and *UC* (travel cost if user pays/household income) are both negative, indicating that the utility function decreases with travel cost. However, the effect of cost reduces as income increases. The absolute value of the coefficient for *CC* is about three times the value of that of *UC* (higher than results from previous study), indicating that when company pays, users behave as having a much higher valuation of travel time than when they are paying for the expenses. Using $45,000 as the household income (the household median income of these respondents is about $44,058), and the mean of the main travel time, the implied money values of travel time are about $343.3/hr if company pays and $122.3/hr if traveler pays. The travel time values are relatively high; this might be due to the inclusion of the cost divided by income variable, which is consistent with the findings from Jara-Diaz et al. (2005). Using real data to simulate the variation in income around the observed average (coefficient of variation increases from zero to a modest 0.3 value), they verify that, given that everything else remains constant, discrete choice models using a cost over income variable yielded average SVTTS (Subjective Value of Travel Time Savings) up to ten times larger than the linear in cost models for the same population data. They also suggest that this is due to the variation of the marginal utility of income estimate.

The coefficient of *ET1* (extra time before meeting up to 30 minutes) is positive, while that of *ET2* (extra time before meeting in excess of 30 minutes) is negative, suggesting that individuals prefer to have certain amount of extra time before meeting, but not too long. These are consistent with the previous study (Holguín-Veras et al., 2003).

The term *TT2CH23* captures the interaction between main travel time and the binary variable for moderate or significant *Change* (this variable takes the value of 1 if the *Change* score is from 3 to 7). The variable *Change 1* did not exhibit a significant effect when interacted with travel time, and thus is not included in the model. This is reasonable because these respondents said that 9/11 did not have much of an impact of their choice of whether or not to travel. The binary variables *Change 2* and *Change 3* were combined here because, when treated separately, the coefficients of these two interaction terms were statistically the same, indicating that the impacts on choice of travel are about the same for respondents reporting moderate and significant *Change*. The coefficients of *TT2CH23* were only significant for air and car, and the absolute value of the coefficient for air is about three times the value of that of car, indicating that the impact on air travel is much larger than the other alternatives, which is reasonable due to the 9/11 events. The only demographic variable included in this model is *MARRIED*, being positive and significant for trains and car.

Overall, travel costs, travel time, inspection time at the airport security checkpoint, income, and marital status were found to be statistically significant explanatory variables in the mode choice process. The results indicate that air travel is much more adversely affected by 9/11 compared to the other three alternatives, which is consistent with the fact that, after 9/11, people avoid traveling by air either out of fear or because of the increasing security and the uncertainty of passenger processing times at the airport.

5. ESTIMATED IMPACT OF SECURITY INVESTMENT ON THE AIRLINE INDUSTRY'S MARKET SHARE

As discussed in the previous section, the estimated behavioral models quantify the importance of inspection time on inter-city mode choice. This suggests that the massive security investment post 9/11 – by significantly reducing inspection time – has had a significant impact in restoring the airline industry's market share.

This section assesses the role played by the reductions of inspection time, brought about by the increased security investment, on helping restore the airline industry's market share. This is accomplished by means of the combined use of: discrete event simulation to estimate inspection times for various configurations, and the discrete choice models estimated in the previous section to estimate the corresponding market shares.

In undertaking the analyses, it would have been ideal to have access to data for a real life airport immediately after 9/11, when passengers experienced huge delays at the security checkpoints. Unfortunately, no publicly available data were found. Instead, the authors decided to simulate an idealized airport checkpoint operation—a composite of different airports—with passenger traffic and checkpoint configurations similar to the ones post 9/11.

The hypothetical airport used in the simulations is a hybrid of two real life airports: the Hartsfield-Jackson Atlanta International Airport (ATL) and the Tampa International Airport (TPA). The arrival patterns in the simulations correspond to the ones for ATL, while the service time distributions come from TPA. In essence, this is equivalent to assuming that the security checkpoint process in ATL follows the same statistical distributions as the ones observed in TPA. Given the data constraint, this seems a reasonable assumption. The data on the security screening process at TPA comes from Yalcin et al. (2005) and Mitchell et al. (2006).

Discrete event simulation techniques were used to simulate the process at the security checkpoint. Figure 1 shows the flow chart of the screening process used in the simulation. As shown, the security screening procedures start when passengers arrive at the checkpoint and join the line where a security guard checks IDs and passports. As passengers approach the screening lanes, passengers remove metal items, take off their coats and shoes, and load them on trays to put them to the X-ray machines. Then the carry-on baggage screening process starts, at the same time the passenger screening process begins. If an alarm is set off, a secondary screening process starts, in which the baggage or the passenger will be searched. Once the passenger and her/his baggage successfully pass the security check, passengers pick up their baggage and go to the gates.

The simulation focuses on a typical one hour period. The simulation program stops when the last passenger is processed. It was assumed that 80% of passengers would pass the primary security screening and go to gates directly, another 10% would need to go through the secondary screening then go to gates, the rest 10% cannot pass the security screening and their entries are denied, which is consistent with the guidelines of Transportation Security Administration (TSA) that the average number of cleared passengers be more than 90% of passenger arrivals.

As mentioned earlier, the objective of this analysis is to see how security infrastructure impacts inspection time. For that reason, inspection times were estimated for various configurations of screening lanes. For each of these configurations the present value of costs (PVC) were computed assuming an economic life of 10 years and an opportunity cost of the capital of 6%. It was assumed that a new screening lane costs $2 million, which corresponds to the average cost reported for the Washington National Airport (Frank, 2006). The salary of the security personnel was assumed to be $15 per hour with 100% overhead and 36% fringe benefits. The labor costs were estimated assuming that there are five security guards at each security lane and all lanes are open for 12 hours everyday. These assumptions are approximately equivalent to a typical profile of lane usage at a large airport throughout the weekdays (Bradley and Goyal, 2003).

Table 2 shows the results from different simulation runs together with the PVCs. As shown, when there are only 10 inspection lanes, the average inspection times is close to two hours, which is what was observed at major airports immediately after 9/11. As shown and as expected, the larger the number of inspection lanes, the shorter the inspection time and the larger the total cost.

Table 3 shows the market shares of the four modes under different configurations, which were estimated using results from the best ML model, using the average inspection time obtained from the simulation models. The results show that if the number of screening lanes increased from 10 to 36, the inspection time would decrease from about two hours to only 10 minutes, and the percentage traveling by air would increase from 32.11% to 49.32%; also, if the number of screening lanes increased from 16 to 36, the inspection time would decrease from about one hour to 10 minutes, and the percentage of traveling by air would increase from 40.76% to 49.32%. Figure 2 shows the change of air market share and inspection time for different configurations, with the PVCs (rounded to the closest integer) shown as labels on top the curve of inspection time. These analyses suggest that the higher investment in security has a significant impact on increasing the airline industry's market share.

6. CONCLUSION

This paper quantifies the behavioral impacts of 9/11 on intercity passenger travel as well as the significance of inspection time on airline industry's market share. The behavioral modeling is based on a sample of 214 individuals, providing SP data about hypothetical intercity travel choices.

The models estimated in the paper considered four competing modes for intercity business trips: two train alternatives (Metroliner and Acela), air and car transportation. The model results show that, when the traveler's company pays, users have a higher valuation of travel time (about two times higher) than when respondents are paying for the expenses personally. The travel time values are about $343.3/hr if company pays and $122.3/hr if user pays (using $45,000 as the household income).

In general, the modeling results are quite intuitive, and indicate that air travel has been much more adversely affected by 9/11 compared to the other three alternatives. This is consistent with the fact that, after 9/11, people avoided traveling by air either out of fear or because of the increasing security and the uncertainty of passenger processing times at the airport.

In addition to the mode choice estimations, the paper also simulated the security screening procedures at a hypothetical commercial airport. Construction, labor costs and PVCs for different configurations of the security checkpoint were estimated, as well as the market shares of the four transportation modes. The simulation results shed light on the impact of security investment on the market share of the airline industry. Specifically, the results indicate that additional resources to reduce inspection time significantly impact the market share of the airline industry. The results show that: (1) for the base case with an average inspection time of about two hours (similar to the situation immediately after 9/11), the market share of the airline industry was about 32% for the three intercity corridors, and the PVC value was about $52 million dollars assuming an economic life of 10 years and an opportunity cost of the capital of 6%, (2) if the average inspection time reduced to about one hour, the market share of the airline industry would increase to about 41%, but this would entail a cost of $30 million dollars, and (3) if the average inspection time reduced to about half an hour, the market share of the airline industry would increase to about 46%, but this would entail a cost of $73 million dollars.

Finally, it is important to mention that, in spite of the contribution made by this paper, there is a need for systematic and long-term research to fully understand the impacts of extreme events on travel behavior.

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Table 1. Estimation Results of the Best Model

Variable	Rail alternatives		Fly	Drive
	Metroliner	Acela	Air	Car
Alternative specific constants	-1.6221	-2.7621	-2.2633	0.0000
	(-5.949)	(-3.969)	(-2.327)	(--)
Standard deviations for alternative specific	--	2.4165	--	--
constants	(--)	(3.082)	(--)	(--)
Main travel time	-0.0367	-0.0367	-0.0367	-0.0367
	(-5.271)	(-5.271)	(-5.271)	(-5.271)
Standard deviations for main travel time	0.0422	0.0422	0.0422	0.0422
	(5.164)	(5.164)	(5.164)	(5.164)
IT	--	--	-0.0347	--
(inspection time)	(--)	(--)	(-4.521)	(--)
CC	-0.2826	-0.2826	-0.2826	-0.2826
(company cost/income in thousands)	(-4.484)	(-4.484)	(-4.484)	(-4.484)
UC	-0.7932	-0.7932	-0.7932	-0.7932
(user cost/income in thousands)	(-7.249)	(-7.249)	(-7.249)	(-7.249)
ET1	0.0533	0.0533	0.0533	0.0533
(extra time before meeting < = 30 mins)	(3.719)	(3.719)	(3.719)	(3.719)
ET2	-0.0075	-0.0075	-0.0075	-0.0075
(extra time after meeting > 30 mins)	(-1.249	(-1.249	(-1.249	(-1.249
TT2CH23	--	--	-0.0106	-0.0039
(Main travel time* Change 2 or 3)	(--)	(--)	(-3.091)	(-5.228)
MARRIED	1.8609	1.5599	--	2.1982
(1 if married)	(3.609)	(3.237)	(--)	(3.602)
Mean Log likelihood function		-1.37377		
Number of Cases		1755		
Adjusted rho-squared bar with respect to constants		0.112		

Table 2: Estimation of Costs Based on Simulation Results

Screening Lanes	Average Inspection Time (min)	Construction Cost ($ million)	Labor Cost ($ million/yr)	Present Value of Cost ($ million)
10	111.3	20	7.75	52.48
12	87.9	24	9.30	62.97
14	70.0	28	10.85	73.47
16	56.9	32	12.40	83.97
18	48.2	36	13.95	94.46
20	39.0	40	15.51	104.96
22	33.7	44	17.06	115.45
24	28.9	48	18.61	125.95
26	24.3	52	20.16	136.44
28	20.4	56	21.71	146.94
30	18.3	60	23.26	157.44
32	14.1	64	24.81	167.93
34	12.2	68	26.36	178.43
36	9.8	72	27.91	188.92

Table 3. Estimation of Market Shares Based on Simulation Results

Screening Lanes	Average Inspection Time (min)	Market Share			
		Metroliner	Acela	Air	Car
10	111.3	20.81%	17.10%	32.11%	29.98%
12	87.9	19.43%	15.61%	35.62%	29.34%
14	70.0	18.31%	14.42%	38.53%	28.75%
16	56.9	17.45%	13.53%	40.76%	28.27%
18	48.2	16.87%	12.93%	42.28%	27.92%
20	39.0	16.24%	12.30%	43.93%	27.53%
22	33.7	15.88%	11.93%	44.89%	27.30%
24	28.9	15.55%	11.60%	45.77%	27.08%
26	24.3	15.23%	11.28%	46.61%	26.87%
28	20.4	14.81%	10.87%	47.73%	26.58%
30	18.3	14.52%	10.59%	48.51%	26.38%
32	14.1	14.52%	10.59%	48.51%	26.38%
34	12.2	14.39%	10.46%	48.87%	26.28%
36	9.8	14.22%	10.30%	49.32%	26.16%

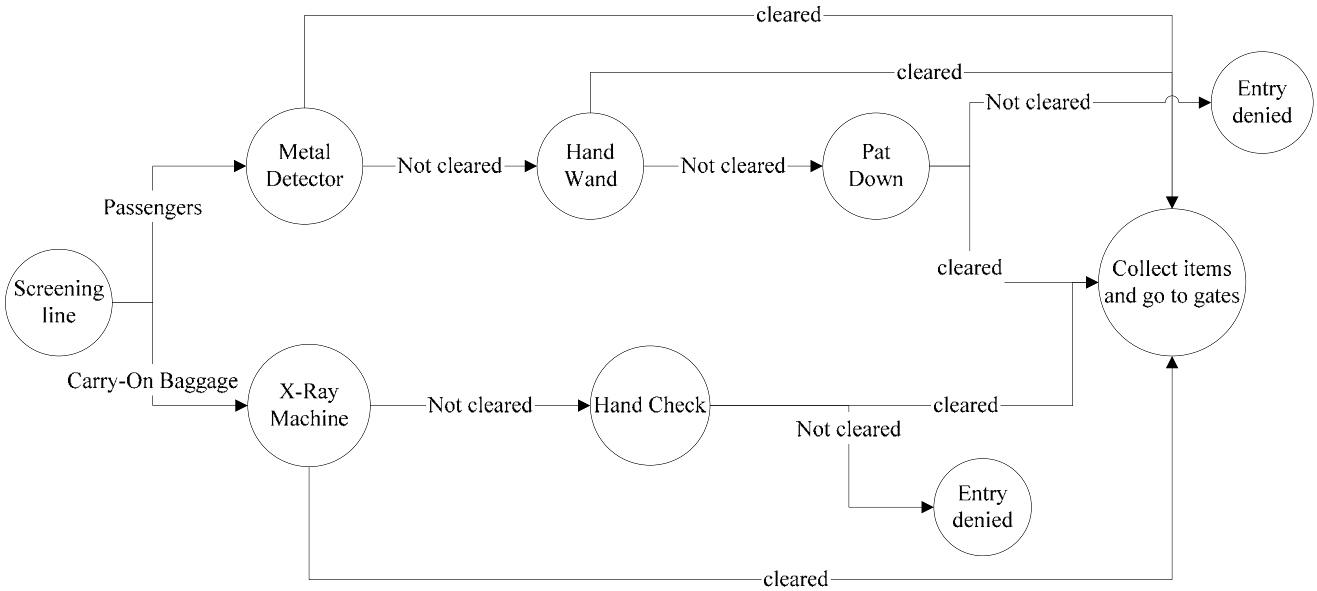

Figure 1. Screening Process for One Screening Lane

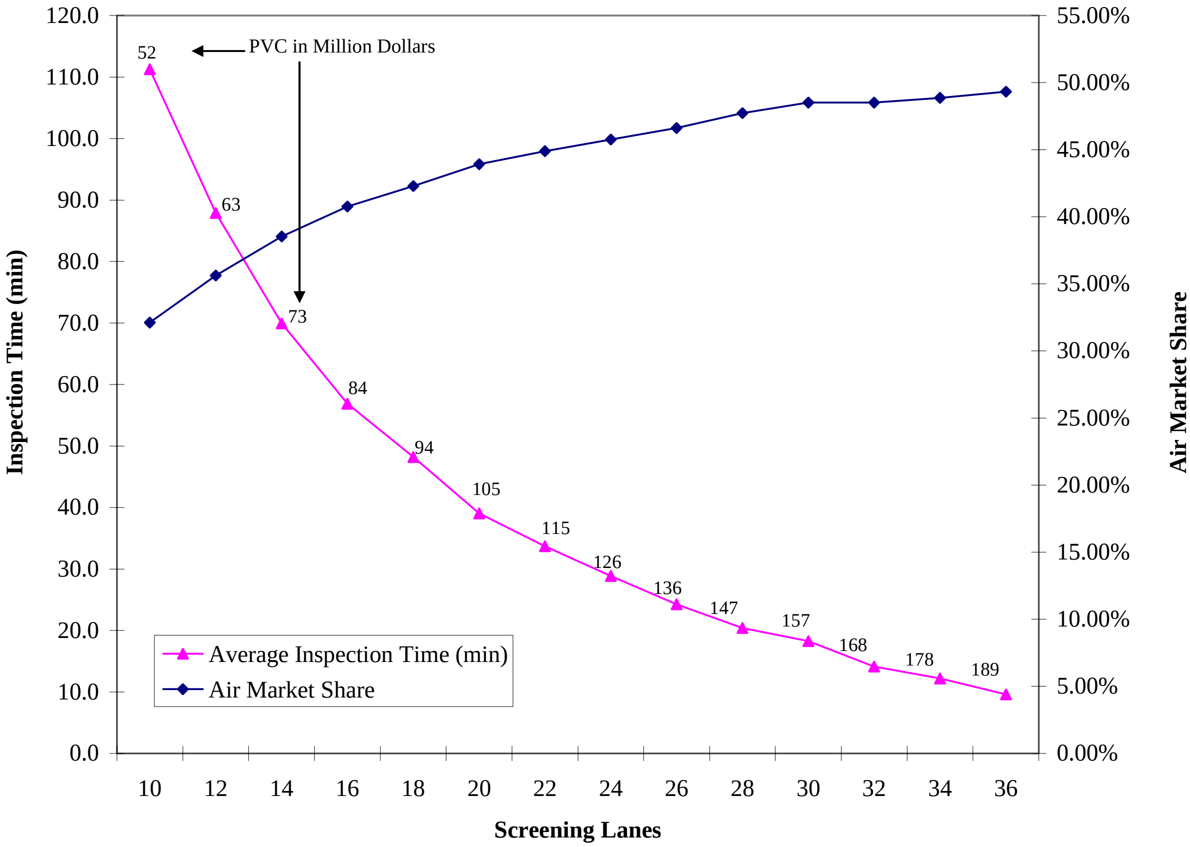

Figure 2. Air Market Share vs. Inspection Time vs. PVC