ADVANCES IN TRANSPORTATION STUDIES
An International Journal

Editor in Chief
Carlo Benedetto

Section A & B

Vol.V • April 2005

Contents

Section A

Section B

ADVANCES IN TRANSPORTATION STUDIES

An International Journal

Section A

The safety perceptions of road, rail and air and their implication on travel choices

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subm. 16th July 2004 *approv. after rev. 30th September 2004*

Abstract

Highlighted by the 9/11 disaster, safety and security concerns have become more paramount than ever, sometimes even becoming the sole decision factor in certain travelers' choice selection process. Closely related to the solutions to national security and infrastructure protection issues, intermodal and multimodal access becomes more important than ever. For example, both Maglev and High Speed Rail (HSR) have been examined as potential intercity travel alternatives and strategic backup systems for the national transportation network. The two key factors mentioned above, have motivated the authors to undertake a travel behavior survey and model calibration to investigate the importance of a few proposed factors in the travel choice decision process. A combination of revealed preference and stated preference survey was conducted to collect travel behavior data for 240 individuals who have made trips between New York and Washington D.C. The stated preference data are particularly applicable in implicating the characteristics and impacts of the potential new high speed ground transportation modes, such as HSR and Maglev. Binary logit discrete choice models have been calibrated to reflect the travel choices affected by four factors, travel time, monetary cost, safety, and reliability. This paper reports the initial findings of model calibration and their implications.

Keywords – Safety, safety perceptions, safety measures, travel choices

1. Introduction

It is necessary to analyze intercity travel behavior and forecast future travel demand to provide adequate intercity travel services. The intercity transportation project development processes in the United States demonstrated that the qualities of the decisions to provide transportation services are largely dependent on the quality of intercity travel analyses including the accuracy of the predicted demand, identification of factors affecting intercity travel demand, and the close approximation of travel demand distribution among available modes [1]. The key issue here is how society values the attributes of different modes for intercity travel.

This research focuses on improving one of the particular modules of travel demand modeling, the mode or service choice model, by incorporating additional explanatory variables. Together with other improvements proposed and undertaken by the transportation community, this effort

will contribute toward incorporating safety and security factors into the long-range transportation planning process.

2. Travel conditions

Safety and security concerns, highlighted by 9/11 Disasters, have become more paramount than ever. Sometimes, it even becomes the sole factor in certain travelers' decision-making process. As a famous psychologist [2] said: "catastrophe did not change people. It merely revealed or highlighted the inner qualities of the same people." By the same token, the September disasters did not create the safety and securities issues connected with transportation systems, but merely serves as a reminder to transportation professionals how important the safety/security factors are in travelers' decision-making processes.

The general travel conditions along the Northeast Corridor, especially between New York and Washington D.C. deserve in depth analyses. There are existing highway, rail, and airline services along this densely populated corridor. Millions of private automobiles and buses travel along the interstate highways and other major arterials. Amtrak operates very frequent services and takes up almost half of the combined air-rail market between the endpoints of New York and Washington D.C. The Metroliner and the newly inaugurated Accela Express trains attract an especially large number of business travelers. There are three large international airports in each area: Kennedy, LaGuardia, and Newark International Airport for the New York Metropolitan area and Reagan National, Baltimore-Washington International, and Dulles International airport for Washington D.C. Metropolitan area.

The massive transportation infrastructure and services are clearly the responses to the large travel demand along this corridor. Currently, the Northeast Corridor is facing a transportation capacity crisis. Its transportation network is severely and unacceptably congested. Its airports face a critical shortage of runway capacity. Its seaports require improved terminals and landside highway and rail connections to ensure their continuous growth and vitality. Its rail system must accommodate the conflicting demands of high passenger and freight movements on an aging infrastructure. The most significant problems are on its highways, which are among the nation's most heavily traveled roadways. According to Federal Highway Administration [3], the average annual daily traffic (AADT) volume on I-95 through the region exceeds 100,000 vehicles. At Washington, Baltimore, Philadelphia, and Newark metropolitan nodes along I-95, traffic volume, which includes commuter traffic as well as intercity traffic, ranges from 175,000 to 200,000 AADT.

To accommodate the existing travel conditions and anticipated future growth, new or improved transportation facilities have to be planned. It is not difficult to convince ourselves that more road construction, restricted by the limited land and negative environmental impact, is not the solution. Two of the high speed ground transportation modes, Maglev and HSR, have been contemplated as potential alternatives in the Northeast Corridor. Either Maglev or HSR with speeds in the range of 200 to 300 mph will provide a new service that can be characterized as somewhere between conventional rail and airplanes. The compact footprints and right-of-way widths are comparable with conventional railroad, and sometimes, they can be erected in or adjacent to the existing rail right-of-ways [4]. When comparing door-to-door travel time, especially for the midrange intercity travel distances, say from 200 to 500 miles, the Maglev or HSR may have great advantages over the airlines.

Considering the key events and factors described above, we conclude that there is a need to evaluate the intercity travel choices based on more comprehensive factors. Additional factors,

such as safety/security and reliability, need to be incorporated into the travel demand models, more specifically the mode or service choice models. Utilization of the combined stated preference data, perceived values, and discrete choice modeling techniques help the authors to test hypotheses and solve problems narrated in this section. The following section describes the conceptual framework of the travel choice analysis. Section 4 presents the methodology proposed for this research. Section 5 documents the model calibration process based on the travel behavior survey conducted along the Northeast Corridor. And the last section summarizes the results of this research and points out potential further studies to be undertaken.

3. The impact of safety perception

Originated from the classic microeconomic theory [5], travel behavior analysis often focused on travel disutility, such as travel time and monetary cost. Variables denoting disutility attributes and their relative significance have been thoroughly investigated within the urban travel demand forecast applications [6]. In the intercity travel context, however, the definition of utilities, positive attributes, or level of service and how they influence the choice behaviors are much less understood.

In an intercity travel choice model, the travel disutility is usually measured by the generalized cost, which is often the sum of the monetary cost through normal market transaction and the cost of the travel time used in making trips. As discovered by a number of researchers, there is evidence that a number of variables, not included in the travel behavior model, have significant impact on travel choices [7]. For example, a traveler will certainly examine how long it takes and how much it costs to make a trip. Meanwhile, he or she is also concerned how safe and convenient each alternative is and how a particular schedule relates to the activities planned. In order to improve the model's predictive ability, the concept of generalized cost should be extended further to include the costs attributable to service characteristics, such as reliability, safety/security, and comfort/convenience.

According to DeDonnea [8], three relevant attributes of each mode should be measured: travel time, travel cost, and comfort. Hensher [9] used an early example of an attempt to incorporate comfort and convenience in a travel mode choice model. Algers et al. [10] included comfort and convenience in a study on the value of travel time. Later on, one of the authors of this paper [11] proposed a conceptual framework that includes travel time, monetary cost, comfort/convenience, and safety/security in the travel choice models. As a part of the continuous effort in improving the travel choice models, this study focuses on the 4th dimension, safety/security factor, proposed in the conceptual framework depicted in Figure 1. The following sub-sections define the individual variables tested in the discrete choice logit model.

3.1 Travel time

For a rational traveler, it makes sense to minimize certain modal attributes while maximizing others. As one of the main factors affecting mode choices, travel time is the attribute that travelers usually try to minimize. Among various explanatory variables, travel time is incorporated in one way or another into virtually all travel mode choice analysis and models.

Travel time is usually counted from door to door because the travel status begins once a traveler leaves his or her starting location and ends when the individual traveler reaches his or her destination. Historically, different segments of total travel time, such as in-vehicle travel time (IVTT), access/egress time, waiting time, and transfer time [4] have been utilized in various travel choice models. However, the weighing factors associated with each type of time segment or

categorical details of out-of-vehicle travel times still vary and are in need of convergence. In the survey designed for this study, the total one-way door-to-door time was collected and incorporated into the utility index.

3.2 Monetary cost

The monetary costs of travel may vary depending on the length, mode, and time of the trip. The relative costs of essential trips affect the choice of mode. Along the Washington D.C. and New York corridor, the monetary costs of intercity trips range from 20 dollars to a few hundred dollars depending on the mode a traveler has taken. The travel party size also affects the monetary cost associated with intercity travel. For example, when driving, the marginal cost for an additional person may be minimal when the group size is between 1 to 4 persons. Trip purpose may not affect the monetary cost of the individual mode, but the source of expenses certainly has a great impact on individual traveler's mode choices.

The authors designed the survey to assess the true monetary costs associated with intercity travel along the North East Corridor. It includes total out-of pocket cost for a single trip, parking cost allocated to the individual trip in case a monthly or long term parking permit is purchased, and subsidies that may adjust the true out-of-pocket costs.

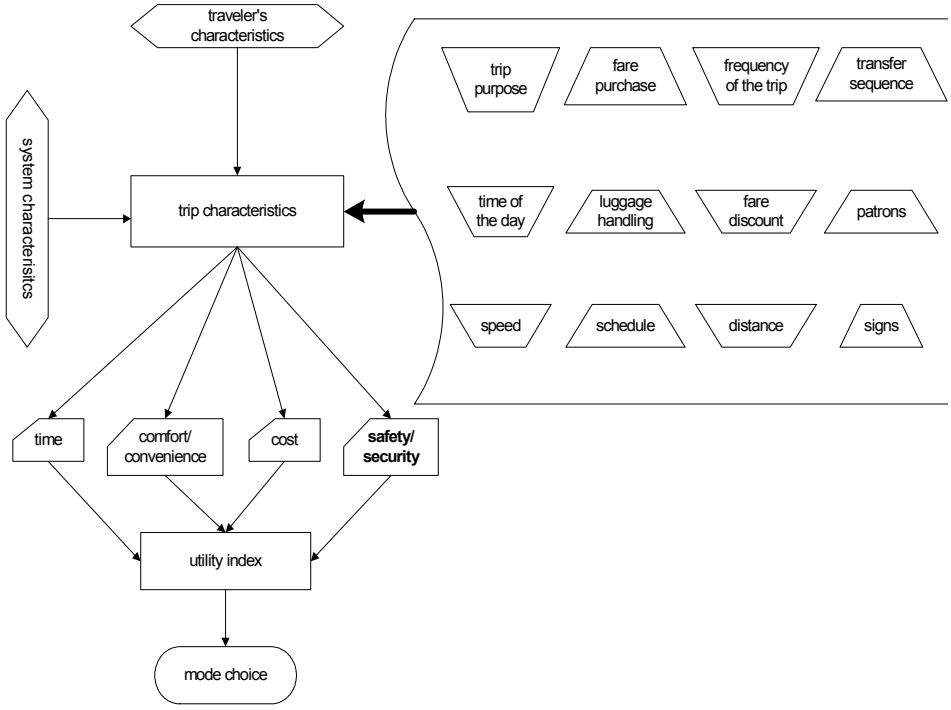

Fig. 1 – Extended General Cost of Travel Choices

3.3 Transportation safety and security

Webster's New World Dictionary defines, "safety" to be freedom from danger, injury, or damage and similarly "security" to have freedom from fear, anxiety, danger, doubt, etc. Transportation safety and security can be collectively referred as a process that strives to provide traveling parties freedom from danger, injury, damage, fear, anxiety, doubt, etc.

Traditionally, transportation safety has been concerned with the risks associated with trip making, such as accident rate, fatality rate, and property damages. The analyses of safety in transportation are often used as a barometer for identifying deficiencies, means and initiatives for improving safety [12]. The tragic event of 9/11, exhibited by the magnitude of the death and destruction, put to rest any doubt or debate on whether we need transportation security.

Generally transportation security threats can be divided into four categories: terrorism and highjacking, robbery and assault, theft and pilferage, and vandalism. A fifth classification, transport of illegal substances, has taken on added significance over the past few years [12]. Therefore, transportation security is charged to accomplish the following objectives:

- ensure the uninterrupted operation of the system,
- ensure the safety of the employees and the public,
- prevent the use of the transportation system for illicit purposes, and
- protect the vital national transportation assets.

Most people are aware of that no form of transportation can ever be completely risk-free. However, the expectation or impression of the safety and security of certain modes or services has great impact on the travel choices travelers make. Not many studies have addressed the safety/security issues, even though its impact on travel choice decisions is indisputable [13]. Part of the reason may be that there are no established common measures of safety/security parameters. The statistics on accident or risk factors does not register with the general public, i.e. it is hard for an individual passenger to perceive the meaning of the accident rate of 5 fatalities per 100 million vehicle mile traveled (VMT), while everyone can assess the impact of $10 fare raise on his or her wallet.

4. Methodology

High quality data is a fundamental element in the construction of a good model. To collect specific data that address the variables constructed in the conceptual model, the authors designed a survey including 21 questions. This questionnaire, similar to other travel behavior surveys, asked the socio-economic status of the travelers in the first part. The middle section of the questionnaire dealt with the current intercity travel behavior of the surveyed. The last section of the questionnaire collected stated preference data on different intercity travel alternatives. Those alternatives are defined by travel time, monetary cost, safety, and reliability factors.

4.1 Intercity travel choice survey

The survey effort yielded 240 valid responses. In other words, about 240 people filled-out the questionnaire completely and in a usable format, among which about one third were female and two-thirds male. The age of those individuals concentrated on two large groups 18-35 and 35-65. In retrospect, the author realized that the step wise might be too big. More detailed classifications may be implemented if another survey is to be carried out. As presented in Figure 2, the

predominant mode of travel is by car, then train, air, and bus in descending order, which is fairly consistent with the general travel modes along the Northeast Corridor.

The household income is clustered around $75,000 to $100,000, which is high compared to the average or mode of household income even in this region. A partial explanation may be obtained via the correlation with the occupations of the surveyed. The large categories of this sample are managers and professionals.

In addition to the assessment of safety/security, comfort/convenience, and reliability of each mode mentioned in last section, we also collected the reasons that the traveler did not select other modes. For example, if a traveler used auto, he was asked why he did not select bus, train, or airplane. The attributes in the selection include monetary cost, travel time, reliability, comfort, and safety. As depicted in Figure 2, monetary cost is the main reason that the travelers surveyed did not choose airlines. Convenience, monetary cost, and travel time are among the reasons for not choosing trains. For buses, the biggest obstacle is convenience.

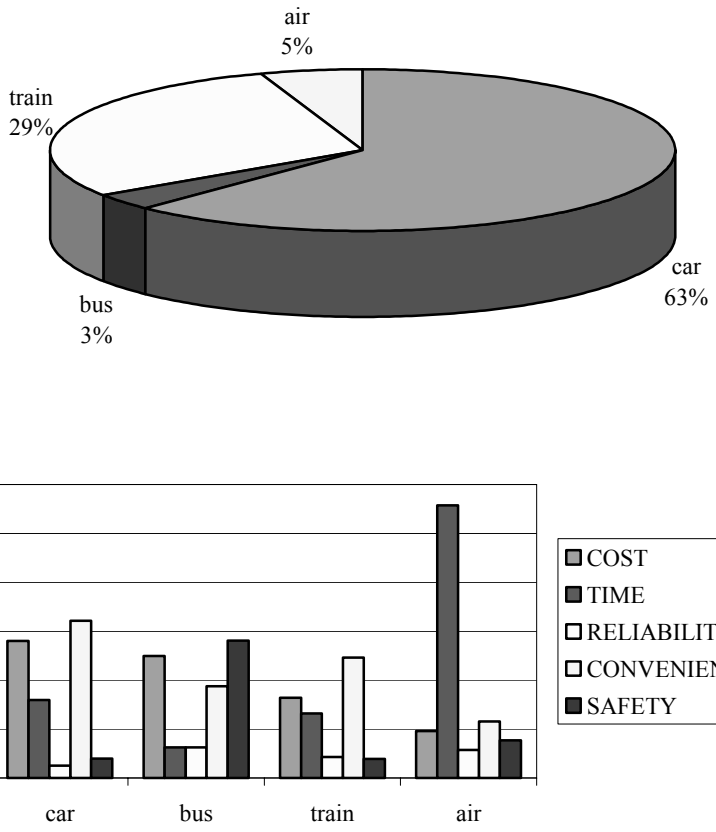

Fig. 2 – Survey Data (Mode share and impediments of different modes)

4.2 Perceived Values and Engineering Measures

As proved by a number of studies [14; 15], the decision outcomes of most travelers are based on the perception values rather than the engineering measures of individual variables. Factors that are not easily measurable, such as comfort/convenience and safety/security, are subject to feelings, attitude, and perceived values [16]. There are obviously certain problems and shortcomings associated with perceived values, however, aided by succinct definitions and rigorous statistic analysis, perceived values may be used as an effective tool in evaluating transportation choices. The fundamental reason is that travel decisions are usually based on perceived values.

Specifically in the area of transportation safety and security, researchers have argued [17] that the perceived safety of the travel modes is important for mode choice decisions. Travelers perceive the values by direct observation and contact with others and through the electronic media/images. These inputs form their perceptions, which may or may not correspond to actual values. Personal taste factors along with perceptions determine a person's preferences for activity participation and travel decision. Different travelers have different perceived safety factor for the same mode. Often, people who have been traumatized perceive higher risk than it is actually present.

This study collected information on the perceptions of current users toward each existing transportation mode. That is, the survey asked the travelers to indicate their assessment of each mode in terms of safety/security, reliability, and comfort/convenience. The question is phrased as the following:

"If safety is defined on the scale of 1 to 10, which means 10 is absolutely safe, 1 means not safe at all, how would you rate the safety of each mode? You can also apply the same scale to Reliability and Comfort/Convenience."

The responses, as presented in Table 1, correspond to the general perceptions of each mode. That is intercity bus services, represented by Greyhound, has the worst perceived safety rank when compared to the other modes. While intercity rail has the highest rank of perceived safety, that of airlines and private automobiles are in the middle.

The perceived safety ranks of each mode may be different from the engineering measurements depending on what proxies are used. For example, when measured by the fatality rate per 100 million vehicle miles traveled (VMT), intercity bus actually has the lowest fatality rate. The measurement of casualties per 100 million VMT yields different ranks, as shown in the lower part of Table 2.

However, the fact is that most travelers make their decisions on the perceptions or perceived values of the individual mode. It is vital to reflect the perceived values of transportation modes so direct linkages can be established for the travel choice decision making process.

It is worth noting that the survey was conducted from March 15th to April 15th, 2002, only 6 month after the September disasters. Most of people participated in the survey live in either New York or Washington Metropolitan area.

The safety concerns are certainly highlighted and may be amplified. It will be helpful to collect another set of data to test the weighing magnitude of safety and security in the traveler's decision process. However, the indications of the survey results certainly do not leave room for doubting the fact that perceived safety and security rankings of transportation modes have a fundamental impact on traveler's choice. This statement will be further proved by the model calibration presented in Section 5.

Tab. 1 – Perceived Values and Actual Measures of Existing Modes

Modes	Safety Security	Safety/Security Rank	Reliability	Comfort/ Convenience
Auto	7.8	2	8.3	8.4
Bus (Greyhound)	7.4	4	7.3	6.5
Rail (Amtrak)	8.4	1	8.1	7.7
Airplane	7.6	3	7.7	7.5

Fatality and Casualty Rates by Mode of Travel, 1997-1999

Type of Vehicles	Death Rate	Death Rate Rank	Casualty Rate	Casualty Rate Rank
		(Per 100 Million Passenger Miles)		
Automobiles	0.87	4	6.4	4
Intercity buses	0.04	1	3.2	3
Intercity railroads	0.06	3	0.528	2
Airlines	0.04	1	0.0112	1

Source: *Injury Facts*, National Safety Council, 2001.

Tab. 2 – Intercity Travel Choices Based on Stated Preference Data

Options	Total Travel Time	Total Round Trip Cost	Safety	Reliability		Option	Base Case
Base	240	$250	8	90%			
1	80 min less	$100 more	Same	Same	→		
2	60 min less	$35 more	1 rank less	2% more	→		
3	40 min less	$25 more	1 rank more	5% less	→		
4	40 min less	$75 more	1 rank more	2% less	→		
5	30 min less	$35 more	1 rank more	1% more	→		
6	Same	$95 less	2 rank less	Same	→		
7	Same	same	2 rank less	9% more	→		
8	20 min more	$15 more	1 rank more	Same	→		
9	40 min more	Same	1 rank less	3% more	→		
10	60 min more	$75 less	1 rank less	5% more	→		
11	110 min more	$25 less	1 rank more	6% more	→		
12	180 min more	Same	Same	9% more	→		

4.3 Stated Preference Data

As early as 1973, Davidson [18] and Louviere, et al. [19] alerted us the importance of evaluating an individual's response to combined attributes of transportation modes and level of services that may not be present or observed in the market place. In other words, a hypothesized mode or service characteristics of a transportation system could and should be evaluated in the travel demand analysis. A number of travel demand researchers have been trying to use stated preference (SP) data, which is surveyed with hypothetical choice scenarios and fully controlled alternatives. In contrast, to revealed preference (RP) data that are generated in natural experiments, SP data are collected in a fully controlled experimental environment and have the following advantages:

- they can elicit preferences for non-existing alternatives;
- the choice set is pre-specified,
- co-linearity among attributes can be avoided,
- the range of attribute values can be extended.

Simply put, a stated-choice question presents an individual with a number of alternatives, each described in terms of their common set of characteristics. Each combination of attributes can be defined as an alternative in the sense of representing a product or service specification that may not be observed in the market. The individual is asked to state his/her preferred alternatives. When there is insufficient variation in relevant factors to allow estimation with revealed-preference data, the stated-preference data complement the revealed-preference data. As pointed out by a number of studies [20; 21] SP data provides great variations in each attribute and are capable of reaching a very satisfactory degree of correspondence between the value-of-time estimates obtained from RP and SP models. Although there are differences between what people actually do when confronted with actual travel choices and what they have indicated in SP surveys, the relative relationship is real and substantial. With appropriate systematic adjustment, the SP data provides an effective tool in evaluating the influence of factors on travel choice decisions.

In this survey, each respondent was presented twelve choice sets, which were to be compared with the base alternative as presented in Table 2. Given 12 choice sets, a sample size of 240 individuals yielded a total of 2,880 choices. These choices are defined by the differentials in four major attributes: total one-way travel time, total one-way travel monetary cost, safety/security, and reliability of the modes.

5. Model calibration

The theory of consumer behavior is concerned with individual choice from a set of feasible alternatives. In transportation, individual behavior is seen as choice of transportation mode, travel time, destination, and route achieving that particular individual's greatest satisfaction [5]. As one of the daily choices of normal life, travel behavior follows the general logic of consumer behavior.

The rational choice theory is the foundation of travel demand forecasting. The conventional theory of consumer choice posits that individuals seek to maximize utility subject to income constraints given the commodities available.