TCRP
REPORT 166

TRANSIT COOPERATIVE RESEARCH PROGRAM

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Characteristics of Premium Transit Services that Affect Choice of Mode

TRANSPORTATION RESEARCH BOARD
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TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP REPORT 166

Characteristics of Premium Transit Services that Affect Choice of Mode

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Research sponsored by the Federal Transit Administration in cooperation with the Transit Development Corporation

TRANSPORTATION RESEARCH BOARD

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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions,* published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), Transportation 2000, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, the National Academies, acting through the Transportation Research Board (TRB); and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by the Transportation Research Board. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended end users of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems. The TCRP results support and complement other ongoing transit research and training programs.

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Special thanks goes to James Ryan of the Federal Transit Administration, whose contributions greatly benefited the translation of the complex modeling features into relevant key findings.

FOREWORD

By Dianne S. Schwager
Staff Officer
Transportation Research Board

TCRP Report 166: Characteristics of Premium Transit Services that Affect Choice of Mode provides a concise presentation of the research on key factors—beyond travel time and cost—that affect travelers' choice of premium transit services. The report is supported by 10 technical appendices that present the detailed research results. The audiences for this research include both travel modelers and transit planners seeking to improve transit forecasting methods at metropolitan planning organizations (MPOs).

Traditionally, travel models use travel time and cost to assess the usefulness of each mode of transportation to make a particular trip. Other factors that affect the selection of mode are accounted for using a single constant term that represents other attributes. In many cases, these attributes represent conditions that may not be the same for all trips. Travel forecasting models would benefit by incorporating an expanded list of non-traditional attributes so that the probability of using transit to make a trip is more specifically related to the characteristics of a potential transit journey. Potential non-traditional transit characteristics include on-board and station amenities, reliability, span of service, and service visibility/ branding. These characteristics are not typically directly considered in travel forecasting models.

This research sought to improve the understanding of the full range of determinants for transit travel behavior and to offer practical solutions to practitioners seeking to represent and distinguish transit characteristics in travel forecasting models. The key findings of this research include the value of non-traditional transit service attributes on travelers' choice of mode, in particular the influence of awareness and consideration of transit service on modal alternatives, and the importance of traveler attitudes toward both awareness and consideration of transit and on the choice of transit or auto in mode choice.

The appendices present detailed research results including a state-of-the-practice literature review, survey instruments, models estimated by the research team, model testing, and model implementation and calibration results. The models demonstrate an approach for including non-traditional transit service attributes in the representation of both transit supply (networks) and demand (mode choice models), reducing the magnitude of the modal specific constant term while maintaining the ability of the model to forecast ridership on specific transit services. The testing conducted in this project included replacing transit access and service modes, such as drive to light rail or walk to local bus, as alternatives in the mode choice model with transit alternatives defined by the elements of the path, such as a short walk to transit path, a no-transfer path, or a premium service path.

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Note: Photographs, figures, and tables in this report may have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

SUMMARY

Characteristics of Premium Transit Services that Affect Choice of Mode

Introduction

Traditional travel forecasting models typically use travel time and cost to represent the usefulness of each transportation mode to serve potential trips. For transit options, time and cost are used to define optimal routing (i.e., boarding locations, routes, and alighting locations) and the probability that the traveler will select transit to make the trip. These techniques have often struggled to represent ridership demand for some higher-speed, higher-frequency transit services, particularly those classified as fixed guideway systems (labeled as "premium services" in this document). Forecasters have tried to represent the higher levels of demand for these services with a variety of techniques including defining separate transit choices in mode choice procedures and adjusting perceived travel times to represent the apparent preference for these services. Typically, these adjustments are applied on an aggregate basis with very little understanding of the underlying factors that cause models to under-represent premium transit ridership.

To improve understanding of these underlying factors, this research focused on identifying and quantifying aspects of transit travel behavior in different urban contexts that affect traveler use of premium transit services. Data on transit service attributes, traveler attitudes, and awareness were collected and analyzed in Salt Lake City, Utah; Chicago, Illinois; and Charlotte, North Carolina to better understand traveler responses to premium transit services. Models were estimated to evaluate the influence of traveler attitudes, awareness, and consideration of transit service characteristics on traveler evaluation of premium transit services. The research also included a demonstration of how transit service attributes could be meaningfully incorporated into travel models to reduce the influence of unobserved factors and modal labels in mode choice models and improve forecasting capabilities of transit services.

Two key phrases used in this report are defined for clarity:

- **Non-traditional transit service attributes** are those attributes other than time and cost that are important to travelers in choosing to ride transit. These aspects of transit services include:
  - On-board amenities (seating availability, seating comfort, temperature, cleanliness of a transit vehicle, productivity features);
  - Station design features (real-time information, security, lighting for safety, shelter, proximity to services, cleanliness of the station, benches); and
  - Other features (route identification, reliability, schedule span, transit frequency, transfer distance, stop distance, parking distance, ease of boarding, fare machines).
- **Premium transit services** are defined based on a series of attributes that together represent a higher class of service. These attributes exist over a broad continuum of transit

services in operation and are not necessarily associated with a particular vehicle technology. For instance, a commuter coach service offering a seat with Wi-Fi service to all customers and a highly reliable schedule may be perceived as superior to a crowded rapid transit rail line with fewer amenities. An analytical approach and framework is described in this paper to acknowledge that these services often exist as a continuum between premium and non-premium and are not easily represented as separate and discrete modes.

Surveys conducted in Salt Lake City, Chicago, and Charlotte were analyzed to evaluate the importance of different attributes on the attractiveness, awareness, and consideration of transit services. The role of traveler attitudes was also extrapolated from these data. Implementation testing was conducted in Salt Lake City to consider practical approaches to incorporating the key findings from this research into transit forecasting efforts.

This research was conducted in two phases. The first phase was exploratory and identified the non-traditional attributes that affect traveler choice of mode. This first phase included surveys and analysis in Salt Lake City. The second phase quantified the contribution of the most important attributes to mode choice decisions and sought ways to incorporate the findings into travel models. This second phase included surveys and analysis in Chicago and Charlotte.

During the course of the research, it was clear that inaccuracies in transit networks and representation of a traveler's transit path in the model were limiting the usefulness of the other model improvements. This reality inspired a change in the model implementation portion of the research to consider how to represent characteristics of premium transit service in transit networks and paths; it also spurred modification of the mode choice model to reflect these characteristics rather than rely on mode or technology labels (e.g., "light rail," or "express bus"). The innovations in this research provide a new process to incorporate these modal attributes in the transit element of the mode choice model.

Key Findings from the Research

Several aspects of the travel forecasting modeling system can be improved—based on the findings—to represent premium service attributes. These model improvements are useful because they specifically account for features of any transit service that may be considered "premium" (e.g., stops with shelter, available seating, or proximity to services around the station) regardless of whether these features are part of what would typically be identified as a premium service (e.g., light rail). One important finding of the research is that the combined **importance of all premium service characteristics** for both commute and non-commute trips was estimated to be between 13 and 29 minutes of in-vehicle travel time. This means that travelers value these premium service characteristics and would pay more or take a longer trip by the equivalent of 13 to 29 minutes in order to use one of these services. Although the combined value of the various premium transit service attributes is significant for all cities and access modes examined during the course of this research, considerable variation exists in the importance of premium service attributes between the different cities, access modes, and individual attributes. Figure 1 presents the details underlying this finding, for each city and service attribute.

Non-traditional attributes also affect the degree to which travelers may be aware of a potential transit option and are willing to consider it for making a journey. Inclusion of **awareness and consideration of transit options** in mode choice modeling is a relatively new concept. In this research, awareness and consideration were analyzed to understand the influence of these factors on decision-making. Several key findings were derived from

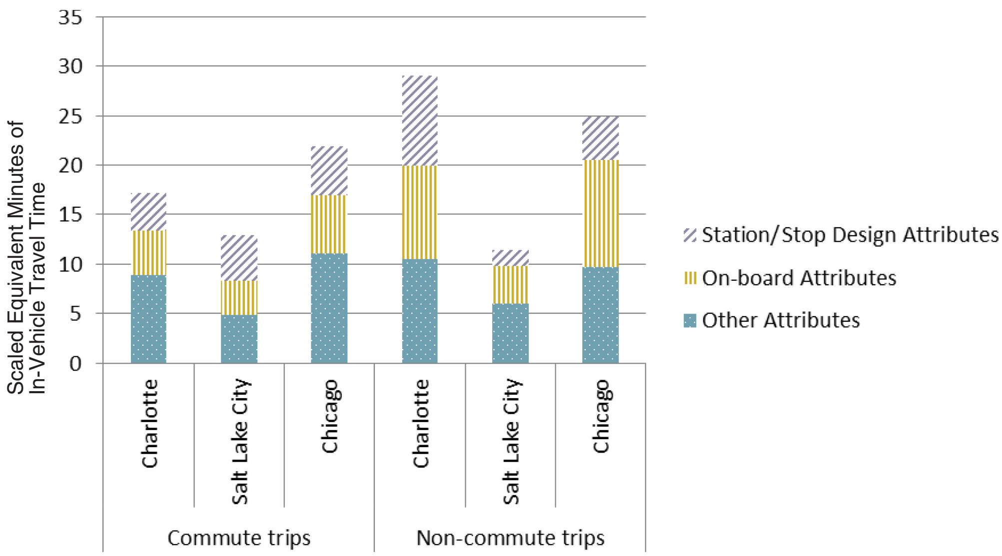


Figure 1. Scaled equivalent minutes of in-vehicle travel time for non-traditional transit service attributes.

these analyses. First, many travelers were not aware of or apt to consider transit options that the models represented as available for their trip. Second, travelers were aware of and considered train alternatives more often than bus alternatives. Third, incorporating awareness and consideration into model estimation did improve the statistical fit of the mode choice models. The awareness and consideration models were not tested directly in the implementation phase of the research, but they did contribute to a restructuring of the mode choice models that reduced the number of available transit alternatives.

The role of traveler attitudes was evaluated in the context of both awareness and consideration of modal alternatives and modal choice. There is evidence that different attitudes about transportation affect the choice between transit and automobile, but there is no evidence that different attitudes about transportation affect the choice between bus and train. Although the former statement is interesting and supported by other research, it was not the focus of this study and was not given further consideration.

Results of the Implementation Testing in Travel Models

The implementation phase focused on ways to **incorporate premium service characteristics** into transit forecasting models. The approach described in this research is just one way to approach implementation; it is recognized that there are many ways to approach this implementation. The results of the test implementation demonstrate that incorporating non-traditional attributes in a travel model is possible and can be used to generate reasonable results. The test implementation succeeded in **reducing the influence of the unobserved factors** in the mode choice model (these are known as mode or alternative specific constants) by separately representing non-traditional transit service attributes. In addition, basing the alternatives in the mode choice model on transit paths, which were validated against observed behavior instead of pre-defined modal alternatives, allowed for **reduction of the dependence on transit-technology-based mode choices (e.g., light rail, bus)**, which often prove problematic in forecasting. These transit paths were developed to represent traveler preferences for different aspects of the trip, like a shorter walk to transit, a preference for direct service (no transfers), or a preference for premium services (on-board Wi-Fi, station services, reliable service, etc.).

Audience and Use of these Findings

The audience for this research includes both travel modelers and transit planners. A concise presentation of the key findings and the information supporting these findings are presented in the final report with minimal technical jargon, making them accessible to a less technical audience. The technical details on methods and results are presented in Appendices A through J, published with the report. These findings may be useful individually or collectively to improve transit forecasting methods at metropolitan planning organizations (MPOs).

CHAPTER 1

Introduction

Motivation for the Project

The purpose of this research was to describe the most important factors that differentiate premium transit services from standard transit services and to quantify, for practical use, the magnitude of these distinguishing features. The research team's goals were twofold:

- To improve the transit industry's understanding of mode choice determinants; and
- To offer practical insights to the forecasting community so that mode choice models and transit path-builders can better represent and distinguish important mode characteristics.

The premise of this research is that understanding and modeling more of the factors determining travel behavior will significantly improve the explanatory power of the models and the potential transferability of travel forecasting models. The inclusion of non-traditional transit service attributes to distinguish premium transit services, instead of mode-specific constants or other fixed parameters, allowed the research team to remove modal labels from the models. This, in turn, reduced the mode-specific constants and other fixed parameters in the mode choice models.

Literature and Practice Reviews

The review of the literature and current practice was conducted to inform the analysis of how characteristics of premium transit services might affect choice of mode. This review focused on three aspects of transit planning:

1. **Awareness of Transit Services.** The lack of awareness and familiarity with transit seems to be significant, and there is not yet abundant research on this topic.
2. **Transit Service Attributes.** The majority of the literature and practice review focused on evaluating non-traditional transit service attributes that could inform mode choice models and transit networks for planning analysis. The long list of attributes was organized into nine categories: monetary cost, journey time, convenience, comfort, accessibility, productivity, information services, fare payment, and safety.
3. **How Mode Choice Models Incorporate Premium Transit Services.** Practitioners have struggled to quantify these additional service attributes and to measure travelers' reactions to them. This review highlighted the need for an in-depth study to quantify these additional service attributes and to incorporate them in travel forecasting models.

To support better behavioral models, it is necessary to extend the conventional set of explanatory variables to include new variables and methods that relate specifically to the decision-making process. Current practice in mode choice modeling typically results in models that are sensitive to the effects of travel times, wait times, frequencies, travel costs, and transfers, and include large, mode-specific constants. In theory, the mode constants capture the differences in the unobserved attributes of modes, but the constants are also adjusted to match observed ridership volumes and therefore help "correct" other errors in the travel model system.

Appendix A presents the findings from a review of the literature and the practical experience in these areas, focusing primarily on identification of distinguishing transit service features and their relative importance in mode choice and transit customer satisfaction. A few successful transit industry anecdotes related to upgrading non-traditional transit service amenities are discussed to provide context for the research. The discussion is based on detailed responses obtained from staff at a few transit agencies and MPOs, which also are reported in Appendix A.

Appendix A also outlines current attempts in research and practice to understand mode choice and improve the reasonableness and interpretability of mode choice models, reducing the extent to which mode-specific constants dominate the utility equations. The review considers the extent to which the public is aware of transit services and whether the presumption of complete knowledge in travel models is reasonable. Finally, the appendix includes a discussion of the ways that non-traditional transit attributes have been included in mode choice models. These reviews together informed and helped focus the data collection effort for TCRP Project H-37 and begin to suggest opportunities for advancement of the practice. Appendix A presents detailed identification and quantification research of non-traditional transit service attributes as well as case studies pertaining to attribute evaluation and incorporation of these attributes in model applications.

Research Process

The project was completed in two phases. The Salt Lake City survey was completed first, then revised before deployment in Chicago and Charlotte; this was done to address limitations discovered in the analysis. The initial phase of the work was exploratory and focused on identifying the non-traditional transit service measures, traveler attitudes and awareness, and consideration of transit modes that affect traveler behavior. This was done by collecting and analyzing data in three different urban contexts:

1. Salt Lake City has light rail, commuter rail, and bus, and has good ridership for a small city. The city is young, temperate, and not very ethnically diverse.
2. Chicago has commuter rail, heavy rail, and bus, and has good ridership for a large city. The transit system is older and more established, and the city is ethnically diverse.
3. Charlotte has a smaller light rail and bus system, and the light rail was recently introduced. Ridership is lower, but it is growing. The city is smaller, older, and ethnically diverse.

Appendix B contains the survey instruments used in each city and Appendix C contains survey methods and detailed survey results. The second phase of the work focused on estimating models for Chicago and Charlotte to quantify premium service characteristics, awareness and consideration, and traveler attitudes. These model estimations focused on testing the full range of possible variables, rather than identifying the best possible statistical fit.

The model implementation phase focused on incorporating premium service characteristics into the transit networks and restructuring the mode choice model to replace transit modes with transit paths as defined by traveler preferences. These premium service characteristics were integrated with traveler preferences for other transit attributes and prioritized by comparing transit paths from on-board survey data. The highest priority preferences represented travelers who prefer a short walk or drive to access transit, travelers who prefer direct service (no transfers), and travelers who prefer premium transit services. The team recalibrated the models to assess the ability of the revised models to reduce the influence of mode-specific constants and other fixed parameters while retaining the ability to replicate observed modal trip tables and boardings.

Structure of this Report

The report is structured to follow the two primary themes of mode choice model improvements: incorporating premium service characteristics and traveler determinants of mode choice. Special terms used in the report are both defined in a glossary and called out in each chapter where the terms are used.

The report has four chapters and ten appendices:

- Chapter 1 introduces the motivation for the project and provides an overview of the literature review, the research process and the structure of the report.
- Chapter 2 reports the key findings for the important non-traditional transit service attributes and the research methods and results in three areas: the effects on the attractiveness of transit, the effects on awareness and consideration of transit options, and the role of traveler attitudes. This includes market research and models estimated for three cities (Chicago, Charlotte, and Salt Lake City).
- Chapter 3 reports the results of the implementation testing in travel forecasting models, the implementation methods, and the outcomes for the Salt Lake City demonstration.
- Chapter 4 describes next steps for research and implementation testing to further the knowledge of how characteristics of premium transit services affect choice of mode.
- The Glossary provides a list of terms used throughout the report that may not be familiar to all readers.
- References are provided for all citations in the report and appendices.
- Appendix A includes the detailed literature and practice reviews for premium service characteristics as a supplement to Chapter 1.
- Appendix B reports the survey instruments and supports the market research discussions in Chapter 3.
- Appendix C details the survey methods and results of the surveys for Salt Lake City, Chicago, and Charlotte, supporting the analysis in Chapter 3.
- Appendix D provides technical details and results for the transit service attribute models (maximum difference scaling, called MaxDiff) in Chapter 3.
- Appendix E includes technical details for the detailed multinomial logit choice models for mode choice in Chapter 3.
- Appendix F provides technical details for the joint bivariate binary probit models of awareness and consideration in Chapter 3.
- Appendix G reports the factor analysis for traveler attitudes to supplement information in Chapter 3.
- Appendix H includes technical details for the integrated choice and latent variable models for mode choice in Chapter 3.
- Appendix I includes a transit travel time analysis that was a pre-cursor to the path-building analysis for the model implementation in Chapter 4.
- Appendix J presents technical details of the model implementation and calibration of the Salt Lake City model used in the transit path choice model tests in Chapter 4.

The report documents the extensive research conducted to address the broad question of how to evaluate the characteristics of premium transit services that affect choice of mode. The research report is intended to be a reference for evaluating premium services and a guide to improving mode choice models.

CHAPTER 2

Important Non-Traditional Transit Attributes

Current practice in regional travel forecasting models typically considers the effects of travel times, wait times, frequencies, travel costs, and transfers when evaluating the benefits of transit services and estimating ridership. In many cases, however, models in metropolitan areas with existing rail services require large adjustments to replicated observed ridership patterns. These adjustments usually are designed to increase modeled rail ridership to match observed (counted) values. These adjustments can take several forms, including:

- Defining rail as a separate mode in the mode choice model and assigning a mode-specific constant that reflects less perceived times and costs for a rail journey than for a similar bus trip; and
- Adjusting the perceived in-vehicle travel time for rail modes so that a minute of time on the train is less onerous than a minute of travel time on the bus.

These adjustments vary from metropolitan area to metropolitan area, suggesting that these parameters are not easily transferred without a better understanding of what causes travelers to prefer fixed guideway services to similar bus options. Furthermore, defining rail as a separate mode introduces a series of potential problems when this type of model is used to analyze transit alternatives. Potential issues include:

- **Mode Definition and Hierarchy.** Individual modeled modes are usually organized into a hierarchy of modes with rail being the highest and bus being the lowest. This structure can create counterintuitive results. A typical example occurs when a new rail line is added to an existing system. Existing bus-to-rail trips might be converted to rail-only trips. The model, however, sees only that the trips are defined as rail in both cases and therefore would not assign any value to this conversion beyond whatever time and cost improvements are associated with this project.
- **Arbitrary Labels and Impedances.** These are defined based on vehicle technology rather than service attributes. Not all buses and trains are the same. Some buses operate over-the-road coaches with seating for all travelers and on-board Wi-Fi service. Some trains are crowded rapid transit services with high levels of crowding and lower comfort levels. Service attributes can be included in the development of travel impedances and mode shares in lieu of arbitrary labels to better represent the service being offered.

Both potential problems suggest that models could be more robust if they focused more on understanding the impact of a broader range of service characteristics and less on the definition of individual transit submodes. Potentially important transit service attributes not typically considered in transit forecasting models include:

- Station or stop design features that provide real-time information about the next transit arrival/departure, security, lighting/safety, shelter, cleanliness of the station, benches, and proximity to services;

- On-board features that address seating availability, seating comfort, temperature, cleanliness of the transit vehicle, ease of boarding, and productivity features (e.g., Wi-Fi, power outlets, etc.); and
- Other features, such as identification of the transit vehicle, schedule reliability, schedule span, and fare machines.

*Non-traditional **attributes** not typically considered in transit forecasting or planning include station amenities, on-board amenities, and other features, such as reliability.*

This research effort serves to improve the transit industry's knowledge of the importance of this broader set of important transit service attributes, focusing on those attributes listed above that are not traditionally considered. Defined in this report as **non-traditional attributes,** these attributes can influence forecasting models in three distinct ways, by:

1. Presenting a complete picture of the attractiveness of a transit option when calculating the likelihood of using transit or a specific transit mode;
2. Accounting for the fact that travelers have different levels of awareness and willingness to consider different transit options; and
3. Incorporating the effect that traveler attitudes have on the likelihood of using transit and selecting specific transit modes.

Effects on the Attractiveness of Transit

Key Findings

The research team found that non-traditional transit service attributes are important factors in decisions about whether to use transit and which transit service to use. Taken together, the importance of non-traditional transit service attributes is equivalent to 13 to 29 minutes of in-vehicle travel time (depending on the city and the purpose of the trip). Recognizing that specific transit routes either do or do not include each of these non-traditional service attributes, accounting for them properly can have a large effect on the relative attractiveness of each route, and therefore on the measurement of the benefits of each transit option.

Research Methods

The research team designed an advanced travel survey to support a better understanding of transit choice behavior and specifically evaluate the importance of non-traditional transit service attributes. The non-traditional service attributes considered in this research are included in Table 1.

The survey consisted of the following four sections:

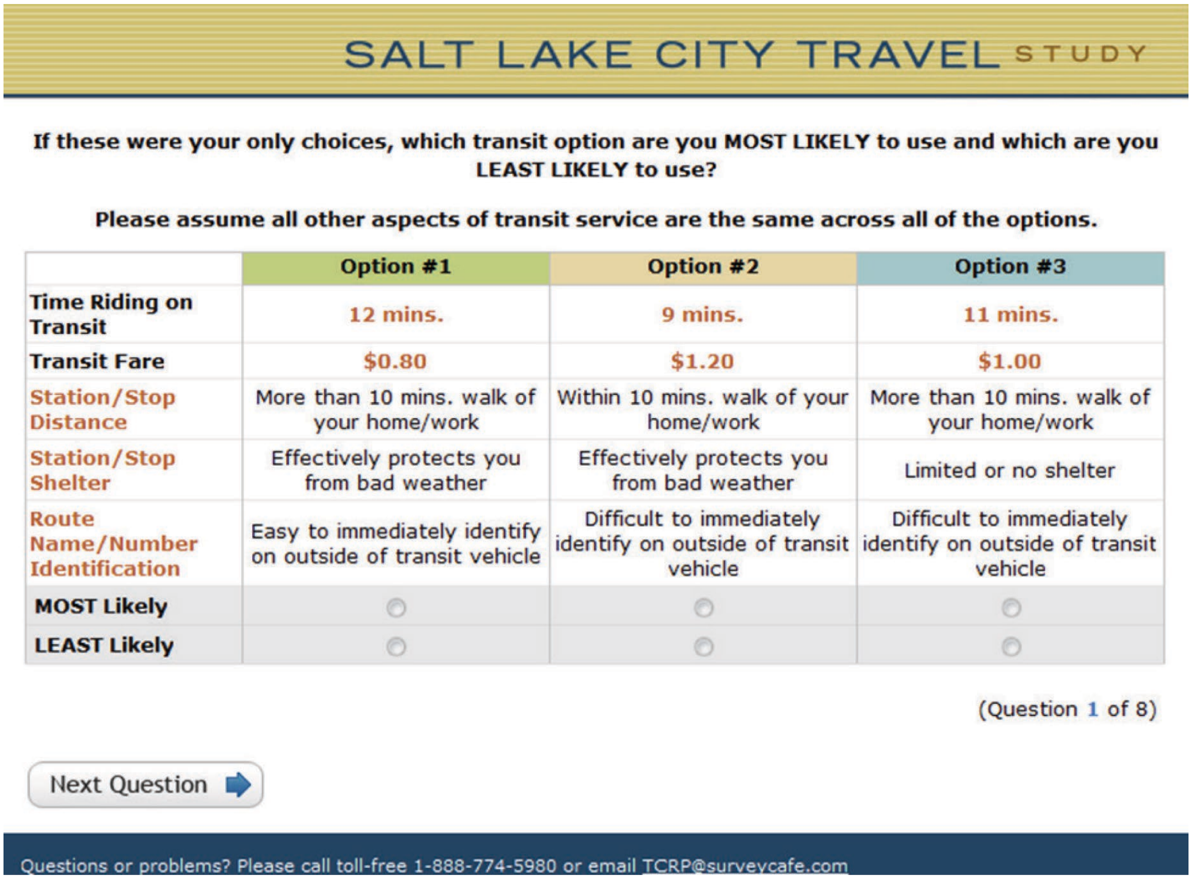
1. Demographic and travel characteristics;
2. Attitudes about transit;
3. Ranking of different non-traditional attributes; and
4. Selection of transit options with varied attributes for a typical trip a person makes.

This survey was specifically designed so that respondents would make trade-offs between different service attributes, and thereby allowed use of mathematical modeling techniques to value the importance of each attribute in the choice of transit options. The research team designed the survey to understand the relative importance of different levels of comfort, convenience, safety, and other non-traditional transit attributes in mode choice decisions, and to further understanding of how different people in different contexts have different values for these attributes. Figure 2 presents an example of a trade-off experiment used in the survey.

Five transit attributes are featured in the specific example shown in Figure 2. In the survey itself, the respondent would see eight experiments in which the attributes were varied, allowing

Table 1. Non-traditional transit service attribute levels in survey.

Bundle	Attribute	Premium Characteristics	Standard Characteristics
Station/stop design features	Real-time information about next transit arrival/departure	Real-time information available	No real-time information available
	Station/stop security	Enhanced (e.g., emergency call-buttons, surveillance cameras, security personnel)	No added security features
	Station/stop lighting/safety	Well-lit with police presence	Normal lighting and no police presence
	Station/stop shelter	Effectively protects you from bad weather	Limited or no shelter
	Proximity to services	Close to coffee shop, dry cleaners, grocery, etc.	Not close to coffee shop, dry cleaners, grocery, etc.
	Cleanliness of station/stop	Well maintained and clean	Not well maintained
	Station/stop benches	Clean and comfortable	Some benches
On-board features	On-board seating availability	Always available seats	Often crowded; you might not get a seat
	On-board seating comfort	Seats are comfortable and a good size	Seats are standard
	On-board temperature	Effective air-conditioning and heating	Some air-conditioning and heating
	Cleanliness of transit vehicle	Very new and clean	Maintained, but not new
	Productivity features	Wi-Fi, power outlets, etc., available	Productivity features not available
Other features	Route name/number identification	Easy to identify on outside of transit vehicle	Difficult to immediately identify on outside of transit vehicle
	Reliability	One in ten trips are 5 minutes late or more	One in ten trips are 15 minutes late or more
	Schedule span	Transit runs from 4:00 a.m. until 11:00 p.m.	Transit runs during rush hours only
	Transit frequency	Arrives every 10 minutes in rush hour and every 20 minutes in off-peak	Arrives every 20 minutes in rush hour and every 60 minutes in off-peak
	Transfer distance	Convenient (short walking distance or on same platform)	Several minutes' walk
	Station/stop distance	Within 10 minutes' walk of your home/work	Not within 10 minutes' walk of your home/work
	Parking distance	Within 10 minutes' walk from station/stop	Not within 10 minutes' walk from station/stop
	Ease of boarding	Easy to board; doors are level with platform/curb	Must step up to board
	Fare machines	Fast and easy to use	Slow and somewhat confusing


SALT LAKE CITY TRAVEL STUDY

If these were your only choices, which transit option are you MOST LIKELY to use and which are you LEAST LIKELY to use?

Please assume all other aspects of transit service are the same across all of the options.

	Option #1	Option #2	Option #3
Time Riding on Transit	12 mins.	9 mins.	11 mins.
Transit Fare	$0.80	$1.20	$1.00
Station/Stop Distance	More than 10 mins. walk of your home/work	Within 10 mins. walk of your home/work	More than 10 mins. walk of your home/work
Station/Stop Shelter	Effectively protects you from bad weather	Effectively protects you from bad weather	Limited or no shelter
Route Name/Number Identification	Easy to immediately identify on outside of transit vehicle	Difficult to immediately identify on outside of transit vehicle	Difficult to immediately identify on outside of transit vehicle
MOST Likely			
LEAST Likely			

(Question 1 of 8)

Next Question

Questions or problems? Please call toll-free 1-888-774-5980 or email TCRP@surveycafe.com

Figure 2. Example trade-off experiment from the Salt Lake City survey.

consideration of a wide range of attributes without imposing undue burden on the respondent in any one experiment. This example in Figure 2 provides only one glimpse into a complex survey, but serves to provide context for similar experimental survey methods. More information can be found in Appendix B.

Research Results

Once the data were collected, specialized mathematical techniques were used to assess the relative importance of different features. This mathematical exercise resulted in an assessment of the importance of each non-traditional attribute in relation to attributes that transit planners and modelers often consider. This value was expressed as equivalent minutes of in-vehicle transit travel time. The concept is analogous to the idea that non-monetary factors (e.g., time or personal injury) can have dollar values for use in economic assessments.

Taken together, the importance of non-traditional transit service attributes was valued as equivalent to 13 to 29 minutes of travel time (depending on the city and the trip purpose). Table 2 presents the details underlying that finding for each city and service attribute.

Although the combined value of the various premium transit service attributes is significant in all cities and for all purposes, it is also clear that travelers in different cities value different features of the transit system in very different ways. The differences suggest that survey research may be required to estimate similar factors in order to apply this approach in new cities that plan to apply these findings in practice.

Technical Details

In technical modeling terms, the survey approach was designed to support maximum difference scaling (MaxDiff) modeling and choice-based conjoint modeling (choice modeling). MaxDiff measures the importance of individual transit service characteristics with respondents choosing the best and worst options from a set of alternatives. In TCRP Project H-37, eight maximum difference experiments were conducted in each of the three surveys. Choice modeling measures the stated preference of a combination of transit service characteristics with respondents choosing the best alternative. In this project eight stated preference experiments were conducted in each of the three surveys. Both survey approaches were analyzed jointly using multinomial logit (MNL) estimation techniques to identify the relative importance of non-traditional service attributes, while also considering the value of traditional service attributes (i.e., time, cost, and frequency).

Current practice in transit and mode choice modeling typically results in a model that is sensitive to the effects of travel times, wait times, frequencies, travel costs and transfers, in addition to mode-specific constants. In theory the mode-specific constants capture the differences in the unobserved attributes of modes, but the constants are also adjusted to match observed ridership volumes and therefore help correct other errors in the travel model system. The goal of TCRP Project H-37 was to improve the reasonableness and interpretability of mode choice models, reducing the extent to which the resulting mode choice model constants dominate the modeled utilities.

For more information, the details of the transit service attribute models are presented in Appendix D and the multinomial logit mode choice models are presented in Appendix E.

Effects on Awareness and Consideration of Transit Options

The next potential contribution of non-traditional attributes involves traveler awareness of individual transit options and the degree to which travelers are willing to consider using these options. Inclusion of awareness and consideration in travel forecasting models is a relatively new concept. To date, models typically assume that all modes are available and considered by all individuals or apply simple deterministic rules to sort out whether certain modes are available and considered by an individual. Examples of the latter approach include applying a rule that individuals residing in zero-car households are assumed to not have “drive alone” available, or that individuals residing more than one-half mile from a transit stop are assumed not to have “walk to transit” available in the mode choice model.

A more comprehensive approach for determining whether transit is considered as a modal alternative may be influenced by numerous factors. These factors may not have much to do with the physical availability of the mode per se. Personal and household constraints (e.g., the need to drop off a child at school on the way to work), individual attitudes, perceptions, preferences, and simple lack of awareness (information) may all contribute to the non-consideration of transit as a viable modal alternative.

Awareness of travel options and factors that affect consideration often are related to individual socioeconomic circumstances that may not be evenly distributed across a metropolitan area. Better understanding of these factors and how they work together to forecast transit usage can improve forecasting procedures.

Table 2. Importance of non-traditional transit service attributes (equivalent minutes of in-vehicle travel time).

Attribute	Commute Trips			Non-commute Trips		
	Charlotte	Salt Lake City	Chicago	Charlotte	Salt Lake City	Chicago
Station/stop design features	**3.71**	**4.61**	**4.97**	**9.06**	**1.57**	**4.42**
Real-time information	0.40	*	0.62	1.06	*	0.44
Station/stop security	0.60	0.88	0.85	1.56	0.22	0.84
Station/stop lighting/safety	0.66	0.88	0.86	1.62	0.20	0.82
Station/stop shelter	0.64	1.10	0.86	1.57	0.37	0.69
Proximity to services	0.40	0.84	0.40	0.89	0.47	0.50
Cleanliness of station/stop	0.73	0.42	0.90	1.74	0.15	0.86
Station/stop benches	0.28	0.49	0.48	0.62	0.16	0.27
On-board features	**4.58**	**3.53**	**5.84**	**9.47**	**3.8**	**10.79**
On-board seating availability	1.46	1.23	2.15	3.32	1.41	4.09
On-board seating comfort	0.56	0.51	0.77	1.02	0.41	1.39
On-board temperature	1.20	0.81	1.41	2.42	0.85	2.41
Cleanliness of transit vehicle	0.60	0.44	0.64	1.26	0.39	1.56
Productivity features	0.76	0.54**	0.87	1.45	0.74**	1.34
Other features	**8.94**	**4.92**	**11.17**	**10.60**	**6.14**	**9.77**
Route name/number identification	0.57	0.60	0.63	1.23	0.58	0.61
Reliability	4.59	0.44***	5.64	–	0.29***	4.63
Schedule span	0.52	0.42	0.77	1.47	0.33	0.82
Transit frequency	0.60	0.75	0.82	1.49	0.38	0.71
Transfer distance	0.46	0.72	0.56	1.29	0.12	0.48
Station/stop distance	0.80	0.64	0.92	1.76	0.13	0.84
Parking distance	0.72	0.54	0.84	1.44	0.17	0.71
Ease of boarding	0.08	0.16	0.21	0.52	3.02	0.25
Fare machines	0.60	0.65	0.78	1.40	1.12	0.72
All premium service features	**17.23**	**13.06**	**21.98**	**29.13**	**11.51**	**24.98**

*The attribute was not part of the station/stop design features bundle in the survey for Salt Lake City.

** The attribute was referred to simply as "Wi-Fi" in the survey for Salt Lake City.

***The reliability measure was redefined in the survey for Chicago and Charlotte, so this value is not comparable to the value for Salt Lake City.

Key Findings

Three key findings relate to travelers' awareness and consideration of transit options:

1. **Many travelers are not aware of, nor do they consider, transit options that travel models represent as available for their trip.** Providing options beyond those considered by travelers will bias the mode choice models because awareness and consideration are more a function of demographics, latent variables, and traveler attitudes than of transit service attributes.
2. **Travelers are aware of and consider train alternatives more often than bus.** This finding is determined directly from the travel surveys, based on questions about travelers' consideration of bus and rail modes once availability is accounted for.
3. **Incorporating awareness and consideration of transit into statistical estimation work improves the statistical fit of the mode choice models.** Mode choice models, estimated with and without awareness and consideration models constraining the choice sets, demonstrated statistical improvement with the inclusion of these models.

This research focused primarily on key findings related to the importance of premium service characteristics and their effect on awareness and consideration, as opposed to broader modeling considerations that go beyond service characteristics.

Research Methods

Questions about awareness and consideration of transit alternatives were included in the surveys for all three cities surveyed. In the initial survey for Salt Lake City, these questions were exploratory. In the second set of surveys, for Charlotte and Chicago, these questions were more systematic and comprehensive to allow for model estimation of awareness and consideration. The following list shows some of the issues related to transit awareness and consideration explored in the Chicago and Charlotte surveys:

- Do the survey respondents know the routes serviced at the public transit stop within walking distance of their homes?
- Do they know how to travel to where they work, go to school, or places where they went on their most recent trips from the public transit stop within walking distance of their home?
- What other types of transportation could they have used for their most recent trip?
- Why didn't they use the transit options available on their most recent trip?
- What did they need their car for on their most recent trip?
- What about the transit service didn't meet their needs for their most recent trip?
- What other types of public transit did they consider using to make this trip?
- For the trip they made, did they know they had an alternative option (together with the associated time, required transfers, and costs of that option)?
- Why would they not consider the alternative transit mode option?

Survey respondents also were asked to say how informed they are about the survey area's public transit services in terms of types of service available, routes, schedules, fare options, and so forth (see Figure 3). These survey results demonstrated that one-quarter to one-third of survey respondents are uninformed about transit, while travel forecasting models represent all travelers having full information.

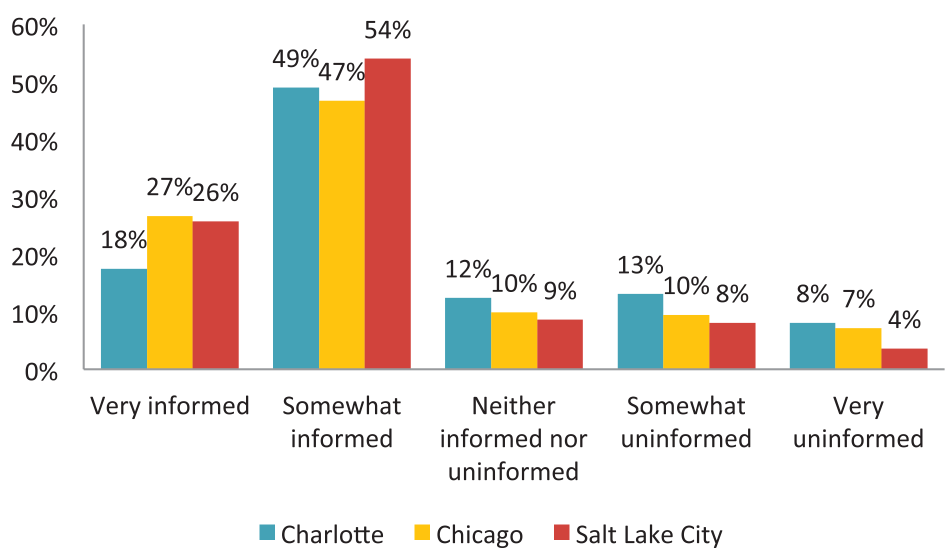


Figure 3. Survey respondents' indications that they are informed about transit for Charlotte, Chicago, and Salt Lake City.

Technical Details

In technical modeling terms, awareness and consideration were examined using joint bivariate binary probit models to first identify whether travelers were aware of a transit alternative and then to constrain these choices to identify whether travelers would consider the transit alternative. The Joint Bivariate Binary Probit model is a generalization of the probit model that is used to estimate several correlated binary outcomes jointly. The results of these models were used to constrain the choices available to travelers in the mode choice models.

This study explicitly accounts for attitudes, perceptions, and values in modeling transit awareness and consideration. The models in this study consider attitudinal factors as possible explanatory variables to account for factors that are traditionally unmeasured, unobserved, and relegated to being absorbed in the random error term.

A key question that merits consideration is the extent to which modal level-of-service variables should enter the awareness and consideration model specifications. It may be hypothesized that people are more aware of and would give greater consideration to transit modes when transit level of service is greater, more competitive with the automobile, and of high quality. In the current study, transit awareness and consideration is modeled whenever transit is available.

More information is presented in Appendix F.

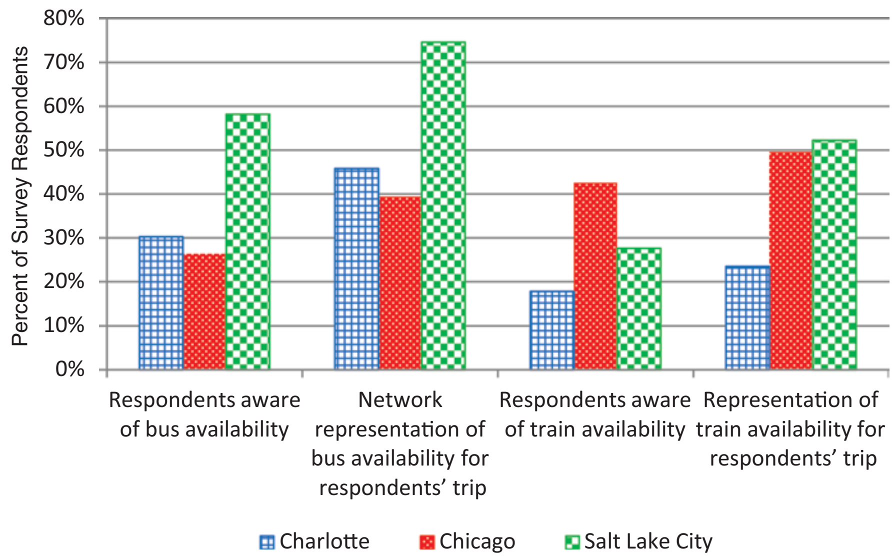
Awareness and consideration models were developed to identify (1) whether travelers are aware of a transit alternative and (2) whether travelers will consider the transit alternative. The results of these models were used to constrain the choices available to travelers in the mode choice models. Awareness and consideration of transit are handled using choice set models as part of the following two-step decision process:

Step 1. An individual's awareness of an option must be determined based on demographic, trip, and attitudinal characteristics.
Step 2. The willingness of an individual to consider an alternative must be determined based on awareness and demographic, trip, and attitudinal characteristics.

The complete choice set for each individual is formed because of awareness and consideration of the transit options (bus and rail). It is assumed that an individual who has a car available to make the trip is aware of the option to use it and always considers it in the choice set. Consequently, the car option enters the choice set in a deterministic way.

Research Results

Direct analysis of the surveys provides evidence that typical models overstate the availability of transit options as compared to the options that are reported by respondents as being available. As shown in Figure 4, respondent awareness is less than the network representation of transit availability for all cities and transit submodes. The differences between respondent awareness and the network representation of bus availability are consistent across all three cities (16% less for Charlotte and Salt Lake City and 13% less for Chicago). The differences between respondent awareness of and network representation for rail were smaller than for bus in two cities



Note: The awareness questions in the Salt Lake City survey were changed when conducting the Charlotte and Chicago surveys, so these results may not be directly comparable.

Figure 4. Respondents' awareness of bus and rail modes available for a trip.

(6% less for Charlotte and 7% less for Chicago). In Salt Lake City, however, travelers were 25% less likely to be aware of rail options than was suggested by the network models. These results may reflect real differences in awareness or different assumptions in the network representation across cities.

Table 3 reports the survey results for consideration of transit alternatives in Chicago and Charlotte for bus and rail modes. In Charlotte, 71% of travelers who report having rail as an available mode would consider taking the train, whereas only 55% of travelers who report having an available bus option would consider taking bus. In Chicago, those percentages are 83% and 56%, respectively. Even among travelers willing to consider a given mode of transit, a higher proportion selects rail than selects bus.

Sequential models were estimated for awareness and consideration, with consideration models limited to choices that travelers were aware of. Bus and train were represented as individual

Table 3. Consideration of bus and rail modes.

		Survey Respondents				Percent of Total			
		Bus		Train		Bus		Train	
Charlotte									
Considered	**Chosen**	380	191	252	156	55%	50%	71%	62%
	Not Chosen		189		96		50%		38%
Not Considered		310		102		45%		29%	
Total Available		690		354		100%		100%	
Chicago									
Considered	**Chosen**	333	207	619	429	56%	62%	83%	69%
	Not Chosen		126		190		38%		31%
Not Considered		259		126		44%		17%	
Total Available		592		745		100%		100%	

Note: Total available in this context represents availability reported by the respondents.

choice alternatives in both the awareness and consideration models. One primary question for these models is whether representing a traveler's awareness and consideration of transit will improve the ability of the mode choice model to explain travel behavior. Mode choice models were estimated with and without awareness and consideration constraints to evaluate the statistical improvement in the models by accounting for these choice set constraints:

- In Chicago, final log-likelihood was 5790 and 4720 for commute trips and non-commute trips, respectively; with awareness and consideration models to constrain, the choice set was 5908 and 4870 without these constraints.
- In Charlotte, the final log-likelihood was 7134 and 3373 for commute trips and non-commute trips, respectively; with awareness and consideration models to constrain, the choice set was 7250 and 3278 without these constraints.

Log-likelihoods represent the likelihood that a given function describes the probabilities that underlie the data in these surveys. The difference in log-likelihood here is significant, based on a statistical goodness-of-fit test (chi-squared) of approximately 100 points difference in log-likelihood resulting in significance beyond the 0.01 level. These results demonstrate that the models that include awareness and consideration are significantly better than the models without awareness and consideration, based on the estimation of the models; however, further research is necessary to evaluate the difference in the model predictions of transit ridership.

*The **log-likelihood** is a function of the parameters of the mode choice model. The objective of mode choice models is to maximize the log-likelihood; therefore, higher values of log-likelihood are preferred.*

The Role of Traveler Attitudes

The third role for non-traditional attributes is in determining how traveler attitudes affect transit usage. Attitudes were obtained from travelers on driving, walking, and taking transit. These traveler attitudes and their impact on transit ridership were evaluated in three different cities using sequential estimation of traveler attitudes and modes and simultaneous estimation of traveler attitudes and modes. Both for sequential and simultaneous estimation, the traveler attitudes enhanced the estimation of the mode choice models by complementing the other socioeconomic factors represented in the models. In all three cities, the attitudes affected the choice of transit versus automobile much more than the choice of bus versus rail.

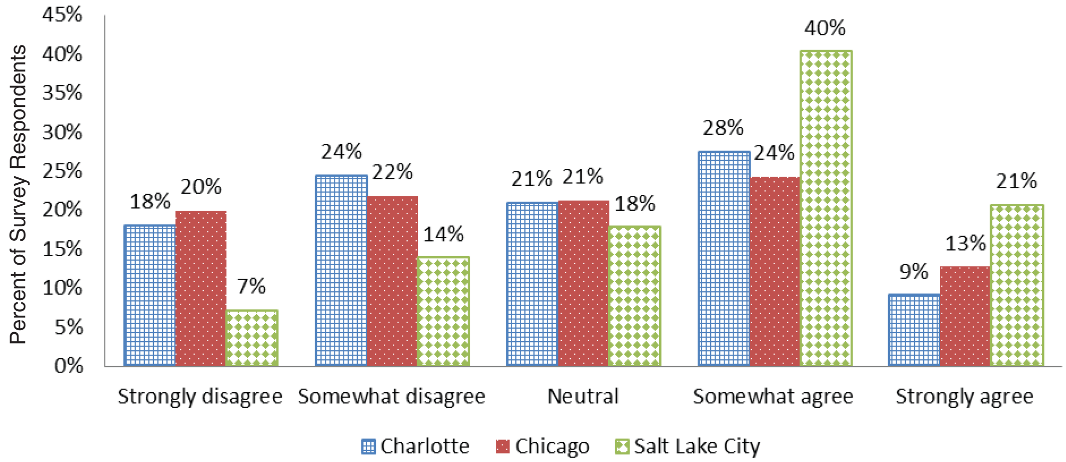
Key Findings

There is evidence that different attitudes about transportation affect the choice between transit and automobile. Although this is interesting and supported by other research, it was not the focus of this research and so it was not explored further.

Based on model estimation results, and in Chicago and Charlotte specifically, there is no evidence that attitudes about transportation affect the choice between bus and train. There is, however, some evidence that traveler attitudes affect the awareness and consideration of transit, which will influence the choice set available for mode choice.

Research Methods

Traveler attitudes were obtained for 18 attitudinal questions from the survey in Charlotte and Chicago and for 15 attitudinal questions in Salt Lake City. Each attitudinal question had five potential responses (strongly disagree, somewhat disagree, neutral, somewhat agree, or strongly agree). In Charlotte and Chicago, traveler attitudes were obtained from all respondents, while the earlier survey in Salt Lake City targeted these questions to specific respondents (six questions were for transit users and nine questions were for non-transit users). As a result of these differences in the surveys, some statistics can be obtained and analyzed from



Statement: "If I wanted to, I could use public transit more frequently."

Figure 5. Willingness to increase transit usage for Charlotte, Chicago, and Salt Lake City.

all three cities while other analyses can only be performed on survey records from Charlotte and Chicago.

For example, more respondents from Salt Lake City indicated that they are willing to increase the frequency of transit usage than did respondents from Charlotte and Chicago. As shown in Figure 5, some 61% of Salt Lake City respondents indicated that they could use transit more frequently. By comparison, respondents from Charlotte and Chicago share similar attitudes toward the possibility of increasing transit usage: In both these cities, 37% of respondents indicated that they could use transit more frequently, which suggests that the potential market share for transit is limited to travelers who feel that public transit is a viable option.

Another important element of the surveys was questions about willingness to walk, which is a strong indicator of travelers who may choose to walk to transit services. Respondents were asked about a recent trip that they took. Willingness to walk is not consistent across bus and rail modes or in different cities, but some trends can be observed. Figure 6 shows Chicago and Charlotte respondents' willingness to walk by mode of travel (auto, bus, and rail) for their current

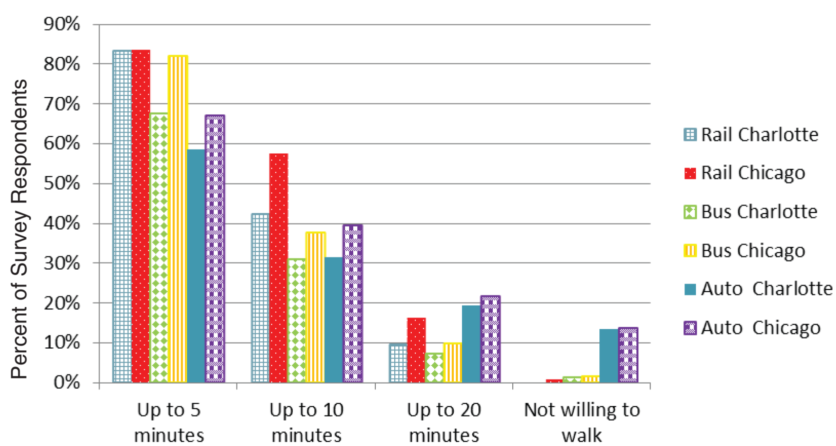


Figure 6. Willingness to walk to transit by reference trip mode for Charlotte and Chicago.

trip. For each level of walking time (up to 5 minutes, up to 10 minutes, and up to 20 minutes), rail travelers are somewhat more likely to report that they are willing to walk to transit than are bus travelers. This outcome suggests that travelers might be more willing to walk farther to rail transit. It is also possible, however, that this outcome indicates that rail users must, on average, walk farther because there is a greater distance between rail stations than most bus stations.

Factor analysis of the Chicago and Charlotte survey data was used to determine the most significant attitudinal factors affecting change of mode. Five attitudinal factors were found to be significant in the awareness, consideration, and mode choice models and therefore contributed to explaining travel behavior in these models. There are two challenges to including attitudinal factors in travel forecasting models:

1. The optimal number of factors from a statistical standpoint is too complex for interpretation and therefore less helpful to planners. For example, in this research three factors tended to favor auto modes (pro-car attitude, transit averse, and low transit comfort level) and two factors tended to favor transit modes (pro-transit attitude, and environment, productivity, and time savings). The interpretation of the factors would be much more straightforward if it were limited to the pro-car and pro-transit attitudes. Further analysis of the attitudinal factors demonstrated that these two factors could be supported by the surveys and it may not be necessary to include as many attitudinal statements in the surveys to estimate these factors.
2. Forecasting attitudinal factors requires either a separate model to estimate the attitudinal factors that are input to the various models or a model that can simultaneously estimate traveler attitudes and mode choice or awareness and consideration. In TCRP Project H-37, a simultaneous model to estimate traveler attitudes as a function of socioeconomic variables within mode choice was developed to demonstrate how this can be done. The results of this model indicate which socioeconomic variables are important for each attitudinal factor. In addition, a utility is associated with the bus and rail modes that indicates some differences between these attitudinal factors and mode choice.

These research tests can help to guide future inclusion of traveler attitudes in mode choice models.

Technical Details

Traveler attitudes were developed using factor analysis to correlate traveler survey responses into groups with similar attitudes. The Chicago and Charlotte factor analysis produced five attitudinal factors that were significant in the mode choice models: pro-transit; consciousness (e.g., of environment, productivity, and time savings impacts); pro-car; transit averse; and low transit comfort level. The Salt Lake City factor analysis produced two significant attitudinal factors for transit users (convenience/inclination and service availability) and two attitudinal factors for non-transit users (inclination and discomfort/inaccessibility). The non-transit user factors were not significant in the mode choice model estimation process.

The integrated choice and latent variable (ICLV) models provide an opportunity to estimate traveler attitudes as a function of socioeconomic variables within mode choice where the multinomial logit (MNL) models require that traveler attitudes be developed outside the mode choice models. This allows us to forecast these attitudes within the mode choice model rather than having to develop a separate model.

For more information, see Appendix G for details on the factor analysis for traveler attitudes and Appendix H for details on the ICLV models for mode choice.

Table 4. Equivalent in-vehicle travel time (in minutes) for traveler latent variables in mode choice models.

	Commute		Non-Commute	
Explanatory Variables	Bus	Train	Bus	Train
Chicago				
Very Informed About transit	8.84			
Pro-Transit Attitude	38.2	38.2	33.32	33.32
Environment, Productivity, and Time Savings	15.16	15.16	11.89	11.89
Pro-Car Attitude	-24.76	-24.76	-24.53	-24.53
Transit Averse	-5.44	-5.44	-9.42	-9.42
Low Transit Comfort Level			5.32	5.32
Not Willing to Walk More than 2 minutes	-27.52	-27.52	-41.11	-41.11
Willing to Walk 10 or more minutes		7.08		8.68
Charlotte				
Very Informed About Transit	21.91	12.91	29.16	29.16
Pro-Transit Attitude	14.5	14.5	22.37	23.11
Environment, Productivity, and Time Savings	15.55	15.55	32.68	34.11
Pro-Car Attitude	-21.82	-21.82	-22.47	-23.32
Transit Averse	-2	-2	-7.58	-7.95
Low Transit Comfort Level	-14.86	-14.86	-25	-26.11
Not Willing to Walk More than 2 minutes	-4.59	-11.55		
Willing to Walk 10 or More Minutes	7.68	7.68	24.63	24.63

Note: Auto modes are not included here because their equivalent minutes of travel time for these variables are zero. The cases where bus and train coefficients did not reflect significant differences were estimated together.

Latent variables are those that cannot be directly observed. In this study, examples of latent variables include traveler attitudes, willingness to walk, and how informed travelers are.

Research Results

Table 4 presents the equivalent minutes of in-vehicle travel time for latent variables in the mode choice models. Most of the latent variables reflect large impacts on the choice of transit versus auto, but only few differences between the choice of bus and rail. The few differences are important to understand premium services:

- Bus travelers are more informed about transit for commute travel than are train travelers, which may reflect the need to understand a more complex system of bus routes given that outbound and return bus trips may be on different routes due to timing and frequency.
- Train travelers in Chicago are more willing than train travelers in Charlotte to walk more than 10 minutes for a train for all trips. These response data are consistent with the prior summary of the survey data shown in Figure 6.
- Travelers in Chicago are more likely than travelers in Charlotte to be willing to walk more than 2 minutes for commute trips on a train than on a bus.
- In Charlotte, travelers with pro-transit and pro-environment attitudes are slightly more likely than travelers in Chicago to choose train over bus, and travelers with pro-car attitudes (including travelers who are transit averse and/or have a low transit comfort level) are slightly less likely to choose train over bus.

Summary of Key Findings

There are a number of benefits to accounting for non-traditional factors and recognizing traveler attitudes or awareness and consideration in mode choice. Non-traditional service attributes, such as on-board and station amenities, are important differentiators for premium transit. Premium service attributes account for a range of 13 to 29 minutes of in-vehicle travel time based on MaxDiff scaling models.

When comparing modal availability predicted by network path-building models, travelers are more likely to report rail service being available than bus service. This may be because bus systems are more complex than train systems and bus stops are less visible than train stations. Consideration of transit options does affect sub-modal choices, with 12% to 14% of travelers with rail available reporting that rail was not considered for the trip and 27% to 38% of travelers with bus available not considering bus for the trip. Awareness and consideration models were estimated and used to constrain mode choice sets, which does statistically improve goodness-of-fit for mode choice model estimation, but the impact on forecasted ridership by mode is unknown.

Traveler attitudes do influence the choice of transit or auto, but do not consistently affect the choice of bus or train for different types of trips or in different cities.

CHAPTER 3

Implementation in Travel Models

Results of Implementation Testing

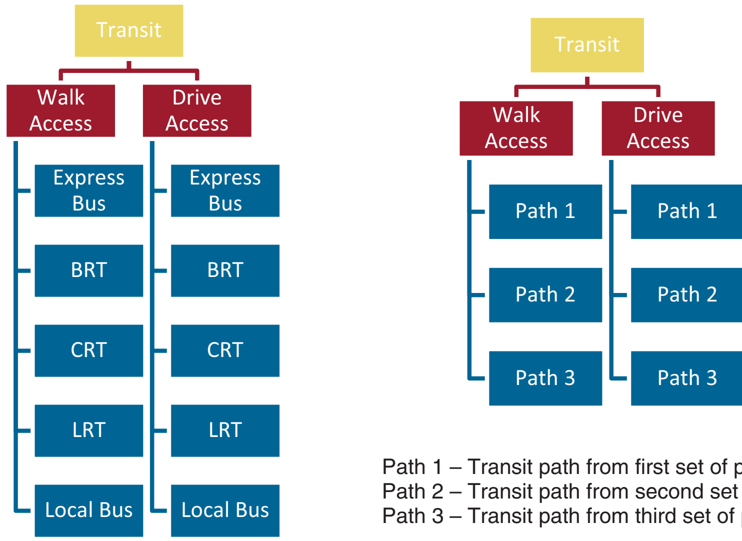
Path-building is a process to identify the access, route, transfers, and egress elements of a transit trip. *Parameters* are used to weight the importance of each element.

As mentioned in Chapter 2, traditional travel forecasting models generally include estimates of travel time and cost to determine the likelihood of using transit. These estimates are derived from the details of a transit route taken, along with information on the time spent waiting and the time and cost to access the transit route. The description of these transit paths and the resulting time and cost details is referred to as *path-building.* These traditional methods often require adjustment to replicate observed ridership on fixed guideway transit modes such as rail. Typically, these adjustments involve creating a series of transit modes and then adjusting the utility of each mode by adding mode-specific constants or scaling the value of each minute of travel time. These adjustments can create illogical relationships among modes, and the types and values of these adjustments are sufficiently different from city to city that the transferability of these parameters is unclear.

This chapter reports on the results of an attempt to implement the findings from the survey in Salt Lake City to address the potential shortcomings of traditional travel forecasting models. Salt Lake City was selected for this test because it has a relatively strong transit forecasting model structured according to current practice (Wasatch Front Regional Council 2011). This model has two transit access modes (walk and drive) and five transit service modes: commuter rail (CRT), light rail (LRT), bus rapid transit (BRT), express bus, and local bus. These mode choices are structured in hierarchical form with commuter rail as the highest mode, proceeding in the order listed above, with local bus as the lowest mode. Each transit service mode is available for each access mode, resulting in 10 possible choices for each trip. This model was recently calibrated to match ridership patterns in the Salt Lake City metropolitan area. Details of the implementation and calibration of the Salt Lake City model are provided in Appendix J.

The implementation test focused on developing an alternative set of transit paths that provide travelers with multiple options for any given origin-destination pair while departing from a hierarchical service mode structure that adjusts utility based simply on the overall mode label. This was accomplished by:

- Creating a series of three service mode neutral paths, each of which used the full set of transit submodes but used different transit path-building weights. (The different sets of weights were identified empirically with the objective of generating a relatively small number of distinct paths that would cover the vast majority of paths used by respondents to the transit on-board survey. Initial work on transit travel times provided insight to support this process, as detailed in Appendix I.)
- Applying the non-traditional attributes discussed in Chapter 2 to affect how travelers view different routes and determine the optimal means of travel between origin and destination.



Path 1 – Transit path from first set of path weights
Path 2 – Transit path from second set of path weights
Path 3 – Transit path from third set of path weights

Express Bus – Peak Period Express Service
LRT – Light Rail Transit
CRT – Commuter Rail Transit
BRT – Bus Rapid Transit
Local Bus – All-day Local Service

Figure 7. Salt Lake City mode choice modeling structures with transit service modes (original) and with transit paths (new).

Together, these two changes result in a model that generates results approximately equivalent to the original model while reducing the negative consequences of a hierarchical transit service mode structure with large mode-specific constants.

Figure 7 presents the mode structure for the original model (left) and the new, path-based structure (right).

Implementation Methods

The implementation of the research methods using the Salt Lake City data focused on a few key aspects of the research: revising mode choice models to represent transit path choices instead of mode choices and accounting for non-traditional transit service attributes in both path and modal choices.

Transit path choice is a term used to describe the modeling process in which travelers choose alternative transit paths based on different path-building parameters.

The availability of non-traditional or premium transit service characteristics for the transit system in the Salt Lake City region was determined for each of 11 service characteristics (see Table 5). Data pertaining to park-and-ride lots, station/stop shelter and seating, and route-level on-time performance information were obtained from the local agencies. Other service information about stations/stops, such as lighting/safety, security, and proximity to services was not available or was deemed too anecdotal and approximate to be useful. In the Salt Lake City region, on-board amenities were not available at a route level, but the perception among local transit agency staff was that variation in amenities and service characteristics among services was more obvious at the "mode" level (or between service types) than it was at the route level. Table 5 shows the asserted premium transit attributes at the mode level based on knowledge of transit systems in the region. The process to incorporate these data into the Salt Lake City model included determining values for the following benefits and penalties:

- **Premium Benefits.** For each premium transit attribute, the values in terms of in-vehicle travel time (IVTT) minutes were obtained by averaging Chicago and Charlotte survey responses

Table 5. Mode level values of premium transit service attributes for commute trips.

Bundled Attribute	Premium Service Attribute	CRT	LRT	LOCAL	EXP	BRT	Value (min. of IVTT)	Scaled Value (min. of IVTT)
Station amenities	Shelter	√	√	x	√	√	0.75	2.88
	Bench	√	√	x	√	√	0.38	1.45
	Lot count	√	√	x	√	x	0.00	0
On-board amenities	On-board seating availability	√	√	√	x	x	1.81	2.90
	Productivity features	√	x	x	√	x	0.82	1.32
	Vehicle cleanliness	√	x	x	√	√	0.62	0.99
Other service features	Reliability	√	√	x	x	√	5.12	7.79
	Mid-day schedule span	√	√	√	x	√	0.32	0.49
	Evening schedule span	√	√	√	x	√	0.32	0.49
	Vehicle ease of boarding	√	√	x	x	√	0.14	0.22
	Fare machines	√	√	x	x	√	0.69	1.06
Premium benefit (minutes)		11.0	9.5	2.5	2.6	8.3		
Scaled premium benefit (minutes)		19.6	17.3	3.9	6.6	15.4		
Relative non-premium service boarding penalty		0	2.3	15.7	13	4.2		

for commute trips for both bus and train. The premium transit attribute values from the Salt Lake City survey were not used because the later surveys had better information from a methodological standpoint.

- **Scaled Premium Benefits.** In the Salt Lake City example, 11 of a possible 20 premium transit service attributes were available. These 11 service attributes were developed to represent the three bundles of attributes reported in Table 2 (station design features, on-board features, and other features, such as reliability), so they were scaled to represent the full benefit that could potentially be gained from premium transit characteristics.
- **Relative Non-Premium Service Boarding Penalty.** The benefits were then converted to mode-specific relative penalties that could be applied at each boarding by the path builder. These mode-specific boarding penalties are a simplification for demonstration purposes only and do not represent the station and route-level premium attributes as accurately as desired. The scaled premium benefits were translated into a relative non-premium service boarding penalty to show a relative change from the commuter rail mode.

Even with the simplification of this process, the transit choice model provides a reasonable estimate of transfers in the system (1.36 boardings per trip) compared to the actual transfer rate (1.43 boardings per trip), which is about 5% lower than observed. In the existing model, the transfers (1.31 boardings per trip) were underestimated by a slightly larger margin (9% less than observed).

Three individual path choices were systematically defined based on a process of comparing possible paths to observed paths identified in transit on-board survey data. This path-building process included premium transit service characteristics as either constants or scaled to in-vehicle travel or waiting time. Possible paths were compared to observed paths to determine path choice

Table 6. Path-building parameters for the transit path choice model.

Walk Path	Drive Path	Traveler Preferences	Transfer Penalty	Access/ Egress Time	Wait Time	Non-Premium Service Boarding Penalty	Premium Service In-vehicle Time
1		Shorter Access Times, Premium Service	0	2	1	0.5	1
	1	Shorter Access Times, Premium Service for Longer Trips	0	2	1	1	0.5
2	2	Direct, Frequent Service	10	1	2	1	1
3	3	Frequent, Non-Premium Service	0	1	2	1.5	1

parameters. The best match was selected by examining expected interpretations of path-building parameters. Judgment was used to evaluate the path choice parameters and select weights for each path choice that were distinct and intuitive relative to the weights that provided the statistically best fit. The process to identify possible paths involved building hundreds of possible paths, based on combinations of reasonable weights for the parameters of greatest interest (e.g., access time, transfers, and premium service characteristics). These hundreds of path choices were then filtered down to a small number of path types that were each plausible and among them provided a path that matched the itinerary reported in the survey. The path-building parameters for the final set of paths are provided in Table 6.

The final step in the path-development process was to remove duplicate paths to avoid problems related to the independence of irrelevant alternative (IIA) property of multinomial logit models. Duplicate paths were defined as those that used the same sequence of transit routes in the same order. When found, these paths were removed from the transit skim data used as input to the mode choice model.

The paths that are generated by this process are interesting in their own right. As shown in Figure 8, the coverage area (shown in green) for walk-to-LRT trips to the University of Utah is somewhat broader in the existing model than in the transit path choice model. The yellow dots

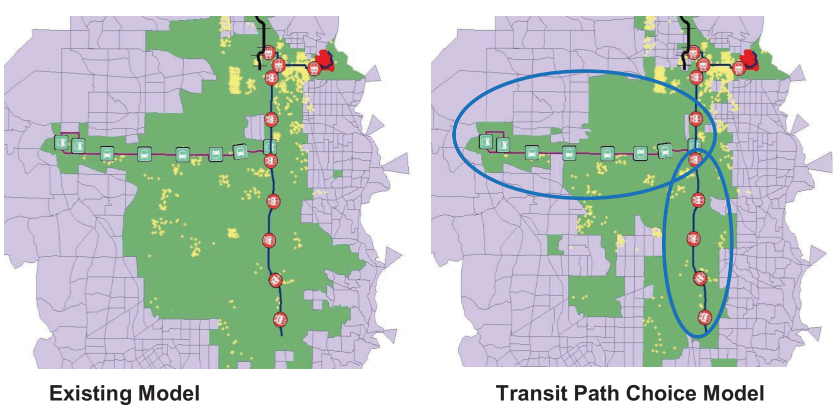


Figure 8. Example comparing geographic coverage for walk-to-LRT in the existing model and transit path choice model to the University of Utah.

Technical Details

In technical modeling terms, the mode choice model structure was revised to incorporate a path choice sub-nest in the walk and drive access portion of the nested logit (NL) choice model. This process required different path-building parameters for each path choice; these were developed by synthesizing all reasonable path choices (486) and matching them to observed behavior from the on-board transit survey. These new path choices incorporated transit amenities and service characteristics using the value of each attribute, scaled according to the in-vehicle travel time coefficient and converted from a benefit (in minutes) to a boarding penalty. This matching process allowed the researchers to exceed the path matches produced by the existing model using 10 access and service mode choices with six path choices. Duplicate or similar path choices were eliminated in order to produce up to three path choices for each origin-destination pair for walk and drive access transit trips. Segmentation of these path choices by age was tested and found to have a significant impact on the path choices in certain areas, but was not significant regionally. The revised mode choice model (with the path choice sub-nest) was calibrated by resetting all constant parameters (alternative specific constant, transfer penalty, direct walk access, and boarding penalties) to zero and then adjusting to match observed boardings by route group, access mode, and main mode.

For more information, the details of the project to calibrate and implement these models are presented in Appendix J.

show the origin location of surveyed trips and suggest that the more limited coverage area of the transit path choice model is still more extensive than observed usage patterns. The blue ovals show two premium service market areas that capture the majority of the travelers destined for the University of Utah. Since the research in Chapter 2 found that the model tended to overstate the availability of modes as reported by the traveler, this more limited coverage may help to focus premium transit trips in the locations where they are most likely to occur.

Implementation Outcomes

The model implementation and calibration part of the research demonstrated that a mode choice model from Salt Lake City could be revised to incorporate premium service characteristics and a path choice model structure and produce significantly smaller alternative specific constants. One objective of this restructuring was to give the constants in the mode choice model a basis in customer survey research. It is useful to understand several aspects of the constants deployed in a mode choice model. (Table 7 and Table 8 provide details for walk access and drive access, respectively):

- **Alternative Specific Constant (ASC)** represents unobserved behavior in the mode choice model. ASCs range from 0 minutes to 53 minutes in the existing model and from 0 minutes to 14 minutes in the transit path choice model.
- **Other Fixed Parameters** provide a summation of several different parameters, as follows:
  - **Transfer Penalty,** which represents additional time spent transferring from one mode to another and ranges from 12 minutes to 24 minutes in the existing model and 0 minutes to 12 minutes in the transit path choice model, depending on the complexity of the paths.

Table 7. Comparison of existing and path choice model alternative specific constants and boarding penalties in minutes (walk access).

Path	Existing Model			Path Choice Model			
	ASC	Other Parameters	Total	ASC	Boarding Penalty	Total	Total Shifted
Local	0	0	0	0	-16	-16	0
BRT	17	5	22	0	-4	-4	12
LRT	33	10	43	14	-2	12	28
Express	33	5	38	0	-13	-13	3
CRT	43	10	53	0	0	0	16
Local-Local	0	-12	-12	0	-31	-31	-15
Local-BRT	17	-12	5	0	-20	-20	-4
Local-LRT	33	-12	21	14	-18	-4	12
Local-Exp.	33	-12	21	0	-29	-29	-13
Local-CRT	43	-12	31	0	-16	-16	0
BRT-Local	17	-7	10	0	-20	-20	-4
LRT-Local	33	-2	31	14	-18	-4	12
Exp.-Local	33	-7	26	0	-29	-29	-13
CRT-Local	43	-2	41	0	-16	-16	0
Local-Exp.-LRT	33	-24	9	0	-31	-31	-15

Table 8. Comparison of existing and path choice model alternative specific constants and boarding penalties in minutes (drive access).

Path	Existing Model			Path Choice Model			
	ASC	Transfer Penalty	Total	ASC	Other Parameters	Total	Total Shifted
Local	0	0	0	0	-16	-16	0
BRT	17	0	17	0	-4	-4	12
LRT	33	0	33	0	-2	-2	14
Express	33	0	33	9	-13	-4	12
CRT	43	0	43	0	0	0	16
Local-Local	0	-12	-12	0	-43	-43	-27
Local-BRT	17	-12	5	0	-32	-32	-16
Local-LRT	33	-12	21	0	-30	-30	-14
Local-Exp.	33	-12	21	9	-41	-32	-16
Local-CRT	43	-12	31	0	-28	-28	-12
BRT-Local	17	-12	5	0	-32	-32	-16
LRT-Local	33	-12	21	0	-30	-30	-14
Exp.-Local	33	-12	21	9	-41	-32	-16
CRT-Local	43	-12	31	0	-28	-28	-12
Local-Exp.-LRT	33	-24	9	0	-55	-55	-39

– **Direct walk time,** which represents additional time to access premium modes directly and ranges from 5 minutes to 10 minutes for direct access to express bus, BRT, LRT, and commuter rail modes for the existing model. This parameter is zero in the transit path choice model.
– **Boarding penalty,** which represents an evaluation of premium service characteristics from the research and is levied by mode for the transit path choice model because more complex representations of station, on-board, and other amenities in the path-building software used in Salt Lake City was not possible. Boarding penalties are accumulated from individual service characteristics but levied as a single modal penalty for each boarding to a given mode as part of a path. They range from 0 minutes to 31 minutes in the transit path choice model, depending on the specific services included in a path.

The total impact of these adjustments is the sum of the ASC and the other fixed parameters. For walk access trips, the existing model contains transfer penalties and direct walk time parameters; for drive access trips, the path choice model contains transfer and boarding penalties. These penalties have been combined in Table 7 and Table 8 for easier comparison. To make a more direct comparison between the two models, the transit path choice model fixed parameters have been shifted so the local bus path is zero. These are reported in Table 7 and Table 8 as "Total Shifted."

The value of the ASC in the transit path choice model is significantly less than the value in the existing model. This demonstration confirms that the changes in model structure and path choice parameters, including premium service characteristics, have achieved this goal of the project. That said, the combined effects of all the fixed parameters mentioned also provide a useful comparison. In the existing model, the highest combined fixed effects total 53 minutes and 43 minutes for walk and drive access of commuter rail, respectively, relative to local bus. As a result, the commuter rail path receives a constant bonus equivalent to 53 minutes of walk to transit travel time, all effects considered. In the transit path choice model, the highest combined fixed effects total 27 minutes for a walk to light rail trip and ~39 minutes for a drive to local bus to express bus to light rail trip. Most of the fixed parameters in the transit path choice model are under 20 minutes, while most of the fixed parameters in the existing model are over 20 minutes, offering a significant improvement for the various mode combinations. Further, this approach of applying boarding penalties based on the specific services utilized in a path avoids the arbitrary but customary practice of defining a mode and associating a constant for that mode based on a hierarchical definition (e.g., a commuter rail to local bus path is designated a commuter rail mode and given the commuter rail constant, traditionally).

One interpretation of the combined total effects of the fixed parameters is to evaluate example trips, as shown in Figure 9. These example trips were selected because they represent the eight highest volume modes in the system. They demonstrate a significant reduction in the combination of ASCs and fixed parameters for all example trips.

One theory behind these new path choice parameters is that different travelers would choose different paths based on their own demographic characteristics and preferences. The path choice evaluation process identified age as the most significant demographic characteristic for choosing a walk to transit path. This hypothesis was implemented in the Salt Lake City model calibration as a market segmentation to evaluate the usefulness of accounting for this market segment in transit path-building. The representation of age had a significant impact in certain areas (up to 29% reduction in walk to transit trips), but did not significantly affect the regional statistics for transit ridership. This outcome is likely because of the small proportion of older travelers in most areas in the Salt Lake City region.

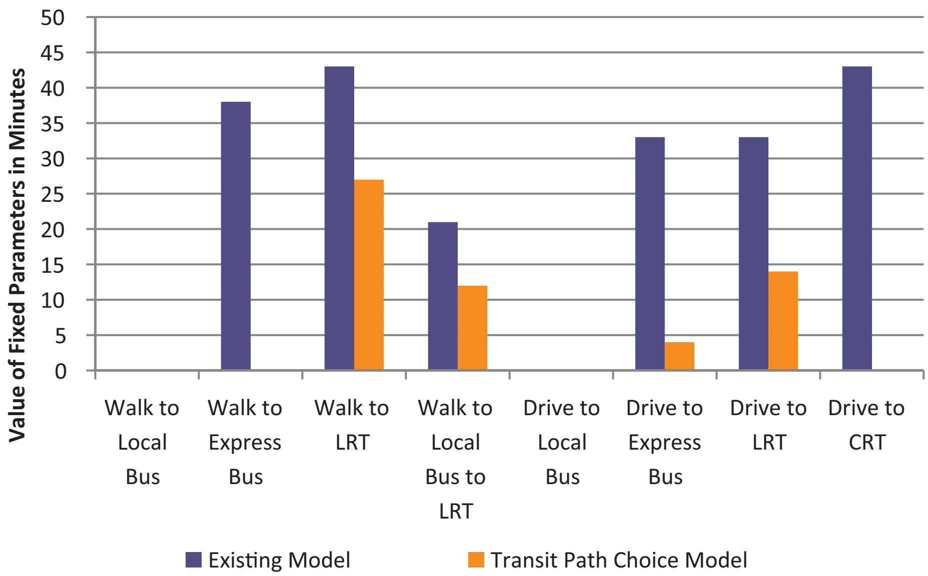


Figure 9. Comparison of fixed parameters for example transit trips.

The final test of the path-based model concerns its results. As shown in Table 9, the path-based model generates results that are very similar to the existing model despite the fact that it does not rely on service mode-specific paths and reduces the magnitude of many of the ASCs. The most significant deficiency of the new model occurs with local bus boardings, which are estimated to equal 59,200 boardings per day compared to an observed value of 77,100 boardings per day, which is probably the result of higher boarding penalties, assessed on transfers as well. Interestingly, the existing model also underestimates this quantity and in this case, it is a result of higher ASC on trips using a local bus to access other services. Future implementations should explore techniques translating the equivalent minutes of benefit for premium services into a transit path-building process, particularly when a transfer is involved. A boarding penalty of 15.7 minutes per boarding for local bus is much higher than typical values (generally 5 minutes) and may result in too few trips on journeys that require a transfer. The similar results from the existing and transit path choice models are encouraging because the transit path choice model has smaller ASC values and the calibration effort on the transit path choice model was much less than it was on the existing model.

Table 9. Comparison of observed and modeled transit ridership.

	Boardings							
	CRT	Express	LRT	BRT	Local	Total	Trips	Transfer Rate
Transit counts	5,300	8,200	47,900	3,400	77,100	141,900	98,900	1.43
Existing model	5,900	7,300	45,200	2,500	68,500	129,400	98,700	1.31
Transit path choice model	5,900	8,700	49,400	4,600	59,200	127,800	94,200	1.36

Source: Trips are derived from the 2011 Utah Transit Authority (UTA) on-board survey, expanded to represent the full population. Boarding data are also provided by UTA. Transfer rates are calculated as the ratio of boardings to trips.

Lessons Learned

Some lessons were learned when accounting for non-traditional transit service attributes in mode choice:

- **Enumerating path choices** based on observed behavior provides improved accuracy of the path-building parameters in the model and the choices provided for each access mode.
- **Revising mode choice model nesting structures** to include several path choices for each access mode (walk and drive), instead of including individual modes, reduced the number of choices for transit, thereby improving the representation of competitive services and reducing the reliance on modal labels.
- **Including non-traditional transit service attributes** in path and mode choice models and modifying the nesting structure to include path choice reduced the influence of ASCs in the mode choice models.

The implementation focused on the inclusion of non-traditional transit service attributes in the travel forecasting process. Other elements of the research related to awareness, consideration, and traveler attitudes were not tested in implementation but could be considered for future research.

CHAPTER 4

What's Next?

This project demonstrated the feasibility of using non-traditional transit attributes in travel forecasting models to differentiate premium transit services. It also documented that these non-traditional transit attributes have a value to travelers. Combined with the implementation testing conducted, the research yielded several lessons useful to transit planners and travel forecasters. Future implementations of this research in existing or new regional mode choice models would add significantly to the usefulness of these findings by comparing model results (reduction in mode-specific constants, calibration results, sensitivity to transit service attributes, etc.) from one place to another. More specifically,

- Conducting future scenarios using these updated models could help to explore these travel behaviors; and
- Implementing the attitudinal and awareness/consideration models, integrated with mode and path choice, would allow testing on the contributions of these traveler behaviors to improving mode choice models.

The research conducted in TCRP Project H-37 also identified awareness and consideration of transit and traveler attitudes as significant elements in travelers' choice of modes. Future research could build from the existing findings to integrate the path-building with the awareness, consideration, attitude, and mode choice models. For example,

- The awareness and consideration models could be tested with level-of-service variables from the revised path-building process to see if this improves the significance of these variables;
- The mode choice modeling structure could be re-estimated with the path choice sets within each access mode instead of the service mode choice sets; and
- Future testing on awareness and consideration models could include single, separate, or joint decisions. In this study, these were considered as separate, sequential decisions, but the added complexity of representing these decisions separately did not appear to improve the models significantly.

The benefits identified in this research are all potential improvements to consider when updating mode choice models for regional travel forecasting purposes. In addition, the values travelers place on non-traditional transit attributes can be used directly in transit planning to evaluate inclusion of these attributes for future premium transit services.

Glossary

This report and the technical appendices that accompany it use terms that refer to concepts from the field of choice-based conjoint modeling. In addition, this report refers to terms that have been specifically defined as part of this research. Because many readers may not be familiar with these and other terms used throughout the report, some definitions are provided below.

- **Alternative specific constant (ASC).** Unobserved behavior in a mode choice model. See also mode-specific constants.
- **Bias constants.** Another term for alternative specific constants, but also more generally applied to any fixed parameter in the mode choice model.
- **Boarding penalty.** An evaluation of premium service characteristics from the research and are cumulated from individual service characteristics but levied as a single modal penalty for each boarding to a given mode as part of a path.
- **Choice-based conjoint (CBC).** A type of behavioral intention research technique in which individuals trade-off (consider jointly) attributes so that the relative importance, or utility, of the attributes can be determined.
- **Choice modeling.** A method to measure the stated preference of a combination of characteristics with respondents choosing the best alternative.
- **Choice sets.** A modeling term that describes the modal alternatives available in the mode choice model.
- **Direct walk time.** Additional time to access premium modes directly.
- **Equivalent minutes.** Term used to value the importance of attributes other than travel time by converting them into time equivalents.
- **Factor analysis.** A method by which many different variables, correlated with one another to different degrees, may be reduced to a set of manageable factors that are orthogonal (not correlated) to one another.
- **Independence of irrelevant alternative (IIA).** A rule that says if A is preferred to B out of the choice set {A,B}, introducing a third option, X, expanding the choice set to {A,B,X}, must not make B preferable to A. In other words, preferences for A or B should not be changed by the inclusion of X; X is irrelevant to the choice between A and B.
- **Integrated choice and latent variable (ICLV).** A type of discrete choice model that integrates latent variable structural equation models to predict simultaneously these unobserved (latent) variables with modal choices.
- **In-vehicle travel time (IVTT).** A component of transit travel time spent on a transit vehicle (bus or train).
- **Joint bivariate binary probit.** A generalization of the probit model used to estimate two correlated binary outcomes jointly. The binary probit model is a type of regression in which the dependent variable can only take two values.
- **Latent variable.** A variable that cannot be directly observed.

- **Level-of-service (LOS) variables.** Attributes that vary due to the type of service being experienced (e.g., IVTT, wait time, boarding time, number of transfers, cost).
- **Log-likelihood.** A function of the parameters of the mode choice model. The objective of mode choice models is to maximize the log-likelihood; therefore, higher values of log-likelihood are preferred.
- **Maximum difference scaling (MaxDiff).** An analytical technique for determining the relative preference that a respondent has for a set of alternatives. The result of a MaxDiff exercise is a set of values that indicate the respondent's top choice and last choice, and where along an interval scale, the middle choices lay. Thus, MaxDiff gives more information than simply asking respondents to order a list of alternatives to show their preference. MaxDiff requires respondents to pick the alternative they prefer most and the alternative they prefer least from a short subset of alternatives (usually 3 to 6). By exposing the respondents to different subsets of alternatives and repeating the exercise, it is possible to infer the relative values or utilities that the respondents place on all of the alternatives.
- **Mode or modal label.** Refers to a segmentation of modes by technology (i.e., bus, light rail, etc.) in the mode choice model.
- **Mode choice model.** A model component that estimates the mode of transport that a traveler (or group of travelers) will use for a specific trip. As a choice model, these estimates are probabilities that a traveler will make a trip using a specific mode.
- **Mode-specific constants.** Values in mode choice models that ensure a mode choice model matches a targeted share of trips by mode. Mode constants are adjusted in the model calibration process. Also frequently referred to as alternative specific constants (ASCs), these values are a primary motivation for this study. According to a discussion piece produced by FTA (2006),

  > Perhaps the largest problem for transit forecasting that occurs in traditional model development is a transit calibration effort that results in adjustments necessary to match current data that are no more than correction factors for errors made elsewhere in the model set. The "calibration" of alternative specific constants is meaningful only when the person-trip tables, highway and transit networks, and observed transit ridership patterns are sufficiently accurate. Errors in person-trip tables, in particular, have frequently led to grossly distorted calibration constants that have nothing to do with travel behavior and that lead to useless transit forecasts.

- **Mode-specific variables.** Variable transit attributes specific to a particular mode, which may be perceived or weighted differently in the mode choice model utility equation. For example, the travel time coefficient for time spent on commuter rail may have a different value than the travel time coefficient for time spent on a local bus.
- **Multinomial (MNL) logit choice.** An exercise in which individuals select an alternative from a finite set of alternatives.
- **Non-traditional characteristic or attribute.** A transit service attribute that to date has not been able to be described and utilized in mode choice models. Non-traditional attributes include the following:
  - On-board amenities (seating availability, seating comfort, temperature, cleanliness of a transit vehicle, productivity features);
  - Station design features (real-time information, security, lighting for safety, shelter, proximity to services, cleanliness of the station, benches); and
  - Other features (route identification, reliability, schedule span, transit frequency, transfer distance, stop distance, parking distance, ease of boarding, fair machines). The terms *attribute* and *characteristic* are used interchangeably in this report.
- **Path-building.** A process to identify the access, route, transfers, and egress elements of a transit trip. Parameters are used to weight the importance of each element.
- **Premium transit services.** A series of attributes that together represent a higher class of service. These attributes exist over a broad continuum of transit services in operation and

are not necessarily associated with a particular vehicle technology. For example, a commuter coach service offering a seat with Wi-Fi service to all customers and a highly reliable schedule may be perceived as superior to a crowded rapid transit rail line with fewer amenities. In this report, an analytical approach and framework is described to acknowledge that these services often exist as a continuum between premium and non-premium; as a result, they are not easily represented as separate and discrete modes.

- **Probit model.** A type of regression model in which the dependent variable can only take two values (e.g., married or not married).
- **Revealed preference (RP).** Questions on the survey that ask travelers to report on a specific reference trip that they have taken recently.
- **Robust t-ratio.** A t-ratio that makes use of standard errors obtained by using a robust variance-covariance estimator also known as the sandwich estimator. A robust t-ratio uses robust variance-covariance estimator accounts for the panel nature of stated preference data (repeated observations from the same individual) and provides consistent estimates even when there is different variability in the data.
- **Stated preference (SP) questions.** Questions on the survey that ask travelers to evaluate a set of hypothetical (although realistically set) assumptions about a set of modes and select the mode they would choose. These questions also can include a set of scenarios in which the traveler is asked to choose a least favorite option and a most favorite option, identified as MaxDiff above.
- **Transfer penalty.** Additional time spent transferring from one mode to another; the value of the transfer penalty depends on the complexity of the paths.
- **Unobserved factors.** See the definition for *alternative specific constant.* Unobserved factors include traveler attitudes, as they are not directly observable.

References

This list includes references from the technical appendices as well as from the final report.

Abdi, H. (2003). Factor Rotations in Factor Analysis. University of Texas at Dallas.

AECOM Consult, Inc. (2006a). Chicago Area New Starts Ridership Forecasting Methods Report DRAFT for the Chicago Transit Authority Circle Line Alternatives Analysis and Metra New Starts Corridor Alternatives Analyses.

AECOM Consult, Inc. (2006b). "JFK-Lower Manhattan AA Commuter Model Enhancements for MTA Regional Transit Forecasting Model" (PowerPoint Presentation).

AECOM Consult, Inc. (2007). "New York City Transit-BRT Phase 2 Travel Demand Framework & Forecasting Approach—Estimating Induced Riders and Diversions from Other Modes."

AECOM Consult, Inc. (2008). "Southeast Florida Regional Planning Model Coefficients and Constants File," Version 6.5 finalized.

Almquist, E., and J. Lee (2009). What do customers really want? *Harvard Business Review.* Available at: http://hbr.org/2009/04/what-do-customers-really-want/ar/1.

Axhausen, K. W., T. Haupt, B. Fell, and U. Heidl (2001). Searching for the Rail Bonus: Results from a Panel SP/RP Study. Presented at 80th Annual Meeting of the Transportation Research Board, Washington, D.C.

Barta, F., W. Brog, and E. Erl (2007). Individualized Marketing for Public Transportation Fostering Light-Rail Systems. Presented at 86th Annual Meeting of the Transportation Research Board, Washington, D.C.

Ben-Akiva, M., et al. (1999). Extended framework, for modeling choice behavior. *Marketing Letters*, Vol. 10, No. 3, pp. 187–203 and Bolduc et al. (2005).

Ben-Akiva, M. et al. (2002). Hybrid choice models: Progress and challenges. *Marketing Letters*, Vol. 13, No. 3, pp. 163–175.

Bolduc, D., M. Ben-Akiva, J. Walker, and A. Michaud (2005). Hybrid choice models with logit kernel: Applicability to large scale models. In: Lee-Gosselin, M., and S. Doherty (Eds.). *Integrated Land-Use and Transportation Models: Behavioural Foundations.* Elsevier, Oxford, pp. 275–302.

Castro, M., N. Eluru, C. Bhat, and R. Pendyala (2011). A Joint Model of Participation in Non-Work Activities and Time-Of-Day Choice Set Formation for Workers. Available at: http://www.ce.utexas.edu/prof/bhat/ABSTRACTS/NonworkActivityParticpationMileage_15March2011.pdf.

Cervero, R. (1993). Ridership Impacts of Transit-Focused Development in California. Monograph 45. Institute of Urban and Regional Development, University of California at Berkeley, Berkeley, CA.

Chicago Metropolitan Agency for Planning (2011). CMAP Travel Demand Model Validation Report. Prepared by Craig Heither. February 23.

Chicago Transit Authority (2011). Performance Metrics Report. CTA Monthly Performance for September. Available at: http://www.transitchicago.com/assets/1/performance_metrics/CTA_Company_Wide_KPI_Sep_11.pdf.

Chicago Transit Authority (2008a). "MAX Capacity Rail Car Experiment: Customer Preferences and Customer Observations." Prepared by Market Research Department.

Chicago Transit Authority (2008b). "Seatless Bus Experiment: Customer Preferences and Customer Observations." Prepared by Market Research Department.

Chicago Transit Authority (2009). Circle Line Alternatives Analysis and Metra New Starts Corridor Alternatives Analyses—Chicago.

Currie, G. (2006). Bus transit oriented development—Strengths and challenges relative to rail. *Journal of Public Transportation* Vol. 9, No. 4, pp. 1–22.

Douglas, N., and K. Karpouzis (2006). Valuing Rail Service Quality Attributes through Rating Surveys. 29th Australasian Transport Research Forum, Gold Coast. Available at: http://www.patrec.org/atrf (as of September 4, 2008).

Evans, J., R. Pratt, A. Stryker, and J. R. Kuzmyak (2007). *TCRP Report 95: Traveler Response to Transportation System Changes, Chapter 17—Transit-Oriented Development.* Transportation Research Board of the National Academies, Washington, D.C.

Federal Transit Administration (2006). Discussion Piece #16: Calibration and Validation of Travel Models for New Starts Forecasting. Available at: http://www.fta.dot.gov/documents/Discussion_16_Calibration_Validation.doc (as of February 24, 2010).

Gould, J. and J. Zhou (2010). A Social Experiment to Encourage Drive-Alone Commuters to "Try Transit." Transportation Research Board, Washington, D.C.

Hensher, D. A., P. Stopher, and P. Bullock (2003). Service quality—Developing a service index in the provision of commercial bus contracts. *Transportation Research*, Vol. 37A, No. 6, pp. 419–517.

Horowitz, A. J., and D. J. Zlosel (1981). Transfer penalties: Another look at transit riders' reluctance to transfer. *Transportation*, Vol. 10, No. 3, pp. 279–282.

Kansas City Area Transportation Authority, Metro Area Express (MAX). Available at: http://www.kcata.org/maps_schedules/max/ (as of July 19, 2008).

Kittleson & Associates, Inc., Herbert S. Levinson Transportation Consultants, and DMJM+Harris (2007). *TCRP Report 118: Bus Rapid Transit Practitioner's Guide.* Transportation Research Board of the National Academies, Washington, D.C.

Li, Y.-W. (2003). Evaluating the urban commute experience: A time perception approach. *Journal of Public Transportation*, Vol. 6, No. 4, pp. 41–67.

Litman, T. (2007). Valuing Transit Service Quality Improvements: Considering Comfort and Convenience in Transport Project Evaluation. Research Report. Victoria Transport Policy Institute, Victoria, BC, Canada. Available at: http://www.vtpi.org/traveltime.pdf (as of January 2, 2008).

Lyons, G., J. Jain, and D. Holley (2007). The use of travel time by rail passengers in Great Britain. *Transportation Research*, Vol. 41A, No. 1, pp. 107–120.

Mix, W., D. Chernoff, and T. Trabold (2009). "A Comparison of Internet and Mail-based Transportation Surveys," Final Paper. Transportation Research Board. Available at: http://www.buffalostate.edu/geography/documents/TRB_FinalPaper.pdf.

Mojica, C. (2008a) "Examining Changes in Transit Travel Behavior through a Smart Card Activity Analysis." (PowerPoint Presentation).

Mojica, C. (2008b). *Examining Changes in Transit Travel Behavior through a Smart Card Activity Analysis.* MS thesis. Massachusetts Institute of Technology, Cambridge, MA.

Northwest Research Group, Inc. (1999). 1998 Rider/Nonrider Survey. Chicago Regional Transportation Authority, Chicago, IL.

Northwest Research Group, Inc. (2004). Chicago Transit Authority 2003 Customer Satisfaction Survey Final Report. Chicago Regional Transportation Authority, Chicago, IL.

Ory, D. T., and P. L. Mokhtarian (2005). When is getting there half the fun? Modeling the liking for travel. *Transportation Research*, Vol. 39A, No. 1, pp. 97–123.

Outwater, M. et al. (2010). California Statewide Model for High-Speed Rail 11th World Conference on Transportation Research, Berkeley, California, June 2007, published *Journal of Choice Modeling*, Vol. 3, No. 1 (March 2010). Available at: http://www.jocm.org.uk/index.php/JOCM/article/viewFile/26/43.

Pepper, J., G. Spitz, and T. Adler (2003). Customers' Perspectives on Using Multilevel Coaches to Increase Rail System Capacity. Presented at 82nd Annual Meeting of the Transportation Research Board, Washington, D.C.

RSG, Inc. (2006a). JFK-Lower Manhattan AA Air Passenger Airport Access Mode Choice Modeling Technical Report.

RSG, Inc. (2006b). JFK-Lower Manhattan AA Commuter Mode Choice Modeling Technical Report.

RSG, Inc. (2007). "NJ Transit MaxDiff Conjoint Training: A Guide to Designing and Preparing MaxDiff Surveys and Analyzing and Interpreting MaxDiff Data." (PowerPoint Presentation).

Shelton, D., and A. Lo (2003). Transit-oriented development in the Seattle, WA, USA, Area. *ITE Journal*, Vol. 73, No. 8.

Spitz, G. M., E. R. Greene, T. J. Adler, and R. Dallison (2007). Qualitative and Quantitative Approaches for Studying Transit Stations. Presented at 86th Annual Meeting of the Transportation Research Board, Washington, D.C.

Swanson, J., L. Ampt, and P. Jones (1997). Measuring bus passenger preferences. *Traffic Engineering and Control*, Vol. 38, No. 6, pp. 330–336.

The Kenney Group (2007). RTD—FasTracks Survey of Denver Metro Residents. Regional Transportation District of Denver, CO. Available at: http://www.rtd-fastracks.com/media/uploads//main/CAC_8_Presentation_12-13-07.pdf (as of September 13, 2008).

Transit Marketing, LLC, and CJI Research Corporation (2006). Findings of Customer Surveys. Sacramento Regional Transit, Sacramento, CA.

U.S. Federal Transit Administration (2007). Proposed Guidance on New Starts/Small Starts Policies and Procedures, Office of Planning and Environment, U.S. Department of Transportation, Washington, D.C.

Utah Transit Authority (2008). FrontRunner Wi-Fi Service Embraced by Riders. Available at: http://www.masstransitmag.com/web/online/Industry-Announcements/FrontRunner-Wi-Fi-Service-Embraced-by-Riders/1$6948 (as of September 15, 2008).

Wasatch Front Regional Council (2011). WFRC/MAG Travel Model Documentation (Version 7).

Washington Metropolitan Area Transit Authority (2006). "Customer Satisfaction Measurement." (PowerPoint Presentation). Available at: http://www.wmata.com/bus2bus/sol/uploads/CSM%20Q3'2006.ppt (as of August 12, 2008).

Williams, B., A. Onsman, and T. Brown (2010). Exploratory factor analysis: a five-step guide for novices. *eJournal of Emergency Primary Health Care*, Vol. 8, No. 3. Available at: http://www.jephc.com/full_article.cfm?content_ id=590 (as of October 14, 2012).

Wirthlin Worldwide and FJCandN (2000). *TCRP Report 63: Enhancing the Visibility and Image of Transit in the United States and Canada.* Transportation Research Board of the National Academies, Washington, D.C.

Woodford, W. (2007). Pathbuilder Calibration with Data on Ridership Patterns. Presented at the 2007 Travel Forecasting for New Starts Workshop, St. Louis, MO.

APPENDIX A

Literature and Practice Reviews

Contents

Overview

The review of the literature and current practice covered three aspects of transit planning: awareness of transit services, transit service attributes, and how mode choice models incorporate premium transit services. The lack of awareness and familiarity with transit seems to be significant and there is not yet abundant research on this topic. Awareness about premium transit services can increase due to visibility of stations or right-of-way over more conventional services. Branding and marketing campaigns can also increase awareness, but this was not the focus of our research. Current mode choice models assume perfect knowledge with regard to awareness and consideration of transit modal alternatives and the research clearly shows this not to be true. This review led to a clear focus on modeling awareness and consideration for transit services and using these models to constrain choices available within the mode choice model.

To support better behavioral models, it is necessary to extend the conventional set of explanatory variables to include new variables and methods that relate specifically to the decision-making process. Current practice in mode choice modeling typically results in models that are sensitive to the effects of travel times, wait times, frequencies, travel costs, and transfers, and include large mode-specific constants. In theory, the mode constants capture the differences in the unobserved attributes of modes, but the constants are also adjusted to match observed ridership volumes and therefore help "correct" other errors in the travel model system.

The majority of the literature and practice review focused on evaluating non-traditional transit service attributes that could inform mode choice models and transit networks for planning analysis. The long list of attributes was organized into nine categories: monetary cost, journey time, convenience, comfort, accessibility, productivity, information services, fare payment, and safety. These attributes were refined for use in market research conducted in three cities for this study in three groups: on-board amenities (comfort, productivity, information services, and safety), station amenities (comfort, accessibility, information services, fare payment, and safety), and other attributes (journey time, convenience, and information services).

Traditionally, travel demand models have underestimated ridership on premium services. People have speculated that this is related to public perception of safety awareness, brand visibility, and various service attributes that are not typically included in mode choice models. Practitioners have struggled to quantify these additional service attributes and to measure traveler's reactions to these service attributes. This review highlighted the need for an in-depth study to quantify these additional service attributes and to incorporate them in travel demand forecasting models.

Contents of the Appendix

This appendix presents the findings from a review of the literature and the practical experience in these areas, focusing primarily on identification of distinguishing transit service features and their relative importance in mode choice and transit customer satisfaction. A few successful transit industry anecdotes related to upgrading "non-traditional" transit service amenities are discussed to provide context for the research. The discussion is based on detailed responses obtained from staff at a few transit agencies and MPOs which have been reported in Appendix C.

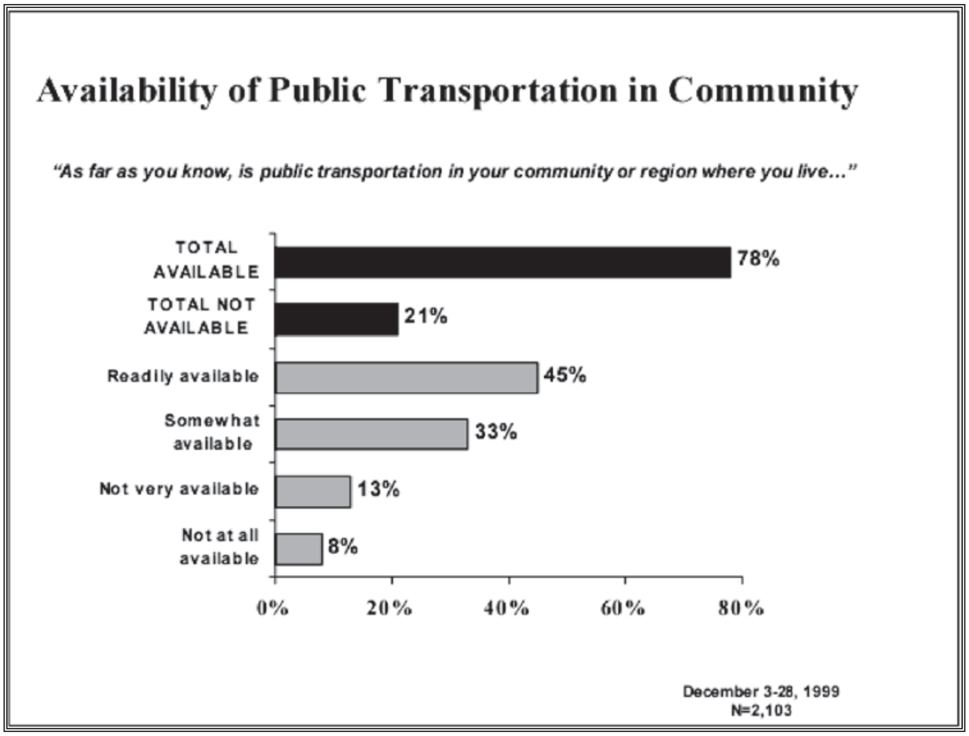
Further, the appendix outlines current attempts in research and practice to understand mode choice and improve the reasonableness and interpretability of mode choice models, reducing the extent to which mode constants dominate the utility equations. The review considers the extent to which the general public is aware of transit services, and whether the presumption of complete knowledge in travel models is reasonable. Finally, the ways that non-traditional transit attributes have been included in mode choice models are discussed. These reviews together informed and helped focus the data collection effort for TCRP Project H-37 and begin to suggest opportunities for advancement of the practice. This appendix presents a more detailed review of research around identification and quantification of non-traditional transit service attributes as well as case studies pertaining to attribute evaluation and incorporation of these attributes in model applications.

Awareness of Transit Services

Mode choice models typically assume that if a transit option is available nearby, it is part of the traveler's mode choice set and has a probability of being used (i.e., models assume "perfect knowledge" with regard to the mode choice set). In reality, travelers are often simply unaware of the transit options available to them. Therefore, when calculating the market share for transit modes, accurately defining the mode choice set and eliminating any zero-probability options will produce more accurate ridership forecasts. Moreover, to the extent that travelers are more aware of different modes, it is possible that this difference in awareness explains some of the observed difference in ridership not explained by level-of-service. This has potential implications for regions considering and analyzing new transit modes for which the regional model is not calibrated.

Transit Awareness and Familiarity

The lack of awareness and familiarity with transit seems to be significant, though there is not yet abundant research on this topic. For *TCRP Report 63: Enhancing the Visibility and Image*



Source: (TCRP Report 63, 2000)

FIGURE A-1. Awareness of transit availability.

of Transit in the United States and Canada (2000), individuals in a variety of transit markets were asked their perception of transit availability; and while all respondents contacted in this study lived in an area with readily available transit alternatives, 21% did not know that transit was available (FIGURE A-1). More than twice that number, 44%, reported being either "not very familiar" or "not at all familiar" with public transportation services in their area.

Unfamiliarity with public transportation is also prominent in major transit markets. A study for the Regional Transportation Authority for Chicago (Northwest Research Group, Inc., 1999) found that 38% of randomly selected residents in the transit service area had not ridden transit in the past year, with 19% reporting they were "somewhat unfamiliar" with transit services and an additional 36% "very unfamiliar" with transit.

An interesting social experiment was conducted at UCLA in the summer of 2008 to get employees to try public transit (Gould, 2010). As gas prices were increasing dramatically during the summer of 2008, UCLA tried to motivate SOV commuters to switch to transit by providing a free transit pass for 12 weeks in return for turning in their employee parking pass. Researchers found that there were several factors that influenced employees' successful conversion to public transit and several other factors that caused some employees (28%) to return to driving upon completion of the program. It was felt that gaining familiarity with using transit over the 12-week period contributed to the program's success because committed transit riders were able to become comfortable with routes and schedules, became more relaxed with the experience, and ultimately found the bus less stressful than driving. Conversely, participants who ultimately went back to driving and reclaimed their parking passes, indicated that they did, in fact, continue to drive a few times per week throughout the program duration.

FIGURE A-2. Conventional bus stop.

While many individuals are unaware of transit in general, determining the differences in awareness between premium and conventional services is of particular importance to this research. Typically, those supporting a positive premium service bias cite the improved quality of non-traditional, more qualitative attributes like comfort and convenience. However, another possible reason for premium transit's perceived appeal is that premium transit services are more visible and therefore travelers are more aware of their existence. For example, newer Bus Rapid Transit (BRT) systems often stand out due to branding, and their right-of-way may be painted or visibly marked in some way. Rail stations tend to be highly visible—as are the tracks and rail cars—and major infrastructure investments receive more publicity owing to cost and the need for infrastructure improvements. The characteristics and marketing of premium services that heighten visibility may resolve some of the currently unexplainable preference for premium transit.

The most obvious way to become aware of a transit service is to physically see it. Conventional bus service may seem visible because it is typically well established and geographically widespread; however, bus stops are often poorly marked and the route and schedule of the service can be difficult to determine (FIGURE A-2).

Premium bus services, on the other hand, typically include many improvements that increase the visibility of the service. Improvements in bus stops such as clear signage, seats and shelters, or off-board ticket vending, bring attention to the service, while branding on the bus exterior captures attention and distinguishes the bus from conventional services. Also, premium bus services occasionally operate in bus lanes or high occupancy vehicle (HOV) lanes, and marked or painted lanes can bring attention to the bus service and its potentially improved reliability and travel time.

FIGURE A-3. Fordham bus lane, Bronx, NY.

In New York City, a BRT service introduced in 2007 incorporates many of these visible service improvements and has shown a significant increase in ridership (J. Barr, pers. comm., September 17, 2008). The new BRT alternative, branded Select Bus Service (SBS) by the New York City Metropolitan Transportation Authority (MTA), runs along Fordham Road in the Bronx. Bus lanes are painted a separate color from the regular street with large signs declaring the lanes as bus lanes (FIGURE A-3). New bus shelters have been constructed to offer better visibility and improve security, and ticket-vending machines have been placed at bus stops and eliminate on-board payment (FIGURE A-4). The SBS buses, which are

FIGURE A-4. Select bus service stop in Bronx, NY.

the same type as conventional buses, are thoroughly rehabilitated and cleaned for the new service, and are equipped with signal priority and on-board cameras. The buses are also "wrapped" with a brand logo.

Awareness of the Fordham Road service and its high priority has increased, likely due to the "hard-to-miss" painted lanes and that some on-street parking was taken away (which makes non-riders aware that something has changed). Ridership is up in the corridor, with a 20% increase in ridership on the SBS over the former limited stop route (a much higher increase than what MTA buses have experienced), though it is not yet clear how much of this increase comes from local bus riders who switched to SBS.

Like the SBS, the Xpress bus service operated by the Georgia Regional Transit Authority has expanded its number of routes from 2 to 27 in the last five years with little to no advertising (R. Alexander, pers. comm., September 26, 2008). The buses serve as "billboards," with branding and website/phone information prominently displayed on the sides. Further details on these projects that have enhanced the visibility of transit services and as a result influenced the ridership can be found in Appendix C.

Light rail and commuter rail, while not as geographically dispersed as conventional bus, are highly visible and the routes can be simpler to understand. Suburban rail stops often have parking lots with clear signage and larger stations, and the tracks and rail cars are typically easily noticed. The fixed track and sequence of stations also indicate the service route.

New premium transit services may also be more visible upon opening because the introduction of new capital improvements is likely to be discussed on television, in newspapers, and among travelers, increasing awareness. For example, a study of the FasTracks rail and BRT service improvements in the Denver area (The Kenney Group, 2007) showed that, "three years removed from the FasTracks campaign and the campaign communications, half of survey respondents feel informed about FasTracks plans." Respondents reporting the primary source of this information cited newspaper (55%) and television news (31%) as opposed to the Regional Transportation District's website (3%) or its newsletters or emails (1% each).

The introduction of premium transit is also often accompanied by targeted marketing campaigns. Marketing has been shown to significantly improve ridership, due to increased awareness of premium transit services. Brog and colleagues (Barta et al. 2007) in particular have detailed the impact of targeted marketing—specifically the IndiMark® program—on ridership increases. Individualized Marketing (IndiMark) is a dialogue-based technique for promoting the use of public transportation based on a targeted, personalized, customized marketing approach. The success of this technique has shown the importance of distributing information to heighten awareness and increase ridership.

Results from two projects show that soft policies such as IndiMark can in fact double ridership (Barta et al. 2007). The introduction of the "Saarbahn," a light rail system in the Saarland region in Germany, led to an increase of 28 public transportation trips per person per year, but in combination with IndiMark, the increase was 56 trips per person per year. In Portland, Oregon, the introduction of the MAX light rail line increased transit use by 16 trips per person per year. Those targeted by IndiMark increased transit use by 32 trips per year.

One additional example, the River Line light rail operated by New Jersey TRANSIT, illustrates how the many visible aspects of a new premium rail service can work together to increase ridership (T. Marchwinski, pers. comm., September 30, 2008; see later in this appendix for more details). This service, introduced in March 2004, connects southern New Jersey to Camden and Trenton and to the Northeast Corridor line to Philadelphia via Port Authority Transit Corporation (PATCO) service.

Many specific infrastructure improvements contributed to the increased awareness of the River Line. Train stations were built with ticket-vending machines, phones, a public announcement system, digital signs to show delays and alerts, platforms, and full signage. The service was accompanied by many new park-and-ride facilities as well as an upgraded transfer point with PATCO, offering a pleasant pedestrian-friendly plaza for transferring between services. Public debate over cost and right-of-way improvements heightened awareness, and once the right-of-way was constructed, the 45 grade crossings were easily noticed by auto travelers and even led to safety trainings conducted in schools, introducing children to the River Line.

Strategic marketing campaigns were also launched to increase awareness of the River Line (FIGURE A-5). Initially, the service was priced lower than the existing bus despite the many benefits provided by the premium service. Also, upon introduction and for the first year, the service was advertised through newspapers, brochures, and connecting services like the Northeast Corridor. Websites, which still continue (http://www.riverline.com), were developed and offer promotions to destinations like the aquarium or entertainment centers for concerts, increasing weekend trips in both the short and long term.

FIGURE A-5. Large crowds during the opening ceremony for the River Line.

While the exact impact of the project's visibility on ridership has not been measured, quantitative evidence suggests that visibility played a key role. Surveys showed that after service opened, 15% of people were riding just to "check it out." Meanwhile, overall ridership increased significantly, with 25% of River Line riders having switched from the existing bus, 50% switching from auto modes, 5% using the service to transfer from the Northeast Corridor to PATCO, and the remaining ridership coming from induced new trips.

The existence and extent of marketing likely contribute to heightened awareness and increased ridership and can be studied alongside other attributes of premium services that heighten visibility to determine the level of awareness and, more specifically, who is aware and under what circumstances. Model adjustments accounting for differences in awareness can be developed and applied so that the market potential for a particular mode can be more accurately estimated.

Transit Service Attributes

The attributes explaining mode choice must be identified and appropriately described in order to estimate each mode's market share. Mode choice models typically specify level-of-service attributes such as travel time, cost, access time, wait time or headway, and transfers. These attributes are considered strong predictors of mode choice, and they are also readily quantifiable, making it easier to measure their importance to travelers and to incorporate them in travel models.

The downside, however, is that these level-of-service attributes only account for a portion of the variation in mode choice behavior and therefore can be poor mode choice predictors. These level-of-service attributes alone do not adequately differentiate among transit options, and models are left to capture the remaining attributes in mode-specific constants. In reality, there are several attributes known to be important in mode choice decisions and transit customer satisfaction that are not traditionally included in mode choice models. These non-traditional attributes tend to either be qualitative (e.g., comfort and safety) or quantitative but difficult to measure (e.g., reliability). Practitioners assume that all the unspecified characteristics of a particular mode are captured in the model's error term and that adding mode-specific constants can then reflect the magnitude of the difference in preference among modes beyond the specified attributes.

Use of mode constants without representing other factors in the models is, however, not generally a sufficient way to represent differences among modes. One reason for the insufficiency of mode constants is that any error introduced in prior stages of the forecasting process will be incorporated in the constant. A problem lies with the transferability of mode constants when new premium transit services are introduced with varied levels of services and amenities. A second problem relates to the Federal Transit Administration (FTA) New Starts project evaluation criteria related to ridership, known as user benefits. User benefits is a measure of the difference in the aggregate utility of different alternatives, and heavy reliance on mode-specific constants has been shown to bias this measure. There are recent changes to the project evaluation criteria regarding user benefits, so a review of these criteria should be completed before use.

One way to improve mode choice models is to identify the most important non-traditional attributes that contribute to the preference for premium transit, quantify the importance of these attributes, and realistically incorporate them into travel models. This is a difficult task because so many of the service attributes that distinguish premium transit from traditional transit services are qualitative factors. However, while quantifying these non-traditional attributes is challenging, there is much literature identifying these factors, and some attempts have been made to quantify their relative importance and their effects on the traveling experience. Finally, while few attempts have been made in practice to incorporate a variety of non-traditional attributes in models, real-world efforts to adjust mode constants and to specify a modest number of non-traditional attributes have been made, and the results of these efforts can offer key insights into predicting mode choice.

Traditional Transit Service Attributes

Most mode choice models characterize service quality in terms of travel time (in vehicles, walking, waiting, and transferring) and cost (fares, fees at park/ride lots), and some models capture the effects of a few other measured attributes (number of transfers, transit/pedestrian friendliness at the beginning and/or end of the trip).

Walk time and wait time are usually specified separately from in-vehicle travel time (IVTT) because time spent out of the vehicle has typically been found to be two to five times more onerous than IVTT (Litman 2007). Time spent walking and waiting during a transfer is also accounted for separately, but transfers are generally thought to impose additional costs through increased unreliability, additional mental effort, and by splitting IVTT into a greater number of stages, which breaks up time that could be more productive with fewer but longer journey stages (Li 2003). These costs can be captured by adding a coefficient specifying the number of transfers and assessing a transfer penalty, estimated as an extra 5 to 15 minutes of IVTT (Horowitz and Zlosel 1981). The monetary cost of a transfer is captured in the cost coefficient along with the fare, parking cost, and any additional fees.

Service frequency can be included in models as a proxy for wait time; however, research has shown that improvements in headway provide greater benefits for high-frequency services than low-frequency ones, and can therefore be specified nonlinearly. In one study, a 1-minute decrease in headway for a service departing every 5 minutes was equivalent to 1 minute of IVTT savings, while the same improvement for an hourly service provided roughly half that benefit (Litman 2007).

Finally, pedestrian friendliness, while not necessarily a service attribute over which the transit agency has control, is occasionally included in models to account for variation in the quality of the accessibility between the station and activity locations.

Non-Traditional Transit Service Attributes

Mode choice models account for the different costs associated with the different stages of a transit journey, but the costs of each stage can still vary considerably based on the conditions in which they take place. Wait time or IVTT spent in dirty, crowded, or unsafe conditions can make a trip seem more onerous, whereas the ability to be productive and enjoy a smooth ride in a comfortable seat can make traveling significantly more enjoyable. Factors beyond the journey time, such as the ease of planning or executing a trip, also impact the overall trip cost and therefore the attractiveness of a particular mode.

TABLE A-1 presents a list of attributes that can impact the cost of travel beyond those traditionally applied in models. To provide structure, the attributes have been organized into nine categories: monetary cost, journey time, convenience, comfort, accessibility, productivity, information services, fare payment, and safety. The attributes listed were identified in quantitative and qualitative research studies as well as customer satisfaction surveys conducted for the Chicago Transit Authority (CTA), Washington Metropolitan Area Transit Authority (WMATA), and the Sacramento Regional Transit District. The full list of attributes measured in these customer satisfaction surveys along with some anecdotal accounts and quantitative valuations of a subset of these attributes can be found later in Appendix A.

TABLE A-1. Transit attributes.

Monetary Cost	
	Cost of one-way ride/pass
	Parking cost
Journey Time	
	Access/Egress time
	Wait time
	In-vehicle time
	Reliability
	Right of way
	Bus goes to front of line at red light
	Bus gets priority at traffic light
Convenience	
Transfers	Number of transfers
	Transfer walk time
	Transfer wait time
	Transfer monetary cost
	Time to transfer before assessed second fare
	Quality of transfer (same vs different platform)
	Transfer information
	Schedule/route coordination w/in b/w agencies
Span/Frequency	Service frequency
	Service hours
	Geographic coverage
	Express service
Comfort	
Station/Stop	Shelter
	Seats/benches
	Cleanliness
	Vandalization
	Maintenance/repair
	Station design/layout
	Station building materials
	Station art
On-board	Layout/design
	Seat configuration
	Seat comfort
	Load factor
	Seat availability
	Heating/cooling/ventilation
	Smoothness
	Quietness
	Cleanliness/appearance interior/exterior
	Smell
	Space for luggage/belongings
	Restrooms
Accessibility	
	Pedestrian friendliness
	Parking
	Bicycle accommodation
	Distance from entrance to platform
	Elevators/escalators
	Wider passages and stairways
	Platform surface
	Low-floor/no steps
	Wide entry
	Availability of handrails
	Stopping position of bus/train
Productivity	
	Ability for activity
	Activity services - WiFi
	Entertainment
	Journey enjoyment
Information Services	
General	Understandability of schedules/routes
	Accuracy of information
	Ease of getting information by phone/online
	Effectiveness of customer service
	Availability of service change information
	Notification of service changes
	Availability of customized local information
Station/stop	Schedule/map availability
	Availability of real-time information
	Usefulness of digital displays
	Clear/timely announcements
	Visibility of signage
	Staff availability
	Station egress information
On-board	Visibility of route names/numbers on outside
	Schedule/map availability
	Clear/timely announcements on board (if any)
	Visibility of station name from inside train
	Driver knowledgeable of schedules/routes
	Driver explains reasons for delays
Fare Payment	
	Pass/fare card purchase location availability
	Ticket vending machine availability
	Ease of purchasing pass/fare card
	Ease of recharging fare card
	Ease of obtaining refund/replacement fare card
	Fare integration with other agencies
	Mandatory off-board payment
	Proof of purchase by fare inspectors
	Ease of paying fare on-board
	Change availability
Safety	
	Station/stop crime daylight
	Station/stop crime nighttime
	On-board crime daylight
	On-board crime nighttime
	Parking lot crime daylight
	Parking lot crime nighttime
	Presence of surveillance cameras
	Presence of emergency call buttons
	Presence of security personnel and/or police
	General visibility/open sightlines
	Lighting
	Accidents
	Availability of on-board emergency exits

Qualitative and Quantitative Research on Premium Service Attributes

The following sections of this appendix present anecdotal accounts and quantitative valuations for a subset of the attributes listed in TABLE A-2. The sections are organized by category, and the attributes described are those most frequently cited in research, those most valued by travelers, and those that transit agencies have some degree of control over.

Note, however, that after reviewing the existing literature, it is apparent that no standard method exists for quantifying, or valuing, non-traditional attributes. Because of the many different techniques and methods used, it is difficult to compare attribute valuations across studies. There are differences in the presentation of attributes (pictorial, text) that can impact the respondent's valuation during survey work, particularly regarding qualitative attributes (e.g., a picture of a crowded bus may have more emotional resonance than the text "crowded bus"). There are also differences in the specification of attributes that confound any specific comparisons across studies (e.g., the following might be used in different studies to describe the ride quality (1) smooth, (2) quiet, (3) smooth and quiet, (4) smooth, quiet, and clean). There are differences in the analytical techniques employed (e.g., stated preference, maximum differences, regression) that can lead to different results due to fundamentally different approaches. And there are differences in the benchmarking of attribute importance (e.g., indexed, equivalence in percent change in IVTT, equivalence in flat IVTT), where the final valuation can be expressed somewhere on a scale of 0–100, or as a benefit equal to a 10% decrease in IVTT, or as a benefit equal to 10 minutes of IVTT.

One study in particular (Douglas and Karpouzis 2006) is frequently cited in this appendix because it is a comprehensive study of both on-board and station attributes. This study, however, presents results in terms of the increased on-board time respondents would be willing to accept for a 10% improvement in customer satisfaction for a specific attribute. While this study is unique in that customer satisfaction ratings are used to derive attribute importance ratings, the study ultimately examines and presents data in a way that is difficult to compare with other studies.

Other differences exist between studies that further complicate comparisons. There are differences in the geography (Australia, Britain, United States) that can impact the value of a bus shelter or heating and cooling. There are differences in demography (middle class, lower class, older, younger) that can affect the value of attributes such as real-time information or a no-step bus entry. There are differences in the existing physical conditions (safe, high-crime, modernized, aged) that can impact the value of security cameras or the appearance of the building. These differences can significantly affect the relative value placed on attributes.

As attributes are presented in the following sections, the absolute values of the attributes are often provided (e.g., a dedicated right-of-way for BRT offers the same benefit as a 10-minute reduction in travel time). However, as discussed, it is difficult to compare these values across studies. Most often, the best comparisons that can be drawn relate to the relative importance of the attribute among other attributes evaluated in the same study. For example, if a 10-minute time savings is the most important attribute evaluated, a dedicated right-of-way is also very important.

TABLE A-2. Relative attribute importance.

		Reference Documents							
		Douglas et al 2006	Litman 2007	Hensher et al 2003	RSG JFK 2006	Swanson et al 1997	Pepper et al 2003	Spitz et al 2007	RSG NJT 2007
Journey Time	Reliability	●●●●	●●●●	●●●●	●●●	●●			
	Right-of-way								
	Moving to front at signal								
	Signal priority								
Convenience	Headway	●●●●	●●●●	●●●●			●●●●		
Station Comfort	Cleanliness	●●●				●●●●		●●●	
	Station building	●●							
	Shelter	●		●●		●●			
	Seating	●		●●					
	High-quality materials							●	
	Art							●	
On-board Comfort	Heating & cooling	●●●							
	Layout & design	●●●							
	Seat comfort	●●●					●●●●		
	Quietness	●●●							
	Cleanliness	●●				●●			
	Smoothness	●●				●●●●			
	Seat configuration						●●		
	Luggage rack						●●		
	Multilevel						●		
	Seat material						●		
Crowding	Seat capacity						●●●		
	Seat availability	●●●●		●●●●	●●		●●●		
	Crowded seat		●●						
	Stand 20+ minutes		●●●●						
	Crush stand 20+ minutes		●●●●						
	Load factor 160%		●●●			●●●			
Accessibility	Entry steps	●●●		●●●		●			
	Bus pulls to curb					●●			
	Stop w/in walking								
	Good sidewalks								
	Elevators/escalators							●●●	
	Wider passages/stairs							●●	
Information Services	Real-time information					●●●			
	General maps/timetables	●		●●		●●●		●●	
	Local maps/timetables					●●●●			
	Announcements	●						●●●	
Fare Payment	Pre-boarding								
	POP								
	Ticketing	●●●							
Safety	Cameras/emergency call							●●●●	
	Security day	●●							
	Security night	●							
	Lighting	●				●		●●	
	Visibility							●●	

●●●● Indicates highest relative importance within the study ● Indicates lowest relative importance within the study

Because the attributes are organized and presented using nine categories and the attributes tested within a study often span many categories, the value of an attribute relative to the others from the same study can be obscured. Therefore, this section provides brief summaries of each valuation study and the quantitative results from that study. TABLE A-2 also presents the relative value of the attributes within each study, and can be used to compare the relative value of an attribute across all research. Presumably, the attributes most frequently receiving high-importance scores are the most important. Finally, where possible, any differences in the relative value of an attribute are explained contextually as the attributes are introduced. For instance, if safety attributes were highly valued in one study and not another, perhaps it is simply a result of the fact that one area has a greater threat of crime.

Journey Time

Travel time is an attribute traditionally accounted for in mode choice models and by path-builders. However, there are aspects that are not well represented but seem to be important, including reliability and specific design elements that accommodate and give priority to transit vehicles.

Reliability. An unreliable transit service imposes obvious costs to travelers. Whether the service has an unreliable arrival time at the boarding station or an unreliable IVTT, the traveler faces an uncertain arrival time at the final destination. If the unreliability is anticipated, a traveler can depart earlier and allow for uncertainty in the total trip time, but this also imposes a cost. The costs of arriving late due to unreliability are evident and can range from significant to incidental depending on the journey purpose.

One study conducted in Australia (Hensher et al. 2003) used a stated preference exercise to quantify the impact of various bus stop and on-board service attributes, including reliability. While choosing among service options, respondents indicated the cost of a bus being 5 or 10 minutes late, compared with an on-time service. Results showed that the cost from an additional minute of delay was equivalent to 2.1 additional minutes of IVTT. However, in many areas, the variation in delay is much larger than 10 minutes, and it is likely that delays exceeding 10 minutes would impose relatively higher costs (i.e., the cost of unreliability is nonlinearly related to the amount of delay). In fact, other research has estimated an additional minute of unexpected delay at 3.7 times the cost of an additional minute of IVTT (Litman 2007).

Perhaps the most realistic way to present unreliability is the same way one would respond to the question, “How long does it take it to get there?” In an area with unreliable travel times, the answer would likely be that, “Most times it takes as little as x minutes, but it could take as much as y minutes.” However, the challenge is presenting unreliability realistically—as the combination of the probability of delay and the amount of delay—while still making it tangible for respondents.

Unreliability, however, was successfully measured in this format and incorporated in an air passenger transit access model developed and implemented for travelers accessing John F. Kennedy International Airport. In this study, the measure of unreliability was presented in a stated preference survey as, for example, “1 in 10 trips, the service is 15 minutes late,” and produced statistically significant coefficients (RSG 2006a). The value of the estimated coefficients for this measure of unreliability ranged from 0.5 to 1 minute of equivalent IVTT per minute of delay incurred 10% of the time, depending on the market segment. To implement this variable in the regional model, Global Positioning System speed data were used to relate average peak-period delay to the standard deviation in travel time. Higher average delay resulted in a higher likelihood of extreme delay, and this deviation in delay was used to estimate the 90th percentile travel time and compute the resulting delay.

Route Accommodations. Transit level-of-service can be improved by operating transit vehicles in a dedicated right-of-way, or in HOV lanes, as well as by cheaper methods such as accommodating queue-jumping and allowing signal pre-emption (FIGURE A-6).

FIGURE A-6. Atlanta XBus using HOV ramp.

In 2007, RSG used a maximum differences scaling conjoint (MaxDiff, or best-worst conjoint) analysis to value BRT attributes in a heavily congested corridor in New Jersey (RSG, 2007). Here, a dedicated right–of-way was found to be particularly highly valued, which is not surprising since the primary benefits of a right-of-way—improved reliability and travel time—are greatest where traffic is heaviest.

Also, while respondents did not specifically answer how much time they thought a right-of-way might save them, the MaxDiff results showed that a right-of-way provided the same benefit as a 10-minute reduction in travel time. If it is assumed that the majority of benefits from the right-of-way are improvements in travel time, it can be interpreted that respondents, on average, estimated that this attribute would cut approximately 10 minutes from their trip.

Other "route accommodation" attributes evaluated in this study included "moving to the front of the line at red lights" and "getting priority when coming to traffic lights." Both these attributes provided benefits of less than a 5-minute reduction in travel time, indicating that respondents, given their awareness of travel conditions, believed that these options would provide lower time savings.

Currie (2006) discusses various features of bus vs. rail modes in the context of transit-oriented development (TOD). He assesses the relative merits of bus and rail and notes the importance of examining the bus vs. rail issues in isolation from market climate and development viewpoint to understand modal-only influences. While the article primarily examines the strengths and challenges of bus vs. rail factors in relation to successful TOD, the research examines several features that are relevant to mode choice: newness, permanence, and bus stigmatization. One advantage that light rail holds over local bus and somewhat surprisingly bus rapid transit is the perception of newness. Light rail routes often replace old bus routes and are introduced as an important new mode while bus rapid transit routes replace buses with buses. Taken as a factor in the success of TOD, and by inference mode choice, rail wins out over bus to some degree.

With respect to bus stigmatization, and relatively speaking of course, "buses have a bad image". Transit operators are trying to change this image but buses are often still perceived as being second-class forms of transportation. In his research, Currie challenges this perception and compared how transit riders felt about on-street bus, dedicated bus rapid transit, light rail, and heavy rail. He found a preferential bias for rail over on-street bus with the benefit valued at between 4 to 10 minutes of travel time. He also found similar results in preference and benefits for fixed-guideway bus rapid transit over on-street bus, suggesting that the technology may be less important than the reliability and service quality provided by a dedicated guideway.

In practice, several successful BRT services have implemented one or more of these route accommodation improvements, including the Kansas City MAX, which, "uses dedicated lanes during rush hour and has the ability to prolong green lights at intersections to remain on schedule" (Kansas City Area Transportation Authority 2008).

Convenience. The relative convenience of transportation options is often cited as a critical element in mode choice decisions. Mode choice models traditionally represent convenience using transfer and headway variables. However, the quality and ease of the transfer is often not represented, and the span of transit service is a detail that often challenges travel forecasters.

Transferring. As described earlier, transfers are specified in many mode choice models because of their impact on the convenience of a transit trip. Transfer walk time, wait time, and monetary cost are captured in traditional attributes and any additional burden of transferring can be accounted for in a transfer penalty; however, it is likely that the magnitude of the transfer penalty can vary. For example, after accounting for the walk, wait, and monetary cost, cross-platform rail transfers may be still inherently more convenient and simpler than transfers involving a bus. Likewise, a second or third transfer is presumably more onerous than the first. Also, the amount of time allowed before a new transfer or ticket must be purchased as well as the coordination of schedules, and routes within and between transit agencies may impact the magnitude of the transfer penalty.

The Utah Transit Authority (UTA) recently began operating the FrontRunner commuter rail service between Ogden and Salt Lake City (FIGURE A-7). This new service operates parallel to the I-15 corridor at 30-minute headways during the day with a distance-based fare that costs as much as $6.50 one-way without a discount pass. Initial ridership in 2008 is approximately 5,000 riders on the average weekday.

FIGURE A-7. UTA's FrontRunner.

One particularly unique aspect of the FrontRunner service is that an extremely high share of riders using the service transfer to reach their final destination (M. Crandall, personal communication, September 2008). Anecdotal evidence suggests that as many as 90% of the FrontRunner riders heading to downtown Salt Lake City transfer to other transit lines. The exact transfer rate has not yet been estimated, but the simple fact is that the FrontRunner was designed to terminate at a new intermodal center on Salt Lake City's industrial and redeveloping west side, approximately ¾ mile from the central business district (CBD) and the majority of downtown. The UTA designed the intermodal center and service routing to ensure convenient and easy transferring between the FrontRunner and light rail and bus services. This example illustrates that well-designed transfers can lead to a successful integration of transit services.

Span of Service. The span of transit service for a particular transit line obviously limits or defines the availability of that service. This service attribute tends to be tracked in transit customer satisfaction surveys and is clearly important. Representing the span of service in a model is sometimes complicated because the span of service in reality is not uniform over the day or within a given time period.

Travel models tend to be aggregated along several dimensions, including time of day. This time-of-day aggregation has implications for transit network modeling related to service availability and headway. For instance, if a traveler makes a trip at midnight but the only available transit service ends at 11 p.m., the transit service is technically not an option. Models, however, tend to be aggregated with respect to time period, and trips at 11 p.m. and midnight may both fall within the "night" time period, during which some transit service is available but the specific availability can only be approximated. Adding a span-of-service attribute better captures service availability that is lost in time period aggregation. Variation in headway, in addition to service availability, is also obscured by time period aggregation. During 1 hour of a 3-hour morning peak period, express bus headways may be 10 minutes, while outside of that 1 hour, the headways could be much higher. In this case, a modeler is faced with the difficulty of averaging the headway during the entire morning peak while the span-of-service attribute can better account for headway costs and benefits facing each traveler in each time period.

Station/Stop Comfort

A transit trip made in comfortable conditions is more appealing and imposes lower costs on the traveler. At transit stations and stops, cleanliness, seating, shelter, and the layout and appearance of the station building all impact the perceived cost of waiting.

Cleanliness. A clean and well-maintained station or stop has been found to be particularly highly valued in studies of both rail and bus services. In a British research study, "the difference between the dirty, vandalized stop and the clean, well-maintained one was the largest magnitude valuation," among 30 bus stops and on-board attributes (Swanson et al. 1997).

Improved cleaning and maintenance were the second most important attribute among New York City (NYC) train station improvements (next to the provision of surveillance cameras and emergency call buttons) (Spitz et al. 2007), and cleanliness was also near the top of the list of station improvements in the Douglas research (fourth out of 24 station attributes). TABLE A-3 shows the increased amount of time travelers would willingly accept for a 10% improvement (in customer satisfaction ratings) of various station-comfort attributes measured in the Douglas and Karpouzis (2006) research.

TABLE A-3. Value of station improvements.

Type of Station Improvement	Additional Time* (Increased On-board Time)
Cleanliness	19%
Station Building	17%
Weather Protection	07%
Platform Seating	05%
Platform Surface	05%

*Value of improving station attribute rating from 50% to 60%
Source: Douglas and Karpouzis, 2006

Shelter and Seating. While not as highly valued as station and stop cleanliness, shelter and seating are routinely identified and quantified in research. In the Douglas and Karpouzis (2006) work, these attributes were relatively less valued, although that research examined train stations where shelter and seating are more likely to be provided than at bus stops. Two bus studies showed higher value for these attributes, with a seat and shelter providing benefits equivalent to a 43% reduction in IVTT in the Hensher et al. (2003) study.

Station Building. Research into the layout and appearance of the station building showed different results depending on the specificity with which the attributes were described. For instance, in the Douglas and Karpouzis (2006) study, the general attribute “design and layout of Main station building” was the fifth most important station attribute (of 24), with a 10% improvement in customer satisfaction ratings providing benefits equal to a 17% reduction in travel time. However, when station appearance attributes were specifically described, as in the NYC station amenities study, “using high-quality/attractive materials such as granite” and “station art such as mosaics and stained glass” were the least valued of 12 station improvements (Spitz et al. 2007). This would suggest that functional improvements to station building design are preferred to aesthetic improvements.

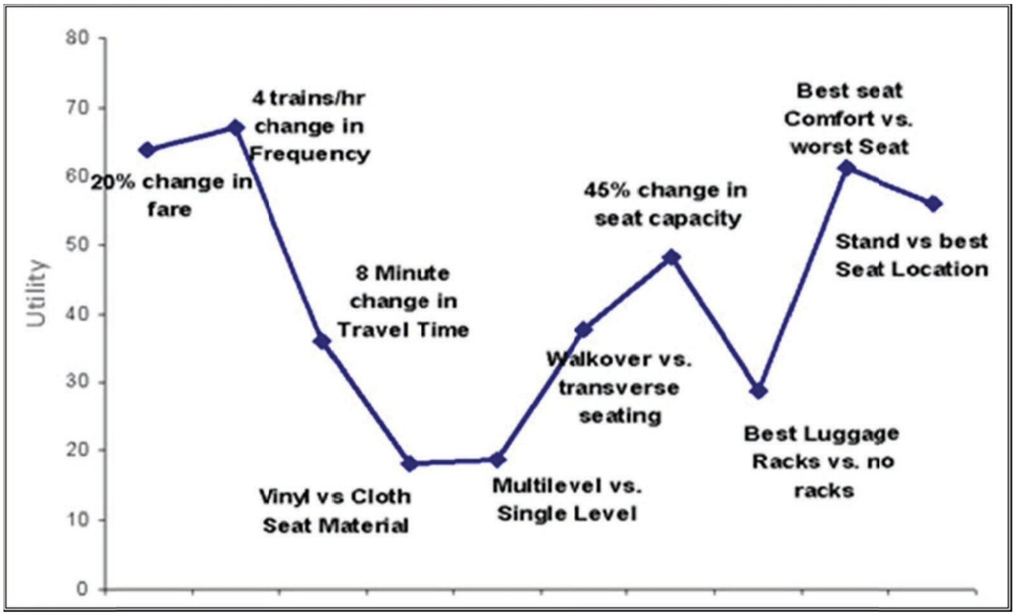
On-board Comfort

While on-board a transit vehicle, cleanliness, crowding, and the vehicle layout also impact the perceived cost of traveling.

Layout and Seating. Once on-board, the perceived cost of in-vehicle time is greatly affected by the level of comfort. The interior layout and seating attributes are often identified as important contributors to transit attractiveness, though the relative values of these attributes have been found to differ across research studies.

In the Douglas and Karpouzis (2006) study, the general attribute “layout and design” was particularly highly valued. Along with air conditioning, this attribute offered the most benefit of any on-board improvement (29% increase in IVTT for a 10% improvement). However, any specific improvements resulting from specific train design elements cannot be discerned from this study.

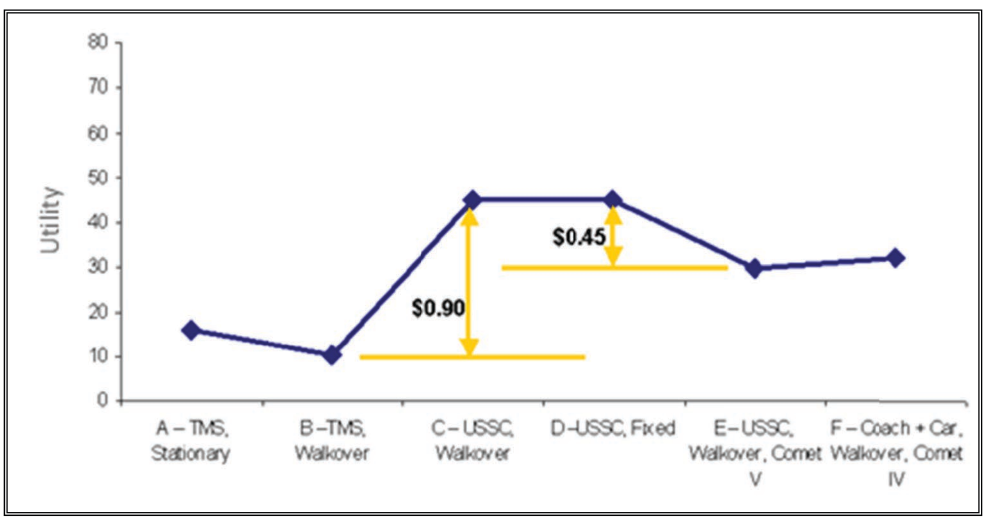
A variety of specific on-board attributes were valued using an adaptive conjoint analysis in a study conducted for New Jersey TRANSIT (Pepper et al. 2003). This study was conducted after New Jersey TRANSIT considered the introduction of multilevel coaches to increase seating capacity on trains traveling in the New York Metropolitan Area. One specific aspect of train layout, seat configuration, was tested, with respondents indicating only a slight preference for walkover seating (where seats can be flipped to face the direction of travel) over fixed seating. A more substantial preference was found for both these configurations over transverse, or subway style, seating, likely because transverse seats offer less capacity and comfort. The value from walkover seating versus transverse seating was equal to an 8-minute savings in IVTT. FIGURE A-8 shows the relative importance of the seating-related attributes measured in this study on an indexed importance scale.



Source: Pepper et al., 2003

FIGURE A-8. Importance of scores for on-train attributes.

In the same study, respondents evaluated six different seat types and were willing to pay roughly 20% more in fare ($0.90 per trip) to have the most preferred seat instead of the least preferred seat, or about half that ($0.45) to have the most preferred seat compared with the seat type currently used on New Jersey TRANSIT trains (FIGURE A-9). As was shown in FIGURE A-8, seat comfort was of particular importance to respondents. Seat comfort was also the third most important on-board attribute in the Douglas and Karpouzis (2006) study behind air conditioning and layout.



Source: Pepper at al., 2003

FIGURE A-9. Importance scores for seat types.

As shown in FIGURE A-8, additional layout and seating attributes such as seat material or the increased seating options from a multilevel train were less strongly valued.

In September 2008, the CTA conducted two seating configuration studies, the max-capacity rail car experiment (Chicago Transit Authority 2008a) and a seat-less bus experiment (Chicago Transit Authority 2008b), to assess configuration preferences within high-capacity vehicles and to observe how customers used the additional space within the vehicles afforded by the altered configurations.

In the high-capacity rail car experiment, 45% of customers preferred the new rail car configuration with less seating and more open space over the standard configuration (36%), but it was observed that this was likely due to the fact that most of these customers were interviewed while standing. The additional open space made it easier for riders to get into the car and move quickly to seats. Nearly three-quarters of respondents had carried on one or more items and the new rail car configuration afforded more space to accommodate these items, mostly stored between their feet. Based on survey and observational data and customer comments, it was recommended that the new rail cars work well but that they should be used during optimal peak periods.

Results of the seat-less bus experiment showed that 54% of riders preferred the standard seating arrangement on the bus vs. 34% who preferred the seat-less arrangement. While the open arrangement again provided more space for carry-on articles, only 36% of bus riders had carry-on bags. Customers preferred getting a seat and suggested that the seat-less design be used only on crowded routes and during peak periods.

Crowding. The level of crowding on-board has an impact on both comfort and the ability to engage in productive activity. Crowding can be expressed as the availability of seating—whether a traveler gets a seat—and also the load factor—the ratio of occupancy to the total number of seats. Including both attributes can improve model fit since the benefit of getting a seat (or the cost of standing) depends on the level of crowding.

Returning to the multilevel coach study (Pepper et al. 2003), a seating capacity attribute was measured in addition to the multilevel attribute to identify the value placed on multilevel coaches specific to the increased capacity the coaches provide. Not surprisingly, given the crowded conditions existing at the time, it was the increased capacity of the coaches, and not the increased seating options, that offered the greater benefit—an equivalent of over 8 minutes of IVTT.

A stated preference study by Hensher et al. (2003) found that the benefit from having a seat for an entire trip nearly offset the cost of IVTT, with respondents equating the benefit to an 88% decrease in IVTT. Respondents were willing to accept an approximately 30% increase in IVTT to only have to stand part of the way. That even sitting part of the way provided positive utility would indicate that travelers are accustomed to high load factors and therefore standing for the majority of bus trips. This could explain the high value placed on having a seat for the entire trip.

TABLE A-4 and TABLE A-5 illustrate the added explanatory power gained from specifying both load factor and seat availability. A train at full capacity (200% load factor) increases the cost of IVTT by 74%. Standing for 20 minutes or longer increases the IVTT cost by 81%. However, the combination of these two conditions—crushed standing—increases perceived IVTT costs by 152% (Litman 2007).

TABLE A-4. Value of on-train load factor.

Level of Crowding (Load Factor)	Crowding Factor (Additional Time)
80%	0%
100%	10%
160%	60%
200%	74%

Source: Douglas and Karpouzis, 2006

TABLE A-5. Value of on-train crowding.

Level of Crowding	Crowding Factor (Additional Time)
Crowded seat	17%
Stand 10 minutes or less	34%
Stand 20 minutes or longer	81%
Crush stand 10 minutes or less	104%
Crush stand 20 minutes or longer	152%

Source: Litman, 2007

An additional study modeling commuter trips between Long Island and Manhattan (RSG 2006b) presented and modeled seat availability as a probability—the number of times the rider gets a seat out of ten trips. This specification produced statistically significant coefficients, and when interacted with IVTT, found that the benefit from seating increased roughly linearly with trip duration (TABLE A-6).

TABLE A-6. Value of seat availability.

Description	Marg. Rate of Substitution
Seating availability very short trip (IVTT < 15 min.)	$1.44
Seating availability short trip (IVTT ≥ 15 & < 30 min.)	$3.83
Seating availability long trip (IVTT ≥ 30 min.)	$6.47

Source: RSG, 2006b

Other Comfort. As mentioned previously, air conditioning (along with layout and design) provided the largest on-board benefit to respondents in the Douglas and Karpouzis (2006) study (TABLE A-7). The importance of air conditioning and heating on-board, as well as in the station, would presumably vary considerably based on climate.

Quietness, smoothness, and on-board cleanliness were also found to be important to travelers in numerous studies. While the relative preference for these attributes varied in studies, they were consistently among the most valued comfort characteristics. Smoothness was found to be particularly important to respondents in the Swanson et al. (1997) bus study, where the benefits from a smooth ride compared with a rough ride were the second most highly valued.

TABLE A-7. Value of train improvements.

Type of Train Improvement	Additional Time* (Increased On-board Time)
Air conditioning	29%
Layout	29%
Seat comfort	24%
Quietness	24%
Cleanliness	22%
Smoothness of ride	21%

*Value of improving train attribute rating from 50% to 60%
Source: Douglas and Karpouzis, 2006

Accessibility

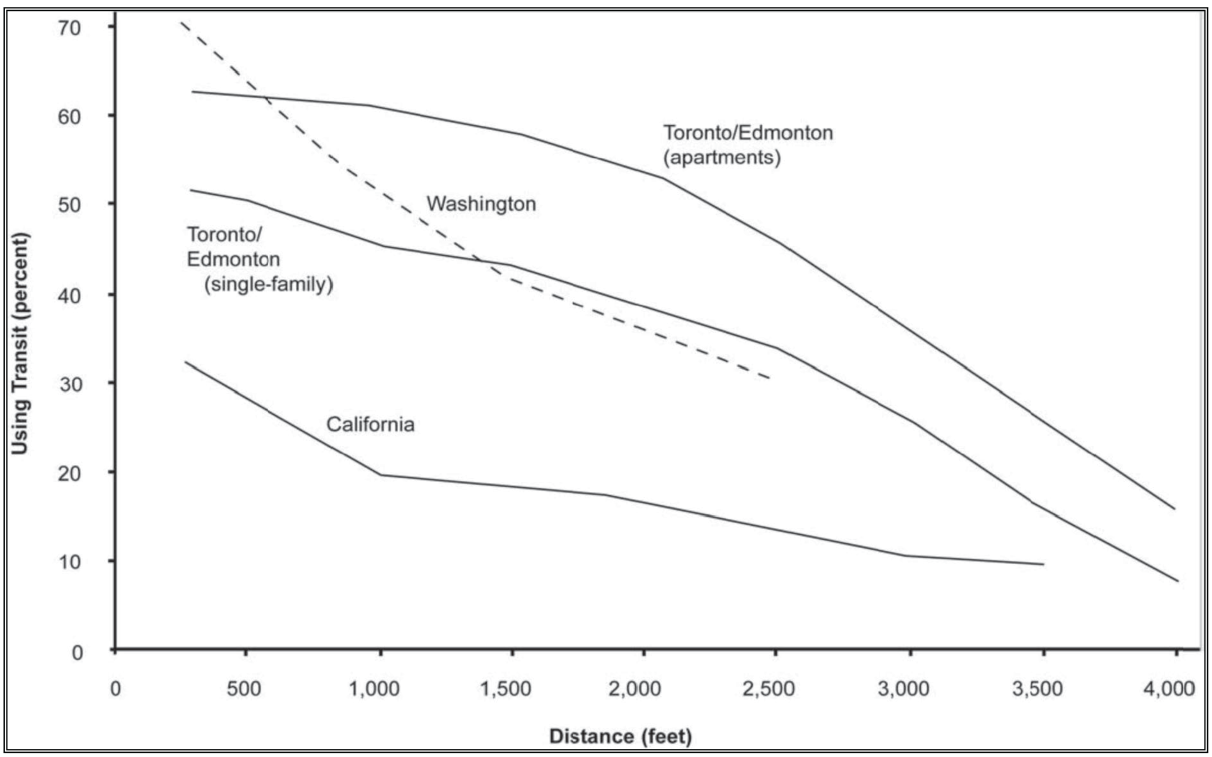
As identified in research customer satisfaction studies, transit accessibility has several aspects to it, including the trip to the station, movement through the station to the vehicle, and boarding the vehicle. Mode choice models traditionally represent walk and drive accessibility to the station at least in terms of travel time, but other accessibility details are often ignored, though they can impact travel time or transit utility measurably.

Auto and Walk Accessibility. Transit travel begins with the access trip to the station or stop. For those living in less urban areas who need to drive to access transit, parking availability can make public transportation significantly more attractive. The existence of parking facilities and their capacity can also differentiate services like commuter rail from those operating in more pedestrian-friendly urban areas.

For those accessing transit on foot, the level of walk accessibility, or pedestrian friendliness, can also influence the willingness to use public transportation. Areas with consistent sidewalks and clear crosswalks make transit access safer and easier. As described well in *TCRP Report 95,* Chapter 17, the proximity of the transit station to surrounding real estate is one of the most important attributes of a successful transit system (Evans et al. 2007). One example cited in this appendix presents data from the San Francisco Bay Area from a 2006 travel survey done by the Metropolitan Transportation Commission. This study found that the transit share for commute trips was:

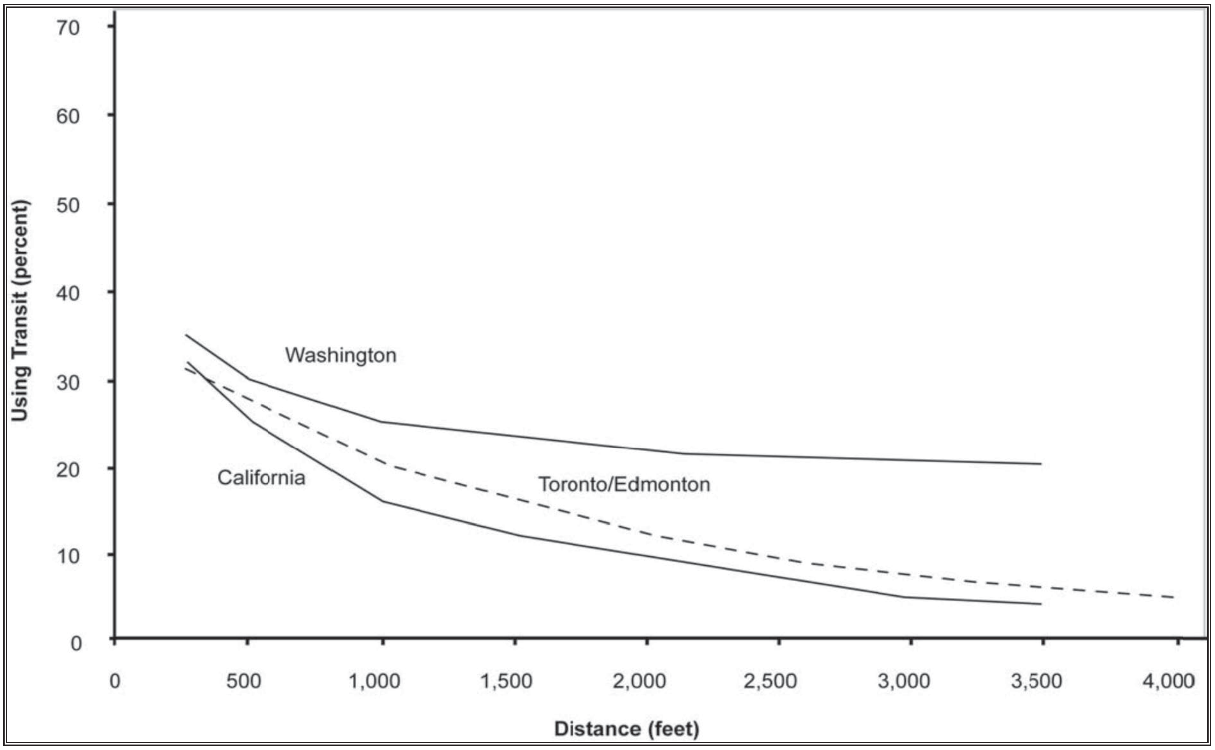
- 42% for trips where both the residence and workplace were within 0.5 mile of a transit stop/station;
- 28% for trips where the workplace was within 0.5 mile of a transit stop/station but the residence was not;
- 16% for trips where the residence was within 0.5 mile of a transit stop/station but the workplace was not; and
- 4% for trips where neither the residence nor workplace were within 0.5 mile of a transit stop/station.

Research by Cervero (1993), also discussed in TCRP Report 95, Chapter 17, shows comparable patterns (FIGURE A-10 and FIGURE A-11). Each of these studies considers contexts that are unique and have confounding factors, but the relationship between proximity and use is striking.



Source: Cervero, 1993

FIGURE A-10. Work trip rail share by distance from residence to station.



Source: Cervero, 1993

FIGURE A-11. Work trip rail share by distance from workplace to station.

Goals related to drive accessibility and walk accessibility conflict. The space required to park vehicles takes up and fragments the land adjacent to the station and diminishes walk accessibility. Additionally, conflicts between pedestrians and vehicles may more likely occur to the extent that both try to access a particular station. Travel models tend to represent both walk and drive accessibility, but clearly issues related to capacity, safety, and comfort mentioned above can apply to the access trip.

As discussed in *TCRP Report 95,* Chapter 17, transit agencies occasionally have the opportunity to work with developers to design TODs and address aspects related to accessibility to the transit station (Evans et al. 2007). Two interesting examples are from King County Washington, as described by Shelton and Lo (2003) and presented in FIGURE A-12. The design of these TODs considered how to integrate transit parking within the development, as well as policies to promote transit ridership, such as providing residents of the developments with free transit passes. The TODs were located adjacent to transit centers.

	Village at Overlake Station	Metropolitan Place
Location	Redmond, WA	Renton, WA
Former use	Surface park-and-ride lot	Downtown auto sales lots
New uses	536 space parking garage 308 rental housing units 2,400 sq ft child care facility	240 space parking garage 90 rental housing units 4,000 sq ft ground-level retail
Affordable Housing Component	All units are priced to be affordable to households earning 60 percent of area's median income and 30 units are wheelchair accessible.	At least half the units are priced to be affordable to households earning 80 percent of the county's median income.
Parking	Integrated two-level parking structure. 150 spaces are reserved for park-and-ride during the day.	Integrated two-level parking structure. 90 spaces are for resident use at all times. 150 spaces are leased by transit agency for park-and-ride; 30 of these are available for residents or visitors during non-commuter hours.
Transit	Adjacent to major bus transfer center. Buses operate at least 80 feet from units. Metal and glass awning on building to shield residents from noise and fumes.	Bus transfer center is across the street.
Incentives	All residents receive a free bus pass.	One free bus pass per unit.
Other		Pedestrian improvements also made.

Source: Shelton and Lo, 2003

FIGURE A-12. Two King County bus transit-oriented developments.

The above examples certainly illustrate the complexity of transit planning, but from a forecasting standpoint the representation of the parking and fare policies in mode choice is relatively straightforward. However, the policies outlined above suggest that people who choose to live in these developments might be more likely to use transit on account of socioeconomic factors, or a desire to live near transit, or because of the free transit pass. If this is the case, understanding how these factors influence or relate to auto-ownership or trip-distribution patterns is important to consider in order to forecast transit usage correctly. Mode choice models could capture some of these impacts with pedestrian environment or TOD variables, but the underlying behavior is quite complex.

In-station Accessibility. Elevators and escalators improve movement and access throughout stations and have therefore been studied in various customer satisfaction surveys and in the study of NYC station amenities (Spitz et al. 2007). In this study, travelers valued the benefit of escalators equal to roughly 4 fewer minutes of IVTT, while the most valued attribute—the addition of surveillance cameras and emergency buttons—provided benefits equal to about 7 minutes of IVTT. The same study also found that wider passages and stairways throughout the station provided half the benefit of escalators, or 2 fewer minutes of IVTT. The value of elevators and escalators was also measured in the Douglas and Karpouzis (2006) work, with a 10% customer satisfaction improvement yielding the benefit of a 16% decrease in IVTT.

Ease of Boarding. Primarily quantified in bus studies, the ease of boarding can significantly impact a large portion of the traveling population, with wider doorways and ground-level entry and aisles serving as attractive features on many bus rapid transit services. Estimates of the effect of this attribute in the Hensher et al. (2003) study showed that the design of the entry-way, in terms of width and number of steps is the most important attribute for certain segments of the population. Ease of train boarding was also a highly important attribute in the Douglas and Karpouzis (2006) study, with a 10% improvement in customer satisfaction equating to a 24% decrease in IVTT—third highest value of on-board attributes after air conditioning and layout.

Two other ease-of-boarding attributes that were identified in the literature include the ability of the bus to be able to pull up to the curb and the material used to make station platforms. For the latter, a slippery surface potentially makes boarding more dangerous.

The UTA recently implemented BRT service on 3500 South, and one important new aspect of the service is the design of the buses (FIGURE A-13). The buses are designed with low floors and three doors for easier and quicker boarding and alighting. The buses are new vehicles that have very large windows and comfortable seating, all of which has increased customer satisfaction.

FIGURE A-13. UTA's MAX BRT vehicle.

Productivity/Enjoyment

Research studies by Lyons et al. (2007) and Ory and Mokhtarian (2005) posit that in-vehicle time, rather than being wasted, can be enjoyable and/or productive and therefore can possess a positive utility.

Ability for Activity. In the Lyons et al. (2007) study of rail passengers in Great Britain, 23% of respondents felt they made "very worthwhile use" of their travel time and an additional 55% made "some use" of their time while traveling. Worthwhile use does not mean that this time was necessarily economically productive (for some people, sleeping on the train was very worthwhile), but this does indicate some utility gained from travel time. Furthermore, the increasing dissemination of electronic devices, whether for work or leisure, is shown to decrease the cost of in-vehicle time. Over one-fifth of rail passengers carrying electronic devices reported that such devices made the time on the train significantly less onerous and 46% agreed that they made the time seem to pass more quickly.

Activity Services (WiFi). To the extent that on-board attributes can facilitate the productive and/or worthwhile use of travel time, there is potential to increase the utility of transit travel. Recently (2008), the UTA introduced on-board wireless Internet service on its

FrontRunner commuter rail line to increase the appeal of the service (FIGURE A-14). Wireless Internet is also available on certain of UTA's express buses, and as this amenity becomes more pervasive, it could serve as a large draw for passengers. According to the UTA, the popularity of WiFi exceeded expectations, with 1,000 passengers, or 1 in 9, using the service.

FIGURE A-14. On-board wireless Internet service.

Journey Enjoyment. Ory and Mokhtarian (2005) identify a number of reasons why individuals travel simply for the sake of enjoyment: adventure seeking, variety seeking, independence, control, status, buffer, exposure to the environment, scenery and other amenities, synergy (excess travel if productive), escape, curiosity, conquest (taking a new route through an unfamiliar area), physical exercise, and the therapeutic value of movement/travel. As transit travel becomes more comfortable, individuals may be more inclined to use transit modes for many of the reasons above.

The same study also asked individuals to rate how they "feel" about travel by various modes whether or not they actually use the modes on a regular basis. Notable to the differentiation between premium and conventional services, 31% of respondents liked, or strongly liked, travel by rail compared with only 8% for travel by bus.

Information Services

One subject of much discussion in research is the impact of travel information on travel choices. Many studies have examined the ability of real-time service information to mitigate the costs associated with wait time, unreliability, and transfers since it is the uncertainty of arrival that increases the perceived time and therefore the cost of waiting (Li 2003). Studies have also frequently explored the effect of providing more basic service information such as timetables and maps at stations and stops.

Route Information. The Swanson et al. (1997) study estimated the value of both general and locally customized paper-based information at stops, as well as the importance of Countdown, a real-time travel information service. The results showed that service information is highly valued, yet the high-technology Countdown system is actually less preferred than the provision of locally customized information at stops. In NYC train stations, "information on platforms and walls" was found to be worth nearly 3 minutes of IVTT, while real-time information at New Jersey BRT stations was found to be equivalent to a 5-minute reduction in IVTT (Spitz et al. 2007).

The somewhat inconclusive value of maps, timetables, or real-time information suggests the need for additional study of the effects of these attributes. In areas with high service frequency, timetables are often ignored. For those who only use transit for frequent or routine trips, such as to and from work, maps and timetables may be unnecessary. However, work trips often demand punctuality, and particularly in areas with unreliable service, real-time information may be highly valued, allowing travelers to change plans mid-trip or to minimize anxiety from arrival uncertainty. As technology develops and laptop and handheld devices become more prevalent, real-time information may be increasingly available with less cost for infrastructure improvement.

Announcements. As with real-time information, clear announcements both in the station and on-board are hypothesized to reduce the uncertainty of transit travel as well as the mental effort required for travel (Li 2003). The NYC station amenities study (Spitz et al. 2007) found clear announcements to be the third most valued attribute behind “improved cleaning and maintenance” but ahead of the benchmark attribute, “five-minute travel time savings on your train trip.”

Further, the understandability, or intuitiveness, of routes and schedules, the accuracy of information, the availability of obtaining information over the phone, and the notification of service changes are also identified as attributes affecting the perceived cost of transit travel.

Fare Payment

Proof of Payment. There have been many new fare payment methods introduced in recent years. One method, proof of payment, requires passengers to purchase a ticket before boarding and tickets may be checked only after being seated—a method significantly reducing the perceived cost of a trip by reducing station dwell times. In a study quantifying BRT attributes (RSG 2007), the attribute, “fare payment is available pre-boarding and is fast,” was worth nearly 5 minutes of IVTT, while “proof of payment by inspectors increasing speed and ease of boarding” was approximately two-thirds as valuable. These attributes, while improving travel time, were still valued less than attributes improving headways, reducing access and egress time, shelter, and real-time information. The respondents in the study lived in a less urban environment, perhaps with fewer stops or fewer passengers boarding at each stop. Also, boarding may have occurred while in traffic, mitigating the savings from reduced dwell time.

Payment Ease and Availability. Customer satisfaction surveys examine many different aspects of in-station fare payment, including the availability of places to purchase a ticket, the number of fare card vending machines, the ease of purchasing a ticket or pass, and the integration and automation of fares among modes. The introduction of innovative fare payment methods (FIGURE A-15) reflects advances in technology but also the value of improvements to passengers. In fact, “ticketing” was the second most important station attribute tested in the Douglas and Karpouzis (2006) study.

FIGURE A-15. MTA's off-board fare vending machine.

Safety

Safety is a significant concern for many transit travelers, particularly personal safety from crime. This can be crime in a parking lot, at a station or stop, or on-board, and the perceived threat of crime increases at night. Safety from accidents is also frequently cited as a concern for travelers, with fixed-guideway services and the presence of emergency exits perceived as easing safety concerns.

While safety is difficult to quantify, among 11 NYC train station attributes tested in one study (Spitz et al. 2007), "adding surveillance cameras and emergency call buttons" was the most highly valued attribute—equal to a 7-minute improvement in IVTT. The same study found less preference for other safety improvements, including "enhanced lighting on station platforms" and "improved visibility and open sightlines." These attributes were valued at roughly 3 minutes of IVTT.

Interestingly, lighting at bus stops, despite being the only safety-related attribute measured, was of relatively little importance to respondents in the Swanson et al. (1997) study. On an indexed willingness-to-pay scale from 0 to 100, the benefit of a clean, well-maintained bus shelter compared with a dirty, vandalized shelter scored a 100, while the benefit of lighting at bus stops scored a 26. This study was conducted in a less urban area, however; with presumably less crime, aesthetic concerns can replace those for personal safety.

Case Studies of Transit Attribute Evaluations

Valuing Rail Service Attributes through Rating Surveys

Douglas and Karpouzis (2006)

The authors conducted research on behalf of RailCorp – a transit rail agency in New South Wales, Australia – using customer satisfaction ratings of individual service attributes to explain overall ratings of service. A regression model estimated the share that each attribute contributed to the overall satisfaction rating.

Survey respondents were further asked the amount of travel time savings required to rate the "on-train time" attribute as "excellent" – the top score. Using the average rating score for each attribute, the value of the attribute could be expressed in terms of the in-vehicle time respondents were willing to accept for a 10% improvement in the individual attribute rating.

The tables below (TABLE A-8, TABLE A-9, and TABLE A-10) display the percentage of in-vehicle time respondents would accept for a 10% improvement in each attribute rating.

TABLE A-8. Value of service improvements.

Type of Service Improvement	Additional Time* (Increased On-board Time)
Reliability	222%
On-train time	100%
Service frequency	76%
Seat availability	36%
Train security day	21%
Station security day	21%
Train security night	12%
Station security night	12%

*Value of improving train attribute rating from 50% to 60%

Source: Douglas and Karpouzis, 2006

TABLE A-9. Value of train improvements.

Type of Train Improvement	Additional Time* (Increased On-board Time)
Air conditioning	29%
Layout	29%
Ease of boarding	24%
Seat comfort	24%
Quietness	24%
Train outside	22%
Cleanliness	22%
Smoothness of ride	21%
Announcements	12%
Lighting	10%
Graffiti	09%

*Value of improving train attribute rating from 50% to 60%

Source: Douglas and Karpouzis, 2006

TABLE A-10. Value of station improvements.

Type of Station Improvement	Additional Time* (Increased On-board Time)
Staff	33%
Ticketing	28%
Bus	21%
Cleanliness	19%
Graffiti	19%
Station building	17%
Subway-overbridge	16%
Lifts & escalators	16%
Lighting	14%

TABLE A-10. (Continued).

Type of Station Improvement	Additional Time* (Increased On-board Time)
Announcements	12%
Information	12%
Signing	10%
Station on-off	07%
Weather protection	07%
Toilets	07%
Platform seating	05%
Platform surface	05%
Taxi	03%
Telephone	03%
Retail	03%
Car park	02%
Car drop-off	02%
Bicycle	02%

*Value of improving station attribute rating from 50% to 60%

Source: Douglas and Karpouzis, 2006

Service Quality–Developing a Service Quality Index in the Provision of Commercial Bus Contracts

Hensher, Stopher, and Bullock (2003)

A stated preference study was conducted evaluating various attributes of bus services in New South Wales Australia. A literature review, interviews with bus operators, and a pilot study identified 13 major dimensions of service quality from the user's perspective, and three levels were developed for each attribute (TABLE A-11).

TABLE A-11. Attributes and attribute levels in the SP experiment.

Attribute	Level 1	Level 2	Level 3
Bus travel time	25% less	Same	25% more
Bus fare	20% less	Same	20% more
Ticket type	Cash fare	Pre-purchased bus-only 10-trip ticket or weekly	Integrated (bus and other mode)
Buses per hour at this bus stop	50% more service	Same as now	50% less service
Time of arrival at bus stop	On time	5 minutes late	10 minutes late
Time walking to bus stop	Same	An extra 5 minutes	An extra 10 minutes
Seat availability on bus	Seated all the way	Stand part of the way	Stand all of the way
Information at bus stop	Timetable and map	Timetable, no map	No timetable, no map
Access to bus	Wide entry, no steps	Wide entry, 2 steps	Narrow entry, 4 steps
Bus stop facilities	Seats only	Seats under cover	No seat or shelter
Temperature on bus	Too hot	Just right	Too cold
Driver attitude	Very friendly	Friendly enough	Generally unfriendly
General cleanliness on-board	Very clean	Clean enough	Not clean enough

Source: Hensher, Stopher, and Bullock, 2003

A paper survey was administered to nine service segments—three bus depots and three route types per depot. These nine segments were treated as individual nests in order to scale coefficients across segments, which allowed direct comparison of coefficient values across segments while also accounting for preference variation between the segments. The same coefficients were evaluated in each segment. TABLE A-12 presents results from the nested logit model estimation. Attributes with insignificant coefficients were excluded from the results.

TABLE A-12. Final model used to identify the importance weights and scale differences between segments for scheduled routes.

	Segment importance and scale weights (t-value in brackets)*								
Attribute	S1	S2	S3	S4	S5	S6	S7	S8	S9
Travel time	-0.0333	-0.0346	-0.0249	-0.044	-0.0396	-0.0356	-0.028	-0.0272	-0.0362
(minutes)	(-3.8)	(-3.2)	(-1.5)	(-4.9)	(-3.9)	(-3.2)	(-3.3)	(-2.7)	(-2.1)
One-way bus fare	-0.6519	-0.7136	-0.7508	-0.5592	-0.6394	-0.5948	-0.6256	-0.5543	-0.5543
($)	(-4.5)	(-4.4)	(-4)	(-4.3)	(-4.6)	(-4.4)	(-4.2)	(-2.9)	(-2.9)
Unreliability	-0.0317	-0.0322	-0.0626	-0.0399	-0.0649	-0.0119	-0.0116	- 0.01127	-0.1029
(minutes)	(-1.8)	(-1.4)	(-1.7)	(-2.6)	(-3.3)	(-0.5)	(-0.8)	(-3.9)	(-1.9)
Access time to	-0.0248	-0.0725	-0.0859	-0.0081	-0.0449	-0.0696	-0.0128	-0.0567	-0.0768
bus stop (minutes)	(-2.0)	(-3.9)	(-3.4)	(-0.8)	(-3.4)	(-3.4)	(-1.1)	(-3.6)	(-2.7)
Bus frequency	0.0923	0.084	0.2729	0.049	0.0858	0.1187	0.0869	0.144	0.0523
(/hour)	(-3.0)	(-2.0)	(-2.8)	(-2.0)	(-2.6)	(-2.2)	(-2.8)	(-2.9)	(-0.6)
Seat all way (1,0)	0.6529	0.6661	0.5159	0.438	0.4622	0.531	0.7734	0.356	0.9531
	(-3.8)	(-3.0)	(-2.5)	(-3.1)	(-2.8)	(-2.1)	(-4.7)	(-1.9)	(-2.0)
Stand part				0.2367	0.2367	0.2367	0.2367	0.2367	0.2367
way (1,0)				(-2.5)	(-2.5)	(-2.5)	(-2.5)	(-2.5)	(-2.5)
No timetable,	-0.185	-0.4216		-0.1372		-0.2464	-0.2913	-0.2033	-0.121
no map (1,0)	(-1.4)	(-2.3)		(-1.1)		(-1.5)	(-1.9)	(-1.2)	(-0.5)
Narrow 4 steps	-0.4455	-0.1535					-0.5709		
(1,0)	(-2.7)	(-0.8)					(-3.1)		
Wide entry 2	-0.5124	-0.4899					-0.5748		
steps (1,0)	(-3.2)	(-2.7)					(-3.3)		
Seat only at stop	0.6102	0.6102	0.6102	0.1851	0.1851	0.1851	0.1851	0.1851	0.1851
(1,0)	(-4.2)	(-4.2)	(-4.2)	(-2.5)	(-2.5)	(-2.5)	(-2.5)	(-2.5)	(-2.5)
Seat under cover	0.6102	0.6102	0.6102	0.1851	0.1851	0.1851	0.1851	0.1851	0.1851
at bus stop (1,0)	(-4.2)	(-4.2)	(-4.2)	(-2.5)	(-2.5)	(-2.5)	(-2.5)	(-2.5)	(-2.5)
Very clean bus		0.3228			0.3228	0.2262		0.3228	
(1,0)		(-2.9)			(-2.9)	(-1.7)		(-2.9)	
Very friendly		0.1704	0.1704	0.2089	0.2263			0.2263	
driver (1,0)		(-1.4)	(-1.4)	(-1.7)	(-1.9)			(-1.9)	
VTTS ($/h)	3.06	2.92	1.99	4.72	3.72	3.59	2.68	2.94	3.92
No. of observations**	580	511	472	454	646	336	463	304	122
Scale value	0.9835	0.5019	0.6326	1	0.727	0.4212	1.065	1.0727	0.837
	-4.6	-3.8	-4.4	(fixed)	-4.7	-3	-5.6	-4.4	-3.2
Log-likelihood	-3848.9								
Pseudo-R^2	0.69								

* Missing attribute weights mean that the attribute was too insignificant to report for the segment where it was highly non-significant.

** The minimum number of observations per respondents was one and the maximum was 3 (i.e., 3 or less SP experiments completed).

Note: School children on passes have been excluded.

Source: Hensher, Stopher, and Bullock, 2003

Measuring Bus Passenger Preferences

Swanson, Ampt, and Jones (1997)

A study of various bus transit attributes performed in Britain aimed to carry out a, "...study of willingness to pay for bus service and infrastructure improvements in order to inform the project appraisal process." "The objectives were to identify those service attributes of concern to respondents, meaning those of which they express awareness, how large changes in those attributes need to be for passengers to recognize a difference, and the best way of summarizing and presenting this experience to respondents in a pictorial format." Artist sketches were deemed the best method for displaying service attributes, offering enough context to make the situation representative (e.g., a bus shelter on rural road as opposed to a city street) without the distracting level of detail from a photograph. A protocol analysis was conducted to understand passengers' decision-making processes, from which attributes were selected and grouped into journey stages (TABLE A-13).

TABLE A-13. Journey stages and attributes tested.

Stage of Journey	Attributes Tested
1. Pre-trip information	Maps
	Timetables
	Customized local information
	Telephone information services
2. The bus stop infrastructure	Type of shelter
	Lighting
	Cleanliness and state of repair
3. Waiting at the bus stop	Fixed information display
	Real-time information (i.e., countdown and/or telephone services)
	Service reliability
4. The bus at the curbside	Compulsory or request stop
	Ease of identifying correct bus
	Stopping position of bus
	Design of vehicle entry steps
5. Encountering the driver	Driver appearance
	Driver helpfulness
	Driver identification
	Availability of change
6. Moving to your seat	Level of crowding
	Design of luggage storage area
	Seating configuration
	Quality of vehicle motion
7. Traveling in a seat	Types of seats
	Spaciousness of seats
	Type of ventilation
	Cleanliness
	Travel time
8. Leaving the bus	Provision of information on bus
	Number and location of doors

Source: Swanson, Ampt, and Jones, 1997

Respondents first evaluated attributes from three randomly selected journey stages. Two alternatives were presented—one sketch matching the respondent's current situation and one sketch of a hypothetical situation—and respondents provided the direction and magnitude of their preference on a 100 point scale. An additional exercise determined monetary valuations for service improvements, asking respondents their likelihood of paying an increased fare given a certain bundle of service improvements. A final "capping exercise" asked respondents to rank areas for improvement, and then showed respondents a text-based stated preference exercise where they evaluated improvements in the highest ranked areas against a fare increase. This determined the maximum willingness to pay for any improvement package. Individual models were estimated, with relevant results indexed and presented (TABLE A-14).

TABLE A-14. Selected valuations, expressed as indices.

Improvement	Mean WTP, Indexed*	t-ratio
Dirty, vandalized shelter vs. clean, well-maintained shelter	-100	-9.1
Rough vehicle motion vs. smooth motion	-89	-7.0
Guaranteed provision of customized information at stops vs. none	85	9.1
Highly crowded vs. low crowding	-81	-6.8
Countdown	76	9.0
Guaranteed current style information at bus stops vs. none	75	8.8
Dirty bus interior vs. clean	-72	-8.5
Best improvement to reliability vs. current (long headway)	66	6.0
Best improvement to reliability (short headway)	60	5.1
Interaction between countdown and best reliability improvement (long headway)	-58	-4.1
Interaction between countdown and best reliability improvement (short headway)	-57	-4.5
Medium-smooth vehicle motion vs. smooth motion	-54	-4.9
Bus able to pull in close to curb	49	4.8
Bus shelter with roof and end-panel vs. no shelter	47	5.6
Medium crowding vs. low crowding	-40	-3.9
Driver gives change when needed	34	3.6
Electronic display of next bus stop name	33	6.5
Lighting at bus stops	26	4.4
Roomy seats vs. cramped seats	25	5.0
Low-floor buses vs. high steps	20	2.4

* The largest willingness-to-pay valuation has been indexed at 100.

Source: Swanson, Ampt, and Jones, 1997

NJ Transit MaxDiff Conjoint Training: A Guide to Designing and Preparing MaxDiff Surveys and Analyzing and Interpreting MaxDiff Data

Resource Systems Group, Inc. (2007)

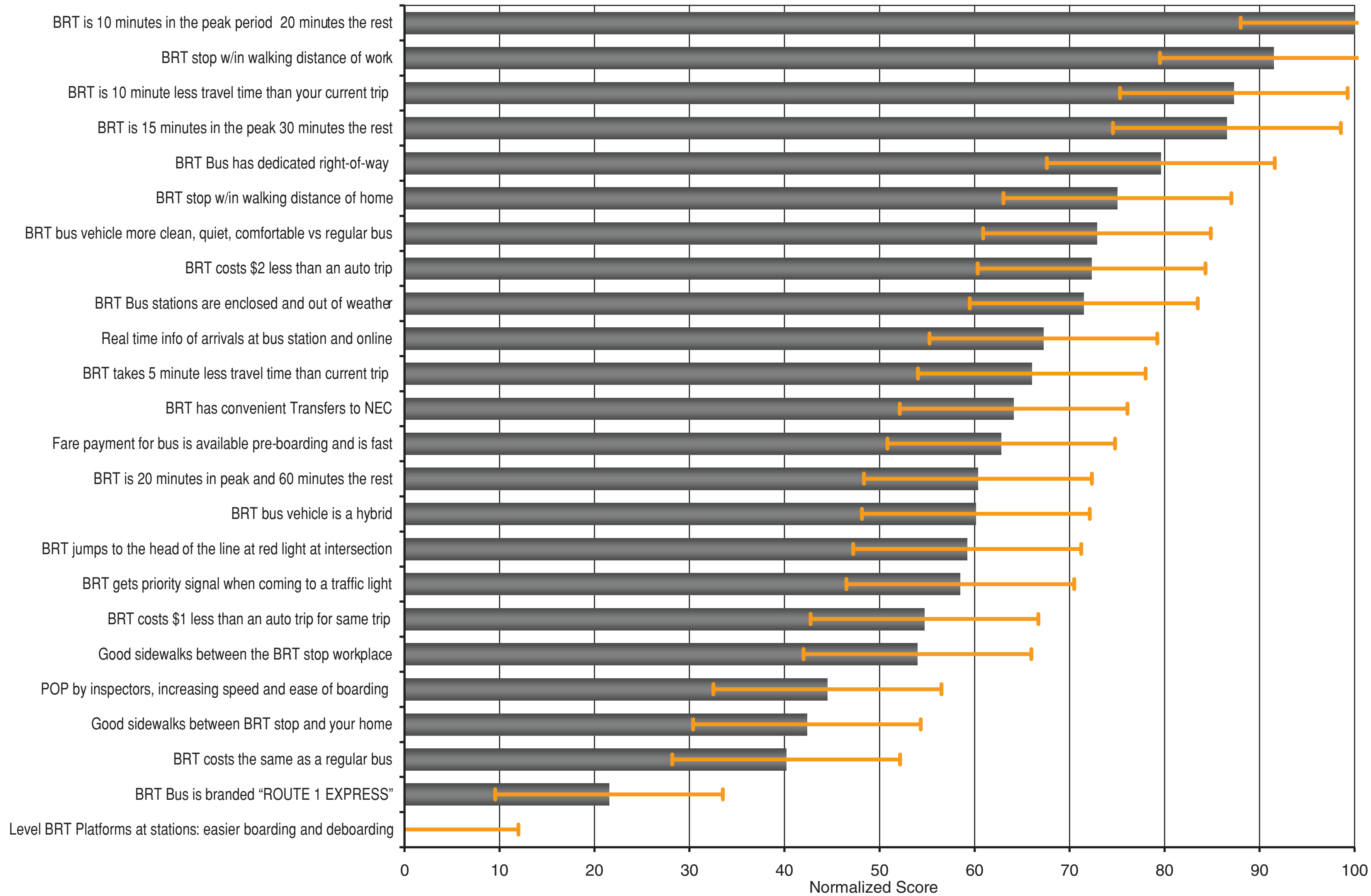
A study of Bus Rapid Transit (BRT) attributes measured the preferences of individuals traveling in a heavily congested corridor in New Jersey. A maximum differences scaling conjoint analysis was performed, displaying four attributes at a time, and asking respondents to select the attribute considered most important and the attribute considered least important (FIGURE A-16).

Most Important (Check ONE)	Of these four features or statements... Which one is most important to you? And, which one is least important?	Least important (Check ONE)
❑	BRT Bus will have convenient Transfers to NEC Rail line (timed transfers, easy walking, under cover, etc) (att 24)	❑
❑	BRT Bus gets preferential priority signal when coming to a traffic light when traveling on public streets (att 4)	❑
❑	BRT bus vehicle is very clean, quiet, and comfortable relative to a regular bus (att 9)	❑
❑	BRT Bus is identifiable with a well-known name, the "ROUTE 1 EXPRESS" (att 11)	❑

Source: Resource Systems Group, Inc., 2007

FIGURE A-16. NJ Transit MaxDiff conjoint screenshot.

FIGURE A-17 model results (normalized to a 0 to 100 scale) indicated that increased headways, expanded coverage (e.g., bus stop within walking distance of work), and decreased travel times were the most important factors to the respondents, while factors such as a level boarding platform or bus branding were of the least importance.



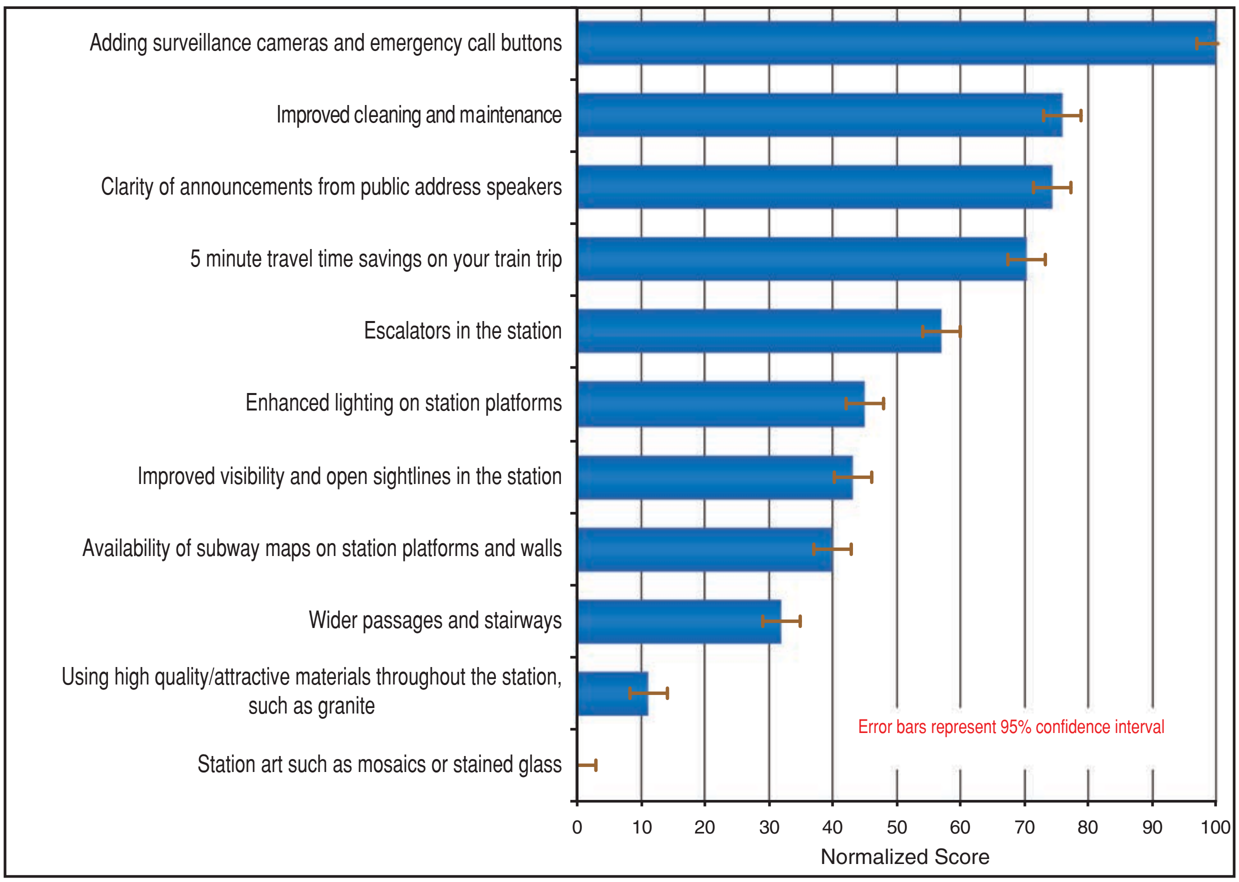
Source: Resource Systems Group, Inc., 2007

FIGURE A-17. NJ Transit MaxDiff results.

Qualitative and Quantitative Approaches for Studying Transit Stations

Spitz, Greene, Adler, and Dallison (2007)

The value of individual train station amenities was quantified for ten recently improved NYC train stations. Focus groups helped identify station characteristics of particular importance to travelers, after which a maximum differences scaling conjoint analysis was performed to measure the relative importance of the amenities as well as the strength of preference for each attribute. Security concerns featured prominently with surveillance cameras and emergency call buttons found to be most important and enhanced lighting and visibility of moderate importance (FIGURE A-18).



Source: Spitz, Greene, Adler, and Dallison, 2007

FIGURE A-18. NYC train stations MaxDiff results.

Customers' Perspectives on Using Multilevel Coaches to Increase Rail System Capacity

Pepper, Spitz, and Adler (2007)

New Jersey Transit planned to purchase multilevel coaches to address a critical passenger capacity issue on trains accessing New York's Penn Station; but first, a study was conducted to determine how the multilevel coaches should be designed to both provide the needed additional system capacity and to reflect customers' preferences. The study used adaptive conjoint analysis to value various interior attributes including seating configuration and seat design, which were directly related to the amount of seated (and standee) capacity that the coaches would provide.

The indexed importance scores (utilities) shown in TABLE A-14 (in prior section) indicate respondents' strength of preference for the various on-board attributes. Level-of-service attributes including travel time, fare, and service frequency were also measured to serve as benchmarks and to allow for estimation of respondents' willingness to pay for attribute improvements.

Customer Satisfaction Surveys

Chicago Transit Authority 2003 and Washington Metropolitan Area Transit Authority (2006)

- **Customer Satisfaction Measurement**.
- **Findings of Customer Surveys.** TABLE A-16 shows the pretest criteria for selection of customer satisfaction variables from a survey conducted for Sacramento Regional Transit.
- TABLE **A-15** shows rail and bus service attributes measured in customer satisfaction surveys.

TABLE A-15. Rail and bus service attributes measured in customer satisfaction surveys.

Dimension	Attributes
Convenience	Using Metrorail/bus for shopping trips
	Using Metrorail/bus for work trips
	Using Metrorail/bus for entertainment trips
	Making transfers
	Parking at rail stations (METRORAIL survey ONLY)
Riding experience	Cleanliness of rail cars/buses
	Cleanliness of rail stations/bus stops
	Comfort of the overall ride
	Smell of rail cars/buses
	Temperature inside rail cars/buses
	Availability of seating when riding on train/bus
	Comfort of seats on the train/bus
	Number of people on the train/bus
	Number of bus stops that have shelters (METROBUS survey Only)
Safety	From accidents while riding
	From crime during daylight hours while riding
	From crime during nighttime hours while riding
	At bus stops/rail stations during daylight hours
	At bus stops/rail stations during nighttime hours
	In Metro parking lots during daylight hours
	In Metro parking lots during nighttime hours
Access	Distance of the nearest bus stop from home (METROBUS survey ONLY)
	Distance of the nearest bus stop from destination (METROBUS survey ONLY)

TABLE A-15. (Continued).

Dimension	Attributes
Access (cont'd)	Frequency of buses from home to closest Metrorail station
	Number of transfers needed to get to final destination
	Wait time at start of trip
	Availability of parking at rail station (METRORAIL survey ONLY)
Vertical transportation	One or more elevators were not working at a rail station
	One or more escalators were not working at a rail station
Reliability	Trains/buses getting to the destination on time
	Stops were announced by train/bus operators
	Metrobus arriving more than 5 minutes early or late (METROBUS survey ONLY)
	Having to wait more than 15 minutes for the next train (METRORAIL survey ONLY)
Customer service	Satisfaction with helpfulness of bus operators (METROBUS survey ONLY)
	Satisfaction with the level of service of Metro personnel in rail stations (METRORAIL survey ONLY)
	Satisfaction with clarity of operator announcements at stops
Fares	Value of ride fare
	Satisfaction with cost of riding
	Process of purchasing farecards and passes
	Process of obtaining refunds or replacement farecards or passes
	Cost of parking at Metrorail stations (METRORAIL survey ONLY)
Communications	Utility of digital displays – PIDS
	Understandability of route/schedule information
	Responsiveness of WMATA
	Timeliness of schedule information
	Information availability

Source: Chicago Transit Authority 2003 and Washington Metropolitan Area Transit Authority (2006)

TABLE A-16. Pretest criteria for selection of customer satisfaction variables.

Attributes
Safe and competent drivers
Buses - Trains running when schedule says
Safety from crime on-board vehicles
Frequency of service on weekdays
Total travel time for your trip
Security at light rail stations and bus transfer points
Friendly, courteous operators
Notification of service disruptions
Freedom from nuisance behavior of other passengers
Availability of schedule information
Frequency of delays for repairs - emergencies
Cleanliness of vehicles
Trains and buses which are not overcrowded
Visibility of security staff on the light rail system
Helpfulness of telephone information center
Fare you pay to ride RT

TABLE A-16. (Continued).

Attributes
Availability of shelters and benches at stops
Cleanliness of light rail stations and bus transfer point
Time buses start running in morning
Usefulness of RT website
Time buses stop running in evening
Safety of vehicle parked at light rail station
Connecting bus service at train stations - main bus stop
Process of filing a complaint
Stop announcements made by operators
Accessibility of vehicles to persons with disabilities
Availability of bike racks
Frequency of service on weekends
Reliability of wheelchair lifts

Source: Transit Marketing, LLC and CJI Research Corporation (2006)

Applied Models

Practitioners have been attempting for many years to improve their models' ability to estimate transit ridership and, in particular, to represent the distribution of ridership among conventional bus and premium modes such as rail or BRT services. Their attempts have been focused in three areas: (1) a more realistic representation of transportation supply, (2) verification of travel patterns, and (3) incorporating non-traditional attributes of premium modes into the modal choice decision. The first two areas are critically important to producing credible forecasts, but the third is the focus of this appendix. A summary of various methods of incorporating non-traditional attributes of premium modes in model choice models and techniques employed in their application based on eight case studies is provided here. Further technical details of the modeling and forecasting procedures along with relevant coefficients and parameters have been provided in this appendix.

Incorporating Attributes of Premium Modes

Practitioners implementing models in areas with successful rail systems have often struggled with the fact that no matter how carefully transit services are represented inside their models, ridership is not estimated accurately on these premium services. Practitioners are also aware of experience in other areas that suggests that premium mode ridership is higher than what would be projected through traditional elasticities and attributes. *TCRP Report 118: Bus Rapid Transit Practitioner's Guide,* for example, notes that new BRT systems in six cities experienced higher ridership increases than their traditional attributes would normally indicate (Kittleson, et al. 2007). The reasons behind underestimates of premium transit services are not usually known but have been speculated to be related to public perception of safety, heightened awareness, brand visibility, and various service attributes that are measurable but not typically included in most forecasting models. An example of the latter is peak travelers considering off-peak service frequency in their choice process since they could elect to travel home in the middle of the day in case of a family emergency.

Even if these factors were known with greater certainty, practitioners would struggle to inform their models about these new transit attributes. The quantification of some attributes is a problem. Concepts such as safety, system awareness, ease of use, and branding are compelling components of the choice process but difficult to quantify by an objective standard. Without quantification, however, it would be difficult to incorporate these attributes properly within travel forecasting models. Other attributes, such as reliability and seat availability, could possibly be correctly quantified and represented in travel models. However, travelers' reaction to these attributes and those currently unquantifiable are unknown beyond general ridership patterns and anecdotal evidence.

Given the uncertainty about modal preference and the difficulties of quantifying the underlying factors, practitioners trying to match observed transit usage typically use simplified approaches that try to represent a general preference toward certain modes without explicitly representing the reasons that these preferences might exist. Often this is done by introducing transit mode-specific constants favoring premium modes within the mode choice utility function. The purpose of these constants is to represent the sum of all non-traditional attributes that accrue to travelers who elect to use the premium service during the course of their trip. The value of the incremental mode-specific constant generally varies between 10 and 15 minutes of equivalent transit IVTT. This reflects the perceived difference between conventional bus and premium modes.

Another less commonly employed technique is to discount the perceived travel time of the premium mode. This approach suggests that premium travel time benefits are proportionate to the time spent on a premium service and has the additional advantage that similar judgments of the merits of different transit options are made in both path choice and mode choice. This helps to present different alternatives that are selected within mode choice, accounting for demographic, attitudinal and the build environment, in addition to level-of-service vectors.

Two recent efforts have attempted to refine both of these general approaches by apportioning benefits across several specific modal attributes. The FTA's latest modeling guidance for New/Small Starts projects relates the size of the mode-specific constant to specific attributes such as schedule-free service, passenger amenities, and branding (FTA 2011). Attributes are assigned certain values. The presence of an attribute is required to increase the size of the mode-specific constant by the assigned amount. *TCRP Report 118* offers a similar process for new BRT systems. The values are based on professional judgment in both efforts. This, in part, has led to further research to better address this issue.

TABLE A-17 summarizes known case studies on this topic. The eight case studies described here represent a cross section of practitioners' efforts to date. Non-traditional attributes were incorporated into the travel model in seven of the cases. Two case studies are guidance on accounting for non-traditional attributes in models. Two other case studies are applied research efforts whose results were not yet applied to model sets.

In most cases, practitioners have attempted to account for the aggregate impact of all unmeasured attributes rather than focus on particular attributes. This occurred in seven of the eight case studies and likely is a reflection of the difficulty of quantifying non-traditional attributes and assessing the traveler's reaction to changes in those attributes.

Two case studies attempt to relate incremental benefits to specific components of premium modes. The FTA New/Small Starts modeling guidance accrues benefits depending on the extent of changes to the following attributes: service reliability, branding, visibility, learn-ability, schedule-free service, hours of frequent service, and passenger amenities. *TCRP Report 118* suggests accruing benefits depending on the presence of these attributes: running ways, station amenities, vehicle attributes, service patterns, intelligent transportation systems (ITS) applications, and branding.

TABLE A-17. Case study summary.

#	Case Study	Attributes	Model Application	
			Phase	Technique
1	FTA New/Small Starts Modeling Guidance	Reliability, branding, visibility, learn-ability, schedule-free service, hours of frequent service, passenger amenities	Mode Choice	Incremental bias constant
2	TCRP 118 – BRT Practitioner's Guide	Running ways, station amenities, vehicle attributes, service patterns, ITS applications and branding	Post-model	Percentage adjustment to ridership
3	Chicago Transit Authority & Metra New Starts Alternatives Analysis	Walk-ability, unmeasured rail preferences	Auto ownership, path-building, mode choice	Utility variable, travel time discount (15%)
4	Discounted travel time coefficient (models for Denver Regional Transportation District and New York Metropolitan Transit Authority)	Sum of all unmeasured LRT attributes	Mode Choice	Discounted travel time coefficient (30% for Denver, 25% for New York)
5	Charlotte New Starts Travel Demand Model	Attributes of formal park-ride lots	Mode Choice	Shadow price penalties of 3-9 minutes on informal park-ride lots
6	Southeast Florida Regional Planning Model (version 6.5)	Sum of all unmeasured premium mode attributes	Mode Choice	Incremental mode-specific bias constant
7	Lower Manhattan-Jamaica/JFK Transportation Project	Seating availability	Mode Choice (suggested)	Utility variable
8	Chicago Transit Authority Smart Card Activity Analysis	Revealed bus vs. rail preference	Mode Choice (suggested)	Discounted travel time (42%) and wait time coefficients (34%)

Only one case study focused on a particular attribute. The Lower Manhattan-Jamaica/JFK Transportation Project studied a number of different attributes, including seat type (bench or forward/reverse), transfer type (whether transfer occurred at a single platform), and seating availability. Only seating availability was found to be statistically significant.

The model developed for the CTA and Metra New Starts Corridor Alternatives Analyses applies a general walk-ability attribute in several different phases of the model (AECOM 2006a). The walk-ability attribute is intended to capture the impact that different area types have on the likelihood of using transit. Although not specifically geared toward premium transit, walk-ability may do a better job than the standard area type definition.

Application Techniques

All of the case studies apply some type of modification to the mode choice model. Four case studies apply an incremental bias constant to premium mode utilities. Incremental bias constants calibrated in areas with premium modes in operation have values ranging from 3.9 to 71.5 minutes, estimated using standard mode choice calibration techniques. The FTA recommends that bias constants be limited to 5–15 minutes of equivalent IVTT—considerably less than some of the constants that practitioners have used in operational models.

Three case studies included a discount on premium mode IVTT coefficient. Discounts range from 25% to 30% in application. The CTA Smart Card Analysis suggests a discount of 42% based on revealed preferences. A second case study, the CTA and Metra Alternative Analysis model, applies a 15% discount to travel time prior to path-building. The travel time discount is carried forward into mode choice via skims. In these cases, the value of the discount was determined by trial-and-error until the model results matched observed values. In a third case, an analysis of revealed and stated preference survey data in Germany quantified an IVTT coefficient for rail that was 25% lower than the in-vehicle time coefficient for bus.

Two case studies involve incorporating a new variable in the mode choice utility to handle unmeasured attributes. For the CTA and Metra Alternative Analysis, the mode choice utility included the walk-ability factor. The same variable was also added to the auto-ownership model. The Lower Manhattan-Jamaica/JFK Transportation Project estimated a seating availability variable to be included in the commuter rail utility.

To improve the model's ability to estimate riders bound for the CBD, the Charlotte New Starts Travel Demand Model applied shadow prices to park-ride lots served by express buses (Woodford 2007). The shadow prices ranged from 3 to 9 minutes. The shadow prices were determined by calibrating the shadow price until the model results matched observed values.

Finally, TCRP Report 118 suggests applying a percentage-based ridership bonus for BRT services of up to 25% (after accounting for time, frequency, and cost) to account for the perceived benefits of various BRT amenities.

Case Studies of Model Applications

The major catalyst for incorporating non-traditional attributes or mode-specific constants/elasticities occurs when model validation efforts using similar weights and traditional attributes for bus and premium transit are found to be insufficient. This was the reason in six case studies. Two case studies provided guidance on incremental bias constants/elasticities in recognition of evidence that capturing traditional attributes was not sufficient to estimate ridership of new premium modes. Two other case studies researched non-traditional attributes but did not incorporate them in the travel model.

This section describes the case studies whose characteristics were summarized in the previous sections. The first two studies involve applied research into the impact of unmeasured attributes on premium modes ridership. These two studies are guidance documents rather that specific travel models. The last five case studies examine existing practitioner applications of unmeasured attributes. Each involves a series of adjustments that attempt to more fully represent the demand for transit services.

Modeling Guidance on New/Small Starts Policies and Procedure—FTA (2007)

For many years the FTA has allowed metropolitan areas with existing rail systems to adjust their travel models to replicate ridership patterns on fixed-guideway and conventional bus systems. Even in cases where models were carefully developed with accurate representations of total travel and transit times, models often required adjustment to properly forecast rail and bus ridership. Frequently, these adjustments have taken the form of mode-specific constants that favor rail modes over competing bus modes. Prior to 2007, this adjustment was not allowed for cities where fixed-guideway transit did not currently exist. In 2007, the FTA implemented a policy that quantifies the credit that can be applied to new fixed-guideway projects applying for Section 5309 federal funding in cities without existing fixed-guideway transit. This credit is applied post-mode choice, meaning that the credit counts toward the computation of user benefits, but NOT toward ridership on the line. The credits are applied in two ways: by favoring fixed-guideway modes over conventional bus using an FTA-specified mode-specific constant and by discounting the perceived IVTT of the project. In both cases, the credits are applied if certain attributes are expected to be part of the proposed system.

The credits are divided into three categories: guideway-like characteristics, span of good service, and passenger amenities. Credits are assigned based on the extent of these attributes and are expressed in terms of transit IVTT (except for the IVTT discount). TABLE A-18 summarizes the FTA's proposals.

The specific values assigned to the proposed service depend on its characteristics. These criteria allow a maximum of 15 minutes of equivalent transit IVTT for trips using park/ride access with no dependence on local bus (i.e., no local bus in-vehicle time) and a 20% discount on the IVTT of the proposed service. The proposed guidance for New Starts/Small Starts policies released in February 2007 state that the maximum values are applied only for drive access trips, without local bus in the path. Therefore, direct walk to premium paths are not eligible for this credit. However, the latest guidance, the FY2010 Reporting Instructions, mention that it is providing case-by-case technical assistance to apply the credit. So there may be a case out there that does allow credit for walk-only/non-local bus-only trips, but our experience is that this only applies to drive access. The minimum credit allowed is 5 minutes of equivalent transit IVTT and no IVTT discount.

TABLE A-18. Summary of unmeasured attribute credit.

Category	Characteristic	Description	Credits Allowed
Guideway-like characteristics	Reliability of vehicle arrival	Depending on the extent that the vehicle right-of-way is grade-separated and the extent of traffic signal priority or pre-emption along portions of the alignment that are controlled by traffic signals	Up to 4 minutes for trips using park/ride access with no dependence on local bus; Up to 2 minutes for all other trips using the proposed project
	Branding/visibility/ learn-ability	Depending on the extent that stations, vehicles, and right-of-way are distinctive, and the system is easy to use	Up to 2 minutes for trips using park/ride access with no dependence on local bus; Up to 1 minute for all other trips using the proposed project
	Schedule-free service	Depending on the extent to which service headways are less than 10 minutes in the peak period and less than 15 minutes during the off-peak	Up to 2 minutes for trips using park/ride access with no dependence on local bus
Span of good service	Hours of frequent service	Depending on the extent to which weekday service extends beyond the peak period with headways that are less than 30 minutes	Up to 3 minutes for trips using park/ride access with no dependence on local bus
Passenger amenities	Stations/stops	Depending on the extent to which these have passenger amenities that relate to safety and security features, protection from the weather, retail activities, comfort, and other features valued by users	Up to 3 minutes for trips using park/ride access with no dependence on local bus; Up to 2 minutes for all other trips using the proposed project
	Dynamic schedule information	Depending on the provision of real-time information on vehicle arrivals at stations	Up to 1 minute for trips using park/ride access with no dependence on local bus
	Vehicle amenities	Depending on factors such as comfort, and the probability of getting a seat on the proposed service	Discount on the weight applied to time spent on the proposed transit service up to 20%

Source: FTA, 2007

TCRP Report 118: Bus Rapid Transit Practitioner's Guide (Kittleson et al. 2007)

Chapter 3 of *TCRP Report 118* discusses methods to account for BRT characteristics that are not represented by travel time, service frequency, and cost variables. The report presents evidence from several research investigations that suggest that, similar to rail, BRT attracts more ridership than would be explained solely by improvements to frequency and running time. Further, the research suggests that factors attracting additional ridership include identity, passenger information, span of service, and other amenities.

Consequently, the report recommends forecasting base ridership using existing models or elasticity techniques to reflect the impact of improvements to time, frequency, and cost. TCRP Report 118 recommends increasing the estimate of base ridership by up to 25% to account for non-time/cost attributes. The specific computation is warranted using the attributes of the BRT system to determine whether all or part of the maximum 25% BRT bonus is applied. This is done by computing a score of 0–100 based on the presence or absence of specific BRT components. Running ways contribute up to 20% of incremental bias. Station amenities, vehicle attributes, and service patterns contribute up to 15% each. ITS applications and BRT branding can provide up to 10% each. If the combined effect of the attributes equals 60% or more then, an additional 15% is used to account for the perceived synergy of the components. The final percentage is used to compute the amount of the 25% ridership bonus that is warranted. A list of the components and required characteristics in order to qualify for incremental bias are shown in TABLE A-19.

As an example, a fully graded separated busway (20%) with full station amenities (15%), high-quality vehicles (15%), high-quality service (15%), full ITS (10%), and full BRT (10%) branding would earn a total of 85% plus 15% for synergy. The total score would equal 100%, indicating that project ridership would likely be 25% higher than that predicted from time and cost impacts alone.

A BRT operating in mixed traffic (0%) with unique, illuminated stations (4%), unique vehicles (5%), all-day, high-frequency service (8%), full passenger information (10%), and BRT branding (10%) would earn a total of 37%, and not obtain any bonus for synergy. Project ridership would likely be 9% (0.25 x 0.37) higher than that predicted from time and cost impacts alone.

For an analysis of three BRT corridors, New York City Transit analyzed methods to estimate induced riders that would utilize the BRT system over and above the operational and service improvements (AECOM 2007). The team based their methodology on the report "Additional Rapid Transit Ridership Impacts," by Herb Levinson (later incorporated into *TCRP Report 118*).

TABLE A-19. Additional ridership impacts of selected BRT components.

Component	Characteristic	Percentage
Running ways (max. 20%; not additive)	Grade-separated busways (special right-of-way)	20
	At-grade busways	15
	Median arterial busways	10
	All-day bus lanes (specially delineated)	5
	Peak-hour bus lanes or mixed traffic lanes	—
Stations (max. 15%; additive)	Conventional shelter	—
	Unique/attractively designed shelter	2
	Illumination	2
	Telephone/security phones	3
	Climate-controlled waiting area	3
	Passenger amenities	3
	Passenger services	2
Vehicles (max. 15%; additive)	Conventional vehicles	—
	Uniquely designed vehicles (external)	5
	Air conditioning	—
	Wide multi-door configuration	5
	Level boarding (low-floor or high-platform)	5
Service patterns (max. 15%; additive)	All-day service span	4
	High-frequency service (10 min or less)	4
	Clear, single, service pattern	4
	Off-vehicle fare collection	3
ITS applications (max. 10%; additive)	Passenger information at stops	7
	Passenger information on vehicles	3
BRT branding (max. 10%; additive)	Vehicles and stations	7
	Brochures/schedules	3
Subtotal (maximum of 85)		85
	Synergy (applies only to at least 60 points)	15
Total		100

Source: Kittleson et al., 2007

Chicago Transit Authority Circle Line Alternatives Analysis and Metra New Starts Corridor Alternatives Analyses—Chicago (AECOM 2006a)

The CTA and Metra developed a New Starts travel demand model that accounts for non-traditional attributes in two ways. First, the attractiveness of rail is accounted for by applying a 15% discount to all CTA and Metra rail running times. This value was calibrated to reflect observed rail ridership patterns.

Also, the model includes a way to differentiate areas with different levels of walk-to-transit accessibility without the need for a constant based on geography or area type. The Pedestrian Environmental Factor (PEF) is defined as the number of census blocks in a quarter section (one-fourth of a square mile). A higher density of census blocks implies a more regular street network and more local streets. The highest PEFs occur in downtown locations. The factor was designed to have a range of 0–64.

The PEFs are used in the auto-ownership model as well as transit path-building and mode choice steps. In the auto-ownership model, the PEF is a variable in the utility equation. The coefficient ranges between 0.018 and 0.435 depending on the number of adults and workers per household. The PEF coefficient is highest for the zero-car household utilities and lowest for the two-car household utilities. TABLE A-20 summarizes their values.

TABLE A-20. PEF coefficients—household vehicle ownership model.

Adults per Household	Workers per Household	Utility		
		Zero-Car	One-Car	Two-Car
1	0	0.075	0.018	--
1	1	0.075	0.018	--
2	0	0.435	0.140	0.064
2	1	0.435	0.140	0.064
2	2	0.435	0.140	0.064
3+	0	0.400	0.102	0.057
3+	1	0.400	0.102	0.057
3+	2	0.400	0.102	0.057
3+	3+	0.400	0.102	0.057

Source: AECOM, 2006a

For transit path-building, the perceived walk times are factored according to the PEF. This reflects the fact that walking is generally easier in urban environments and more onerous in less pedestrian-friendly environments. The walk time factor is lowest for PEFs greater than 50.0 and highest for PEFs less than 30. TABLE A-21 details the walk time adjustments according to each zone's PEF. These adjusted walk times are used during transit path-building and skimming.

TABLE A-21. Walk time adjustments by PEF value.

Pedestrian Environment Factor		Walk Time Adjustment
Low Value	High Value	
0.0	30.0	3.0 x actual time
30.0	50.0	1.5-3.0 x actual time, linearly interpolated between 3.0 and 1.5
50.0	64.0	1.5 x actual time

Source: AECOM, 2006a

Use of the PEF in mode choice is intended to capture the impact of different area types on the likelihood of using transit. The PEF is expressed as a utility variable in the mode choice model. The walk-transit variable reflects the fact that the highest walk-transit shares occur in locations where both trip ends are in walk-accessible areas. The walk-transit utility equations are:

$$PEF - production = \frac{1}{1 + e^{\min\left(0.2*(ProductionPEF-30),-0.25*(AttractionPEF-40)\right)}}$$

$$PEF - attraction = \frac{1}{1 + e^{\max\left((0.2*(ProductionPEF-30),-0.25*(AttractionPEF-40)\right)}}$$

$$PEF - WalkUtility = \min\left(0.5*(PEF - production + PEF - attraction),2.0\right)*3-1$$

The drive-transit variable reflects the fact that the highest proportion of these trips occur in locations where the attraction end is highly walk-accessible. The drive-transit utility equations are:

$$PEF - DriveTransitAttraction = \frac{1}{1 + e^{\left(-0.25*(AttractionPEF-40)\right)}}$$

$$PEF - DriveUtility = \min(0.5*PEFDriveTransitAttraction,2.0)*3-1$$

Discounted Travel Time Coefficients—Denver and New York City

Several cities use an IVTT coefficient for premium modes lower than the coefficient for conventional bus transit. Two cities are briefly highlighted here. The Denver Regional Transportation District's initial calibration of the mode choice model for the West Corridor light rail transit (LRT) project (Woodford 2007) overestimated the number of bus riders while simultaneously underestimating LRT riders. A discount to the LRT IVTT coefficient was calibrated to observed rail ridership patterns, resulting in a final discount value of 30%.

In its Regional Travel Forecasting Model (RTFM), New York's MTA (AECOM 2006b) uses an IVTT coefficient for commuter rail discounted relative to bus and subway modes. The commuter rail IVTT coefficient was calibrated to observed ridership, resulting in a value 25% less than bus and subway IVTT. TABLE A-22 shows the IVTT values used in Denver and New York City.

TABLE A-22. Premium IVTT and wait time coefficient values.

Agency	Conventional Mode Coefficients		Premium Mode Coefficients	
	Mode(s)	Value	Mode(s)	Value
Denver Regional Transportation District	Bus	-0.025	Light rail, future commercial rail extensions	-0.0175
New York MTA	Bus, subway	-0.04306	Commuter rail	-0.03222

Source: AECOM, 2006b

Charlotte New Starts Travel Demand Model—Charlotte, North Carolina (Woodford, 2007)

The Charlotte Area Transit System (CATS) evaluated their regional travel model prior to analyzing five transit corridors. During the initial calibration, it was found that the model overestimated park-ride trips on local buses and underestimated park-ride trips on CBD-destined express buses. This matched an overestimation of park-ride trips using shared commercial or church parking facilities, serviced by local buses, and an underestimation of formal CATS lot usage served by express buses.

Shadow prices were applied to improve the model's ability to estimate the number of riders with a CBD destination. Formal CATS park-ride lots received no shadow price. Informal park-ride lots received between 3 and 9 minutes of equivalent IVTT based on the number of parking spaces. These values were determined by calibrating the shadows price until the model results matched park-ride vehicle counts.

TABLE A-23 summarizes the shadow prices applied to each lot type.

TABLE A-23. Shadow prices applied to park-ride lot type.

Lot Type	Number of spaces	Shadow Price (in equivalent transit IVTT)
Formal CATS lot	Any	No shadow price
Informal lot	<20	9 minutes
	20-70	6 minutes
	70+	3 minutes

Source: Woodford, 2007

Southeast Florida Regional Planning Model Version 6.5 Update—Miami/Ft. Lauderdale/ West Palm Beach, Florida (AECOM 2008b)

The Southeast Florida Regional Planning Model (SERPM) mode choice model includes mode-specific constants for its two rail services, Metrorail and Tri-Rail. Metrorail is a 22-mile, 22-station heavy rail system in Miami-Dade County. Tri-Rail is a 71-mile, 18-station commuter rail system connecting Palm Beach, Broward, and Miami-Dade counties.

The same IVTT coefficient (ranging from -0.150 to -0.200 by trip purpose) is applied to all transit modes. Separate incremental bias constants are applied to Metrorail and Tri-Rail paths, representing the perceived difference in unmeasured attributes between conventional bus and the two premium modes. The incremental bias constants are adjusted until the model results match observed ridership. Similar setups are used in many U.S. cities with premium transit service.

The latest calibration effort (for the base year 2000) produced constants ranging in value from 21.8 minutes to 51.5 minutes of equivalent IVTT for Metrorail and 3.9 to 71.5 minutes for Tri-Rail. The full listing of the mode-specific constants is shown in TABLE A-24.

TABLE A-24. SERPM v6.5 incremental mode-specific constants (equivalent IVTT).

Purpose/Period	Mode-Specific Constants	
	Metrorail	Tri-Rail
Home-based work peak	21.8	3.9
Home-based other peak	29.4	24.6
Non-home-based peak	30.8	37.2
Home-based work off-peak	36.4	13.6
Home-based other off-peak	51.5	71.5
Non-home-based off-peak	25.6	68.6

Source: AECOM, 2008b

Lower Manhattan-Jamaica/JFK Transportation Project—New York City

The New York MTA recently conducted an analysis of alternatives that would provide a one-seat connection between Lower Manhattan and the Jamaica station. Jamaica is an important station as it serves as the major hub for the Long Island Railroad, connecting Manhattan, Queens (including JFK International Airport) and Long Island. Jamaica station is also an important intermodal station for the New York City Transit system. Jamaica station connects the eastern end of this subway system with local and express buses from Eastern Queens and Nassau County.

A stated preference survey was conducted of travelers between Lower Manhattan and Jamaica/JFK International Airport in the fall of 2005. The purposes of the survey were to verify the values of the core variables of MTA's RTFM, and identify key modal attributes that are likely to materially affect travel behavior in the corridor depending on mode selection (commuter rail vs. subway). Such key attributes include seating availability, transfers, seat type, and fares.

The survey asked travelers about their preferences for seating availability and other variables such as transfer and seating types. Seating availability on commuter rail trips of at least 15 minutes was found to be the only statistically significantly factor. Transfer type (whether the transfer took place on the same platform or a different platform) and seating type (whether a bench or forward/reverse) were both found to be statistically insignificant. TABLE A-25 shows the estimated model coefficient, standard error, and t-statistic for seating availability. The coefficient for this variable was estimated for all trip purposes.

TABLE A-25. Estimated seating availability coefficients.

Commuter Rail Trip Length	Between 15 Minutes and 30 Minutes	At least 30 Minutes
Estimated coefficient	0.4931	0.8332
Error	0.124	0.107
T-statistic	4.0	7.8
Equivalent minutes of IVTT (estimated)	21.9	37.0
Equivalent minutes of IVTT (RTFM)	15.3	25.9

On the basis of these estimates, seating availability is equivalent to 21.9 and 37.0 minutes of IVTT for 15–30 and 30+ minute commuter rail trips, respectively. If the standard RTFM commuter rail IVTT coefficient is used, seating availability is equivalent to 15.3 and 25.9 minutes.

Although recognized as an important characteristic, seating availability was not incorporated into the mode choice model. One problem was that the medium- and long-trip seating availability coefficients would overestimate commuter rail trips for those lengths. Instead, a continuous variable was preferred, and work was initiated for its development. Another problem was that new software procedures would be needed to estimate the number of seats available for each train at each station. It was decided to test the sensitivity of a continuous seating availability variable before beginning work on the new procedures. Ultimately, the client advanced the project schedule, and was unable to incorporate seating availability into the RTFM.

Chicago Transit Authority Smart Card Activity Analysis—Chicago (Mojica 2008a and 2008b)

As part of a research collaborative effort with the Massachusetts Institute of Technology, the CTA analyzed changes in travel behavior before and during planned station closings made necessary by the Brown Line Capacity Expansion Project. These changes in the modal shift from rail were revealed by reviewing Smart Card activity and boarding counts.

The analysis was able to quantify the trade-offs in in-vehicle and wait time for rail and bus modes. It showed that 1 minute of in-vehicle time in a bus was worth 1.7 minutes in a train, and that 1 minute of wait time for bus was equal to 1.6 minutes of rail wait time.

The data were used to develop a binary choice model. The estimated coefficients also showed major differences between bus and rail wait and in-vehicle time, with the rail coefficients 34% to 42% lower than the corresponding bus coefficients (TABLE A-26). Note that the bus and rail wait coefficients were not found to be significantly different from zero.

TABLE A-26. Estimated bus and rail time coefficients (binary choice models).

Variable	Coefficients		Relative Difference
	Bus	Rail	
In-vehicle time	-0.053	-0.031	-42%
Wait time	-0.133	-0.088	-34%

Source: Mojica, 2008a and 2008b

Before-and-After Mode Choice Analysis—Dresden, Germany

For some time there has been an assumed "rail bias," that there exists an inherent superiority in rail-based over bus-based public transportation alternatives. Axhausen et al. (2001) describe a study done to measure preference of rail over bus, expressed in LOS coefficients, which was done in Dresden, Germany, when a planned replacement of a tram line with bus service was being considered. Choice models (auto, bus, and rail) were estimated using RP and SP data collected before and after the service change. RP data was collected in a one-day travel diary.

Two SP experiments were conducted: (1) inter-mode choice between auto and transit and (2) intra-mode choice within transit, between rail and bus, in terms of differences in levels of service, such as comfort, travel time, and transfer trade-offs.

Results of this study showed that there is a small but consistent preference for the rail-based transit, with a lower disutility of IVTT and higher valuation of new and improved vehicles (TABLE A-27). The authors did note that the preference for rail-based transit was stronger for more frequent public transit users.

TABLE A-27. Joint RP and SP estimation results.

Mode	Attribute	----- Sample ----- All	1)	2)	3)	Random sample	1)	2)	3)	Choice based	1)	2)	3)
Car													
	Travel time	-0.0139			*	-0.0122			*	-0.0029			
	Cost	-0.1101		*	*	-0.0768			*	-0.0243			
	Ln (VMT)	0.0193		*	*	0.0102			*	0.0045			
	Trip into the core	-0.2228			*	-0.1156				-0.4522		*	*
	Wave 1	-0.2073			*	-0.1357				-0.3827			*
	Choice-based sample	-0.1622			*								
Bus													
	Travel time	-0.0132		*	*	-0.0168			*	-0.0030			
	Access time	-0.0133			*	-0.0141			*	-0.0033			
	In-vehicle time	-0.0125			*	-0.0155			*	-0.0027			
	Cost	-0.1762			*	-0.1290			*	-0.0403			
	Transfer	-0.1062			*	-0.1220			*	-0.0245			
	New vehicle	0.0215			*	0.0287			*	0.0043			
	Trip into the core	0.4960		*	*	1.0086	*	*	*	-0.1728			
	Wave 1	-0.0777											
	Choice-based sample	0.9056	*	*	*								
	Inertia	0.0901											
Tram													
	Travel time	-0.0127		*	*	-0.0126			*	-0.0033			
	Access time	-0.0133			*	-0.0141			*	-0.0033			
	In-vehicle time	-0.0095			*	-0.0075			*	-0.0026			
	Cost	-0.1645		*	*	-0.1243			*	-0.0352			
	Transfer	-0.1148			*	-0.1348			*	-0.0252			
	New vehicle	0.0310			*	0.0406			*	0.0066			
	Trip into the core	0.3429		*	*	0.7062	*	*	*	-0.0587			
	Wave 1	0.1822			*								
	Choice-based sample	1.0168	*	*	*								
	Inertia	0.1663			*	0.1705			*	0.0364			
Lambda[4)] Between-mode SP		3.6534		*	*	4.9912			*	17.2051			
Lambda[4)] Within-mode SP		17.1673			*	15.9116			*	72.8210			
L (0)		61,249				27,963				33,285			
L (Constants)		18,276											
L (B)		13,764				6,352				7,274			
N		15,189				6,684				8,505			
K		35				26				26			
adj. Rho squared (0)		0.7747				0.7719				0.7807			
adj. Rho squared (Constants)		0.2450											

1) Significant, if corrected with square root (number of observations/person)
2) Significant, if corrected with third root (number of observations/person)
3) Significant, uncorrected
4) Scaling parameter of the error variance of the respective SP relative to the RP data

Source: Axhausen et al., 2001

Transit Agency Interviews

One of the objectives of this research project was to discuss the results of the literature and practice reviews to get direct feedback from staff at transit agencies and MPOs. Two rounds of interviews were conducted by Greg Spitz of Resource Systems Group, Inc., during the summer and early fall of 2008. The first round was done to obtain descriptions from various transit agencies and MPOs of methods they are using to perform their premium transit studies, reasons behind those methods, how they are approaching their modeling and forecasting with respect to assigning values to non-traditional attributes, and feedback on the results of the literature and practice reviews. The second round of interviews was conducted later to see if any collaboration would be possible between the needs of this research study and other ongoing survey efforts the transit agencies and MPOs are involved in. This section presents the efforts that were made in contacting transit agency/MPO staff and the outcomes of those efforts.

Round 1: Post Literature and Practice Reviews Interviews

Once the literature and practice reviews were complete, select staff at various transit agencies were contacted to obtain the perspective of agencies operating and forecasting transit on an everyday basis. Greg Spitz conducted the agency staff interviews during August 2008 with Christopher Chesnut of UTA (Utah Transit Authority), Jeff Busby of CTA (Chicago Transit Authority), Tom Marchwinski of New Jersey TRANSIT, and Rob Alexander of GRTA (Georgia Regional Transportation Authority), and Joe Barr of NYC DOT (New York City DOT). Most agencies seemed very interested in the TCRP Project H-37 topic and were eager to cooperate, and some also participated as members of the project panel.

The goals of the first round of interviews were:

- To hear about recent experiences agencies have had upgrading transit services and implementing premium services
- To obtain anecdotes to help compare and contrast real-world experiences of transit agencies to that of the literature
- To get feedback on results of literature and practice reviews

Christopher Chesnut, Utah Transit Authority

UTA upgraded a local bus to a bus rapid transit in the 3500 South corridor. The local bus had headways of 30 minutes and 2,200 boardings, then increased service to 15-minute headways and 3,200–3,600 boardings; then the service was upgraded to BRT with 4,500 boardings. The service has been open 4 months. There were no changes to parking.

The MAX BRT service has different vehicles, with Type 3 doors, different wrap, seating arrangements, etc. The service offers off-board payment, POP system, limited stops roughly every half-mile, and BRT machines at every stop with the same fare. You can board and alight at any door. There is signal priority in the corridor and travel times are roughly 10%–15% faster without the new lanes, while the 3500 South is under construction. There are better covered shelters.

There were advertisements at the MAX stations prior to implementation and there were people at each station helping customers for the first few days of operations. The BRT service was branded as "MAX" and wrapped in a logo.

Several technologies changed with this service: fare collection, vehicles, and signal priority. When construction is complete, MAX will have its own permanent lane separated. The new lane is expected to raise awareness about the service because it will be 2 miles of exclusive right-of-way in a 10-mile corridor in the most congested area. Bus stops have special signs; there is all MAX marketing throughout the corridor. The new vehicles have nicer windows, are quieter and cleaner, and the boarding process is faster and easier than with local bus vehicles, but there are fewer seats and people are expected to stand.

Jeff Busby, General Manager, Strategic Planning, Chicago Transit Authority

CTA implemented "X" buses (limited stop express buses) on long corridors without parallel rail service. Bus X49 for example has limited stops every half-mile vs. a typical local bus of 1/8-mile stops. Besides fewer stops farther apart, there is very little difference between the X buses and the local service.

Some marketing was done for the X buses on CTA local buses that parallel the new X bus services and on trains all over the city. The trains advertised the links between X buses and the "L" trains. (e.g., connecting to the Blue Line from the Irving Park X80 bus). There were no advertising purchases—very low cost marketing was all that was done on-board CTA vehicles.

On the system map, the X buses are indicated slightly differently on the map; X bus stops are actually shown on the map, which is not the case for local bus stops.

The X buses have no special branding or "wrap" of any sort. The one distinguishing characteristic is that the destination sign on the bus itself is black on yellow vs. yellow on black for locals, so the X bus can be distinguished by passengers by sight based on this difference, though it is a small one. The X buses also provide more information at the bus stop: there is a drum on the pole with all the stops listed (like a train diagram) and better schedule information.

X bus vehicles and technologies are the same as local buses; the only difference is the service with the limited stops, as described above. In the future, CTA is going to implement BRT in some corridors, but the X bus is simply a slightly enhanced limited-stop bus service with no technology or significant structural changes over local buses.

As for awareness, transit riders do know about the X bus service and seem very positive toward it. For example, anecdotal observations show that riders will go out of their way to get to the X bus corridor to get to the Blue L line. Conversely, non-riders don't seem any more aware of the CTA transit service versus prior to the implementation of X bus service (there being no way they would know anything is different).

Ridership in X bus corridors has gone up over and above general trends, indicating additional riders/trips. Recently, CTA added revenue hours/frequency over what had existed previously (after X buses had already been implemented). When accounting for this additional service, X buses still increased ridership overall in its corridors (including X buses and local bus ridership). Customer satisfaction also went up for corridors with X bus service.

One challenge CTA continues to work on is finding the optimal mix between local bus and X bus service. Fifty percent express trips seems to be the minimum ratio required to make an express bus system work in parallel with local service. This is a minimum, as it appears to be more effective if a percentage above 50% express is implemented. However, the express service ratio can only get so high. While express bus works especially well in the rush hour, it can present problems in the middle of the day for those making shorter/more local trips. Too much express service means that local buses can become very crowded in the middle of the day for shorter trip purposes such as shopping.

Transit consideration question: increasing party size is clearly a major deterrent for transit, as are complicated trip tours: the higher the party size and more complicated the tour, the less desirable transit becomes.

CTA has studied the issue of baggage to understand how that affects transit usage. CTA found that over 50% of their customers are "encumbered" with baggage of some sort, meaning the baggage required customers to use two hands. So, clearly people are using transit with baggage, but probably no more than they can carry themselves in two hands.

Finally, another interesting piece of CTA research Mr. Busby mentioned was their ability to track Chicago Card customers' revealed behavior anonymously after the closure of a number of Brown Line stations due to a major construction renovation. What they found was that there was premium for rail—customers would walk further to it—and that it appears that IVTT on bus was perceived much higher (or possibly customers were unaware of the bus). Rail waiting time was also revealed to be less onerous vs. bus wait times.

Tom Marchwinski, Direct of Forecasting, New Jersey TRANSIT

New Jersey TRANSIT implemented the River Line LRT service in March 2004. It is the first US diesel-powered DMU LRT and runs 33 miles connecting southern New Jersey to Camden and Trenton and to the Northeast Corridor line to Philadelphia via PATCO service. Most of the corridor had parallel bus lines, and most of these buses are still running, but these bus services were cut back significantly and just run in the peak hours.

As noted, the River Line is an LRT service that replaced bus service, meaning travel time is now faster but with nice stations that are spaced farther apart than the previous bus stops. The service is more permanent and includes many new park/ride facilities. The LRT service, while premium, was priced the same as bus or even less in some cases to build ridership. The service includes stations with ticket-vending machines (TVM), phones, a PA system, digital signs to show delays and alerts, platforms, and full signage. Service only runs to about 9:30 p.m. on weekdays due to freight conflicts. Buses run in the later hours (the bus/LRT passes are interchangeable).

Upon opening and for the first year there was a major marketing campaign: web sites, newspaper ads, and brochures. There were no TV or radio buys, however. Service was advertised on all Northeast Corridor timetables as it connects to the NEC. This included connection times and a small map. Websites, which still continue (http://www.riverline.com/), were developed with destinations and promotions (e.g., to an aquarium, entertainment center for concerts etc.) Lots of weekend riders were generated due to these attractions and these riders continue to be strong. The service had a logo and was branded: River Line. Some aspects of the branding/look of the service have changed slightly over time, but there have always been logos and nicely painted vehicles.

The technology is a first in the US: a self-powered diesel LRT (DMU). The entire line but for the last mile in Camden is exclusive ROW. The line has gates at rail crossings, and the train has many crossings on its ROW. There were also a few new tracks laid for sidings, but most of the ROW was already there. The River Line does mix with traffic in a couple places and there are new tracks in streets in Camden. A major transfer point between the River Line and PATCO was upgraded with a nice walkable and pedestrian-friendly plaza between them as well as facility to transfer to buses.

Awareness of the system was increased over previous buses without a doubt. Surveys showed that, after service opened, over 15% of people were riding just to check it out! People just wanted to see it and knew it was there. This curious ridership went down over time, but there was significant awareness of the system as it was the first new rail service in southern New Jersey.

Ridership increased for sure. Twenty-five percent came from bus. The rest are new riders from auto trips (50%), 5% were going from NEC rail to PATCO, and the rest of the ridership came from induced new trips.

The corridor ridership is up overall, including buses. Ridership met forecasts and grew for the first 3 years then leveled. Now it is going up again due to gas prices, etc.

The system is successful but cost a LOT to build ($800 million) and carries 9,000 trips per day. There is still not enough rolling stock in peak, and trains can therefore be packed.

There was a LOT of awareness of the project: partly due to ads and partly due to the costs, objections to the line (NIMBYs), etc. Big projects mean people notice them. Grade crossings also mean people notice the system: there are more than 45 on the line. Due to the number of grade crossings, a lot of safety trainings were conducted in schools, which also increased awareness. People are therefore definitely more aware of the service. In fact, the NJ network (public TV) has a picture of the River Line coming through when advertising their TV station identification.

There are lots of bikes on the River Line due to an innovative on-board bike hanging system. There are lots more local trips versus commute trips compared to what was expected. Commute trips are still the majority however.

Rob Alexander, Georgia Regional Transportation Authority

GRTA operates commuter coach (cruiser) buses from suburban Atlanta to the center city and transfer locations with MARTA, the urban transit operator in Atlanta. The service is called Xpress. It is relatively new (within the last 5 years), and no other transit service preceded on all routes (except for one). The service began with just two routes and now is up to 27; demand remains very strong; they need more funding and more buses, as they cannot keep up with ridership.

As mentioned, there was no preceding service to these routes; however, the service is definitely premium. The coaches are nicely maintained with typical "luxury" coach amenities: reading lights, reclining seats, overhead racks, etc.

There has been no purchased advertising except for some small buys in local papers. The fact that people can see the coaches on the road is what gets people seeing them, and the website/phone number is on the sides of the buses. The buses are their "billboards."

The bus service is very customer-service focused with lots of communications with customers via email, the web, and phone. All emails are answered individually; all calls are taken by a person. Delays are put out via email if possible. Newsletters and blog articles are distributed to over 4,000 customers via email and web. GRTA customer-service answers about 500 to 700 customer queries per month. They encourage customers to express their needs.

Service went from no prior service to 57-seat MCI coaches/cruisers; premium buses, reclining seats, ac/overhead bins, etc. This is new to metro Atlanta. Half of GRTA customers had never used transit, the other half are experienced in transit from other parts of the country and have higher expectations. The service collects people at P&R lots. Funding from state and counties for maintaining and adding service is an ongoing issue.

Buses run in regular traffic with no special treatment of any kind. People become aware of the service by seeing the coaches in traffic and through word-of-mouth from other customers. GRTA does go to some commuter fairs and such events at major employment centers to increase awareness.

They have grown to 27 routes from two and are booked solid and having a hard time keeping up with demand. They want to buy another 28 buses and eventually another 32 on top of that for 60 new buses. They are struggling to find the money from the state and local governments.

They are trying hard to keep up with the regular demands of the system as noted. Therefore, services such as Wi-Fi are something they would like to do but cannot start until they have their main service goals under control: serving the demand. They would like to set up a Twitter system for delays as well to broadcast information to their riders. Again, these additional attributes are taking a back seat to serving the growing demand.

Joseph Barr; Deputy Director, Policy Technology & Management Analysis; New York City Department of Transportation

NYCDOT has established two high-profile BRT/Enhanced bus projects. The interview conducted by RSG focused mostly on the Fordham Road BRT, or the "Select Bus Service (SBS)" as it is branded by MTA NYCT.

This SBS service is a BRT: the bus lanes are painted a separate color from the regular street, with large signs declaring the lanes as bus lanes. Stops have been reduced slightly to every half-mile over the previous limited service. All ticketing is done off-board the buses at TVMs at the bus stops. TVMs take Metrocards or cash but cannot issue Metrocards. The SBS buses are "wrapped" with a brand logo. There are no ads inside or outside the buses currently, though that may change due to MTA's financial situation.

To promote the service, there was some small advertising done in local papers, but not much. The service has had a fair bit of mostly positive press (not press releases). MTA and NYC DOT also direct-mailed an informational brochure in the SBS corridor, but this was not so much advertising as information. Finally, they placed "customer ambassadors" out at stops in the first couple of weeks to help people adapt to the new system.

The buses are equipped with signal priority, off-board fare collection, and on-board bus cameras (though Mr. Barr felt most customers don't realize there are cameras). The buses are the same type as they always have been, but were thoroughly rehabilitated and cleaned for the new service. New bus shelters are coming to the service soon, and they have better visibility to make people more secure. They are new and larger, too.

Buses are told not to wait at time points anymore and to drive the route as fast as possible. Schedules are just headways during different hours of the day (e.g., the bus comes every 5 minutes between 6:00 a.m. and 9:00 a.m.) without time points. Due to these changes, travel time on this route is 14% to 24% faster than the old, limited service.

Awareness of the bus corridor and its high priority has definitely increased. This is likely due to the painted lanes (which are hard to miss) and the fact some on-street parking was taken away (which makes non-riders aware that something has changed). Overall ridership is up in the corridor, with a 20% increase in ridership on the SBS over the former limited route (this is a much higher increase than what MTA buses have experienced), though it is not yet clear how much of this increase consists of local riders who switched to SBS.

Round 2: Contacts on Potential Collaboration with Other Survey Efforts

The second round of interviews took place early in Fall 2008 in anticipation of the start of planning for the research approach. The early start was made to ensure that the project's survey research could realistically be incorporated into other agencies' research efforts. The effort therefore required long lead times.

The objective was to determine the possibility of collaborating with agencies' ongoing survey efforts. Agencies were contacted that had received other FTA survey funding. All agencies contacted were interested in the TCRP Project H-37 research, and all were willing to consider ways to cooperate. Agencies contacted included:

- L.A. Metro
- Denver RTD
- Boston MBTA/CTPS
- New Jersey Transit
- New York MTA
- Chicago Pace
- Georgia Regional Transit Authority
- Portland Metro

Greg Spitz, RSG, contacted a number of MPO's and transit agencies based on guidance from the panel and FTA about which agencies would be conducting rider research in the near future. Mr. Spitz also contacted other agencies of panel members, etc., to further explore other potential survey opportunities for TCRP Project H-37. An example of the email that was used (after an initial phone call) to inform transit agencies about the goals of the research and to ask for cooperation is shown in FIGURE A-19.

The following paragraphs recap the notes and initial thoughts from each Round 2 interview and summarize how each agency might participate in the TCRP Project H-37 research:

LAMTA: Spoke to LAMTA modelers and researchers Chaucie Chu and Robert Farley. LAMTA recently finished the Metro Rapid BRT study but they have additional funds to conduct more surveys, likely in spring 2009. We [the researchers] are working with them to incorporate at least an email question in their future surveys, if not additional conjoint questions. They are concerned about questionnaire length, and therefore want to test long/short survey versions. This likely means an email address is our best method to capture these respondents.

Denver RTD: Spoke to Lee Cryer. RTD has recently done two on-board surveys. They did not collect email addresses and were hesitant to try to contact respondents post-hoc via other means (e.g., mail or telephone). They were, however, very cooperative about involving us in a future customer satisfaction study. Susan Henry is the market research person at RTD and she will be surveying about express bus service in fall 2008 or spring 2009. RSG has already sent her an email and will follow up shortly.

Boston MBTA/Boston MPO: Spoke with Karl Quackenbush. They have just finished an extensive on-board survey in Spring 2008 which we attempted to be part of, but for which the survey design had already been finalized and was already considered long enough. However, they are conducting a statewide HH Diary survey which we will try and add email questions so that we can be part of that research.

Columbus (MORPC): This on-board study is being conducted for MORPC by NuStats. Field will likely be in fall 2008 and we will contact MOPRC to see if we can become involved. We have not yet contacted them but will do so soon so as to try and obtain at least an email question in their questionnaire.

New Jersey TRANSIT: We have contacted New Jersey TRANSIT panel member Tom Marchwinski who has been extremely cooperative. While there has been at least one localized bus study where we were considering adding a question, we decided the sample size was too small and the study specific to one area. Instead, we are working with New Jersey TRANSIT to gain permission to use their customer email database from previous broad based surveys.

NYMTA: RSG conducted a major OD study for MTA/Metro-North Railroad and had a database of email addresses for these customers. We have requested permission to use these addresses for this study and are hopeful that we will obtain approval over the next month.

Dear [Transit Agency],

At the bottom of this email is a summary of the TCRP study we're conducting, Characteristics of Premium Transit Services that Affect Choice of Mode. I was glad to hear that H-37's research issues resonate with some of the issues you're confronting in your own modeling.

Attached also please find a short PowerPoint deck which discusses MaxDiff research techniques. This is a potential technique we expect to apply when trying to understand and quantify some of the non-traditional attributes of premium transit (reliability, comfort, seating availability, etc.) when RSG conducts our own survey for this study (hopefully with your customers and/or potential customers).

We very much appreciate your interest and willingness to cooperate in this effort. As we discussed today, probably the best way to work together on this would be to ask respondents of your upcoming XXXX survey if they would be willing to participate in future research and, if yes, to provide their email address. Your agency would then approve and monitor any subsequent questionnaire RSG might use to survey your customers, but we would take care of all the work and make it as easy and painless for you as possible. In addition, your agency would have full access to the data generated from your customers and possibly learn some new research techniques, etc.

I will follow up in the next few weeks and feel free to contact me with any questions or comments. Thanks again for your help and interest.

Greg

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Greg Spitz

Director

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Note: Text is generic, but was personalized for each agency contacted.

FIGURE A-19. Email example.

Summary Scope of the TCRP H37 Study

The purpose of this research is to describe the most important factors that differentiate premium transit services from ordinary bus services, and to quantify for practical use the magnitude of these distinguishing features. A successful research effort will both improve the transit industry's understanding of mode choice determinants and offer practical insights to the forecasting community so that mode choice models and transit path-builders can better represent and distinguish important mode characteristics.

Understanding and modeling the real drivers and factors determining travel behavior and eliminating "flat" constants-based model structures will significantly improve the explanatory power as well as potential transferability of travel models. This is a very ambitious and long-term task that includes numerous aspects of travel model improvement. The proposed research is intended to identify the most important "breakthrough" directions with respect to mode choice model systems and consolidate the already acquired experience.

1. Research and practice synthesis – The focus of this synthesis will be to identify (1) distinguishing features of premium transit services, (2) the factors that influence mode choice decisions, and (3) advanced methods to model mode choice relevant to this research effort. This summary will also identify factors or modeling methods that may confound our ability to interpret the mode constants because the constants are correcting for them.

2. Data collection and Analysis – Our data collection effort will, first, seek to understand the extent to which transit alternatives (premium and non-premium) are known and considered as an option. Second, we will use adaptive conjoint analysis and related market research techniques to understand the relative importance of different levels of comfort, convenience, safety and other non-traditional transit attributes in mode choice decisions. Finally, we will conduct segmentation analysis to understand how different market segments respond to these attributes.

3. Advise FTA and practitioners on bringing results into practice – This study will make recommendations on data collection and mode choice model specifications and parameters so that premium transit services can be better distinguished and transit forecasts, in turn, can be refined. Additionally, the need for consistency between choice models and transit path-builders will be addressed.

Note: Text is generic, but was personalized for each agency contacted.

FIGURE A-19. (Continued).

Chicago Pace: Chicago Pace will soon be issuing an RFP for a combined O-D and Customer Satisfaction Study. RSG has been communicating with Pace on this future project and is expected to have good cooperation on adding an email question, if not more questions related to TCRP Project H-37.

Portland Metro: Portland Metro is expected to issue an RFP for a study that is very interested in understanding the modeling characteristics of premium transit and how to best characterize premium modes in forecasting. This study is the one where we hope to be able to actually contribute significantly to the questionnaire for the good of both Portland Metro and TCRP Project H-37, as our interests appear to align on this project. Tony Mendoza of Metro has been contacted and was made fully aware of TCRP Project H-37. He is very excited and eager to cooperate on this issue and he hopes to use stated preference and other conjoint techniques, which is important because that is the clearest way to quantify premium transit attributes. The RFP has still not been released, but we are in touch with Metro and will be ready to discuss this more with them once the RFP is made available.

Although every agency contacted was extremely cooperative and some even said we could ask a question or two in future research, it became clear that to understand premium transit differences we needed to use a more comprehensive survey than what a question or two could provide. Therefore, the general consensus after speaking with these agencies was that the most realistic way for them to cooperate was to provide email addresses of their riders (and potential riders) to RSG so that we could survey their customers with our own survey instrument developed exclusively to address the objectives of TCRP Project H-37.

One suggestion we made to the agencies was to add to agencies' questionnaires, when feasible, a question on whether respondents have an email address and whether they are willing to participate in future research. The question looks essentially like:

May we contact you for future research?

*Yes, email address*____

No

Not only did email lists make it possible to contact an agency's customers or potential customers easily, it allowed us to send them a comprehensive survey dedicated to the needs of TCRP Project H-37. It was usually easier for the agency to provide emails than to somehow incorporate new questions into a major research initiative, which typically had its own objectives and therefore could not be easily combined without adding to already time- and space-constrained questionnaires.

Summary

Based on the findings in the literature review and actions taken in practice, it is clear that typical mode choice model specifications lack important features differentiating transit services and this omission affects the quality of forecasts and our ability to represent the merits of one alternative over another. The fact that creative actions have been taken in practice underscores that this issue is not new by any means, but the increasing variety of techniques to address, to some extent, these shortcomings is encouraging. It is the goal of this research to both refine our understanding of transit mode choice behavior and refine these strategies or come up with new strategies for improving mode choice models and transit path-builders.

The literature review focused on both the awareness of transit services and the features of transit services. Though the literature on transit awareness is relatively thin, a few studies have shown that simply assuming perfect knowledge of the transit system is wrong, and may result in models dramatically overstating the potential market for transit in terms of which travelers see transit as a choice in models. Overstating the potential market for transit in applied mode choice models means that calibrated constants and estimated coefficients will be biased in order to calibrate the model. Understanding this bias, particularly the differences in awareness of premium vs. non-premium transit, is a useful step in understanding transit mode choice and explaining the components of calibrated mode choice model constants.

The literature review helped identify over 90 transit service attributes, as previously shown in TABLE A-1. Many transit agencies conduct periodic customer satisfaction surveys, and the surveys from four transit agencies were reviewed and cross-referenced with the attributes identified in research literature. One goal of this research was to quantify the relative importance of these attributes; however, this can be done to varying degrees for only half of the 90+ attributes, as shown in TABLE A-17. There is clearly some overlap among certain attributes, but the fact remains that extensive research does not appear to have been done covering the importance of all of these service features. Based on the research and studies reviewed for this appendix, the most important service features are identified in TABLE A-2. Notably, the non-traditional attributes that seemed to be the most important include level-of-service variables (e.g., reliability and service priority), seat availability, on-board comfort (e.g., seats, smoothness of ride), station cleanliness, and information services.

In practice there have been several attempts to account for and model accurately differences in observed ridership on different modes, other than typical model specifications that include mode-specific constants and the standard variables. These techniques include asserting mode-specific constants, valuing travel time differently for different modes, and enhancing the specification to include non-traditional variables such as reliability. The goal of this research is to inform and build on these techniques.

APPENDIX B

Survey Questionnaires

Contents

Salt Lake City

Introduction

Intro	Did you know that your travel habits help shape our transportation system? It's true! The purpose of this survey is to learn from you and others about where you go and how you get there in the Salt Lake City area. The Utah Transit Authority is conducting research to understand what is important to residents when and how you decide to make a local trip. You have been chosen as one of a select group of residents to take part in this study. The results of this survey will help the Utah Transit Authority to better serve citizens' transportation needs. Please click "next question" to continue.
Instruct	To back up, use the browser's "back" button, which is the left-pointing arrow in the upper left corner of the screen. If you back up to change an answer, please be sure to click "next question" to continue forward. It is important that you do NOT use the browser's "forward" button because your new answers will not be recorded. Answering all of the questions will take about 15-20 minutes. For information: 1-888-774-5982 or tcrp@surveycafe.com Please click "next question" to continue.

Background Questions (All respondents)

SLCres	Are you a resident of the greater Salt Lake City area? Yes No ***[TERMINATE]***

Employ	What is your employment status? Employed full-time Employed part-time Homemaker Retired Not currently employed Are you a student? Yes - full-time student Yes - part-time student No – not a student
Univ	*(If student)* Where are you a student? Brigham Young University Salt Lake Community College University of Utah Utah Valley State University Weber State University Westminster College Other, please specify: Did you attend school there last week? Yes No, out for the season, but attended in spring of 2009 No, taking time off from school right now
workHome	*(If employed)* Do you typically work from home as part of your job? No Yes

Familiar	How informed do you feel you are about the Salt Lake City area's public transit services (e.g., types of service available, routes, schedules, fare options)? Very informed Somewhat informed Neither informed nor uninformed Somewhat uninformed Very uninformed
trans	Which types of public transit have you used in the Salt Lake City area within the past 12 months? Please select all that apply. Frontrunner (Commuter Rail) TRAX (Light Rail) MAX (Bus Rapid Transit) Express bus Local bus I have not used transit in the past 12 months ***[This question defines transit user vs. transit NON-user]***
transAcc	***[Skip if hasn't used any transit]*** For each of the following types of transit you use, how do you typically get to the station/stop?

[Show transit selected in previous question]	Walk	Bike	Drive and park	Get dropped off	Taxi	Transit
Frontrunner (Commuter Rail)						
TRAX (Light Rail)						
MAX (Bus Rapid Transit)						
Express bus						
Local bus						

triptype	In the past week, which types of trips have you made? Please indicate all trips where you left home and traveled by car, transit, walking, biking, etc. Please select all that apply. Home to work (hide if not employed or if usually work from home) Home to school (hide if not student or not currently going to school) Home to shopping (groceries, drug store, clothing, etc.) Home to entertainment, recreation, eating out Home to other personal activities (medical appointment, church, visiting family and friends, etc.) None of the above **[TERMINATE]**
carAvail	Do you usually have a car available to get to [*insert trip type*]? Yes No
bikeUse	In the past month, have you used a bike to get to [*insert trip type*]? Yes No
carshare	In the past month, have you carpooled, shared a ride, or been dropped off at [*insert trip type*]? Yes No

parkFree	*(If employed)* Is parking free at your work? Yes No
farepaywork	Does your employer offer subsidies on transit/parking costs for your trip to work? No, I pay my transit/transportation costs Yes, my employer pays all the costs *If checked, then pop up:* Please indicate how much your employer pays for your transit fare: ____________ Please indicate how much your employer pays for your parking costs:___________ Yes, my employer pays part of the cost *If checked, then pop up:* Please indicate the amount your employer pays as part of your transit fare: ____________ Please indicate how much your employer pays as part of your parking costs:___________
farepayschool	*(If student)* Does your school pay for/subsidize any transit costs for your trip to school? No, I pay all the cost Yes, I have a free transit pass provided by my school/university Yes, I get a discounted transit pass through my school/university *(If pay for transit)* How much do you pay for your transit pass each month? Does your school pay for/subsidize any of your parking costs for your trip to school? Parking is free where I go to school/university Yes, I get discounted parking at my school/university: *(If pay for parking)* How much do you pay for parking at school each month?

transitCheck	*(If transit user AND employed)* Are you enrolled in a program (like TransitChek ™) where you use pre-tax contributions to pay for the following? Yes - I'm enrolled in a program to pay for transit Yes - I'm enrolled in a program to pay for parking No, I am not enrolled in this type of program

Transit Awareness and Consideration Questions (All respondents)

home	*(All respondents)* What is your home address? Street or nearest intersection______________ City_______________ State_______ Zip_______
tranHome	*(All respondents)* What types of public transit are currently offered in your neighborhood **within walking distance** of your home or primary residence? Please select all that apply. Frontrunner (Commuter Rail) TRAX (Light Rail) MAX (Bus Rapid Transit) Express bus Local bus There is no public transit currently available in my neighborhood *[Skip to origstop]* I don’t know what public transit services are available in my neighborhood *[Skip to tranPNR]*

TranHomeDet	*(If transit user)* Please tell us a little more about the public transit within walking distance of your home. (Show only what they checked in Tranhome1) | I have used this service in the last month. | How many minutes does it take to walk from home to the stop/station? Frontrunner (Commuter Rail) | ❑ | Drop down # minutes TRAX (Light Rail) | ❑ | Drop down # minutes MAX (Bus Rapid Transit) | ❑ | Drop down # minutes Express bus | ❑ | Drop down # minutes Local bus | ❑ | Drop down # minutes
BusRoute1	*(If transit user who selected local bus in Tranhome1detail)* Can you tell us what bus routes are available within walking distance of your home? [insert 5 text boxes for respondent to enter up to 5 routes]
hstop1	*(If transit user)* What is the location of the public transit stop that is **closest** to your home or primary residence? *Use geocoder map or enter address/intersection* __________________ Address or Intersection (i.e., corner of 7th Avenue & Main Street) City____________ St___________zip___________ Don't know

<table>
<tr>
<td>origstop</td>
<td>(If transit NON-user only and did not say “don’t know” in tranHome)

Please answer yes or no for each of the following statements about the public transit stop that is within walking distance of your home.
<table>
<tr><td>Do you know the route(s) serviced at the public transit stop within walking distance of your home?</td><td>Yes</td><td>No</td></tr>
<tr><td>Are you familiar with the transit schedule(s) at the public transit stop within walking distance of your home?</td><td>Yes</td><td>No</td></tr>
<tr><td>Do you know how to pay the fare of the transit service(s) that stop within walking distance of your home?</td><td>Yes</td><td>No</td></tr>
<tr><td>Do you know what the transit fare cost is at the public transit stop within walking distance of your home?</td><td>Yes</td><td>No</td></tr>
<tr><td>Do you know how to travel to where you work, go to school, the place where you went on your most recent “[insert triptype]” trip from the public transit stop within walking distance of your home?</td><td>Yes</td><td>No</td></tr>
</table>
</td>
</tr>
<tr>
<td>tranPNR</td>
<td>(If auto available)

What types of public transit are currently available at a Park and Ride location convenient to your home or primary residence?

Please select all that apply.

Frontrunner (Commuter Rail)

TRAX (Light Rail)

MAX (Bus Rapid Transit)

Express bus

Local bus

There is no public transit currently available at a Park and Ride convenient to my home [Skip to tranOth]

I don’t know what public transit services are available at a Park and Ride convenient to my home [Skip to tranOth]</td>
</tr>
</table>

TranPNRDet

(If transit user and if selected a transit mode in tranPNR)

Please tell us a little more about the public transit at Park and Rides convenient to your home.

(Show only what they checked in TranPNR2)	I have used this transit at a Park and Ride in the last month.	Which Park and Ride location do you typically park at to use transit?
Frontrunner (Commuter Rail)	❑	Drop down
TRAX (Light Rail)	❑	Drop down
MAX (Bus Rapid Transit)	❑	________
Express bus	❑	________
Local bus	❑	________

Drop down lists

FrontRunner	**TRAX**
Pleasant View, 2700 N. Hwy. 89	900 South - 900 S
Ogden, 2350 S. Wall Ave.	Ball Park - 1300 S 180 W
Roy, 4155 S. Sandridge Dr.	Central Pointe - 2100 S 221 W
Clearfield, 1250 S. State St.	Millcreek - 3300 S 210 W
Layton, 150 S. Main St.	Meadowbrook - 3900 S 188 W
Farmington, 450 N. 850 W	Murray North - 4400 S 71 W
Woods Cross, 750 S. 800 W	Murray Central - 5200 S 140 W
Salt Lake City, 250 S 600 W	Fashion Place West - 6400 S 222 W
	Midvale Fort Union - 7200 S 180 W
	Midvale Center - 7720 S 95 W
	Historic Sandy - 9000 S 165 E
	Sandy Expo - 9400 S
	Sandy Civic Center - 10000 S 115 E

TranPNRexp	*(If transit user who used Express Bus in last month)* From a Park and Ride, which of the following express buses have you used in the past month? 451 - Tooele Express 456 - Ogden/UNISYS/Rocky Mtn. Express 472 - Ogden - Salt Lake Express 473 - SLC - Ogden Hwy 89 Express 685 - Brigham City/Ogden Express 801 - SLC/Orem/Provo Express 802 - SLC/Utah County Express 803 - North Utah County/Salt Lake Express 804 - SLC/Lindon Express 805 - South Utah County/SLC Express 806 - Eagle Mtn/Saratoga/SLC Express 807 - PG/Cedar Hills/Highland Express 810 - UofU/American Fork Express 817 - Provo/Orem TRAX Express Other
tranDest	*(All respondents)* Do you know the location of the public transit stop that is closest to your *[insert destination]*? Yes No
transDestDet	*(If transit user and answered "yes" to tranDest)* Please tell us about the public transit stop that is closest to [*insert destination]*. *Use geocoder map or enter address/intersection* __________________ Address or Intersection (i.e., corner of 7th Avenue & Main Street) City____________ St___________zip__________

<table>
<tr><td>considtran</td><td>[If transit user]
Would you consider using transit for any of the following types of trips?
Check all that apply.

Yes, for work (if employed)
Yes, for school (if student)
Yes, for shopping (groceries, drug store, clothing, etc.)
Yes, for entertainment, recreation, eating out
Yes, for other personal activities (medical appointments, church, visiting family and friends, etc.)
No</td></tr>
<tr><td>deststop</td><td>(If transit non-user and answered “yes” to tranDest)
Please answer yes or no for each of the following statements about the public transit stop that is closest to [your work/your school/ the place where you went on your most recent “[insert triptype]” trip].
<table>
<tr><td>Do you know the route(s) serviced at the public transit stop closest to [your work/your school/the place where you went on your most recent “[insert triptype]” trip]?</td><td>Yes</td><td>No</td></tr>
<tr><td>Are you familiar with the transit schedule(s) at the public transit stop closest to [your work/your school/the place where you went on your most recent “[insert triptype]” trip]?</td><td>Yes</td><td>No</td></tr>
<tr><td>Do you know how to pay the fare at the public transit stop closest to [your work/your school/the place where you went on your most recent “[insert triptype]” trip]?</td><td>Yes</td><td>No</td></tr>
<tr><td>Do you know what the transit fare cost is at the public transit stop that is closest to [your work/your school/the place where you went on your most recent “[insert triptype]” trip]?</td><td>Yes</td><td>No</td></tr>
</table></td></tr>
</table>

Specific Trip Questions (All respondents)

mode	*(All respondents)* Next we'd like you to ask you about your most recent trip from your home to *[insert trip type].* How did you get from your home to *[insert trip type]*? If you walked or biked to *[insert trip type]* on your most recent trip, please think of another trip using a car or transit. If you used more than one type of transportation, please select the one you spent the most time on during this trip. Drove own vehicle (car, truck, SUV, minivan, motorcycle) Rode with someone else/Carpool/Vanpool/Rideshare FrontRunner (Commuter Rail) (*only show if used transit in past year*) TRAX (Light Rail) (*only show if used transit in past year*) MAX (Bus Rapid Transit) (*only show if used transit in past year*) Express bus (*only show if used transit in past year*) Local bus (not express service) (*only show if used transit in past year*) Taxi
AnyTran	*(If drove/rode as primary mode)* Did you use transit for any part of your trip from your home to *[insert trip type]*? Yes No
dest	*(All respondents)* What is the destination address of your most recent *"[insert triptype]"* trip from home that you make using *[insert mode]*? Street or nearest intersection _______________ City________________ Zip_______ Click here to use a map *[insert mapping module]*

cbcmodealt	*(All respondents)* We see that you used *[insert mode]* for your most recent *[insert triptype]* trip: What other types of transportation could you have used for this trip? Please select all that apply. *[exclude mode that was used]* No other types available Drive own vehicle (car, truck, SUV, minivan, motorcycle) Rode with someone else/Carpool/Vanpool/Rideshare FrontRunner (Commuter Rail) TRAX (Light Rail) MAX (Bus Rapid Transit) Express bus Local bus (not express service) Taxi Walk Bike
ynoAltMode	Why didn't you use the transit option(s) available to you on your most recent trip? I don't know much about my transit option(s) I don't like taking transit I need my car for other reasons Transit service isn't good enough
ynoaltmode2	*[If selected needed car for other reasons]* What did you need your car for on your most recent trip? Need car for work-related trips Running errands Can't carry what I need on transit Need car because transit doesn't run early/late enough Need to pick up/drop off up kids/spouse Need car to match my flexible schedule Other, please specify:

Ynoaltmode3	*[If selected transit service wasn't good enough]* What about the transit service didn't meet your needs for your most recent trip? Too many transfers Didn't run often enough Travel time was too long Would take too long to get to the station/stop Didn't run early/late enough Not reliable enough Other, please specify:
AccessMode	*(If transit user from "mode" in this section)* At the start of the trip, how did you get from your home to the first [*insert mode*] station/stop? Drove car and parked Rode in car and was dropped off Taxi Walked or biked Took transit
Transfers	*(If transit user from "mode" in this section)* How many transfers did you make on your [*insert triptype]*? No transfers 1 transfer 2 transfers 3 or more transfers *(If transferred pop up…)* Where did you transfer?

TripTime	*(All respondents)* How long did it take you to get from home to [*insert trip type*]? Please enter the number of minutes in the appropriate boxes, or enter a zero if there was no time. ______*<insert access mode>* from home to the first [*insert transit type*] station/stop (*if transit user from "mode" in this section)* ______ waiting for transit *(if transit user from "mode" in this section and made transfers)* ______traveling in transit vehicles *(if transit user from "mode" in this section)* ______getting from final transit station/stop *(if transit user from "mode" in this section)* ______getting from final transit station/stop *(if transit user from "mode" in this section)* ______getting from final transit station/stop *(if transit user from "mode" in this section)* ______Total door-to-door travel time (adds automatically)
TripCost1	*(If transit user from "mode" in this section)* How much did it cost to make your trip from home to [*destination*] for each of the items below? Please enter a zero where there was no cost. $_____ Transit fare $_____ Parking (show if accMode = drove) Check the type of transit pass you used: Daily Monthly: Adult Monthly: Reduced Fare (Seniors/Disabled) Premium Express Premium Express Reduced (Seniors/Disabled) Free Education Pass (University of Utah employees and students) Paratransit: Monthly Paratransit: 10-trip Paratransit: 30-trip

TripCost2	*(Show if drove or rode in car in mode)* What is the average gas mileage per gallon for your car? 10-15 mpg 16-20 mpg 21-25 mpg 26-30 mpg 31-40 mpg Over 40 mpg How much did you pay to park at [*insert triptype*]? Please enter a zero if you parked for free. $_____Parking
tripstops	For your most recent "*[insert triptype]*" trip, did you make any stops (not for transfers) along the way? No stops 1 stop What was the reason for your stop? *(Drop down choices below)* 2 or more stops What were the reasons for your stops? *(Drop down choices below SATA)* [randomize order] To pick up/drop off child To pick up/drop off spouse/partner To buy groceries To stop for coffee, newspaper, etc. To pick up/drop off dry cleaning To get gas *(if drive or carpool selected above)* To make a business/school related stop Pick up/meet other carpool members *(if carpool selected above)* Other, please specify: ___________________________

<table>
<tr>
<td>transitopin</td>
<td>

(If transit user)

Please indicate how strongly you agree or disagree with each of the following statements. *Statements will be shown in random order.*

<table>
<tr><th></th><th>Strongly Agree</th><th>Agree</th><th>Neutral</th><th>Disagree</th><th>Strongly Disagree</th></tr>
<tr><td>I currently make an effort to take public transit whenever I can.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>If I wanted to, I could use public transit more frequently.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>I am able to take transit from my neighborhood to downtown Salt Lake City.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>I am able to take transit from my neighborhood to important and useful destinations (i.e., places I work, shop, go to school, run errands, etc.)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>The transit system makes it easy for me to purchase my fare.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>When waiting for transit, I know when the next bus or train is scheduled to arrive.</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

</td>
</tr>
</table>

notransitopin

(If transit NON-user)

Please indicate how strongly you agree or disagree with each of the following statements. *Statements will be shown in random order.*

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Don't Know
It's easy to plan a trip using transit.						
I'm the kind of person who rides transit.						
Transit is often dirty.						
For me, car is king! Nothing will replace my car as my main mode of transportation.						
There's just not enough transit frequency or hours of service for transit to be convenient.						
I'm not afraid to ride transit.						
Getting to and from transit stations/stops is not pedestrian friendly and is very unpleasant.						
I have to drive to get to transit anyway, so I may as well just drive my car the whole way.						
I would take transit if the environment in and near the stations/stops was improved with nice lighting, benches, and convenient vendors, like coffee shops, dry cleaners, etc.						

CBC Section (All respondents)

cbcintro	In the questions that follow, think about your recent one-way *"[insert triptype]"* trip you described earlier using *[insert mode]*. Please imagine that you could make your trip in any of the three ways shown on the following pages, and think about the different times, costs, etc., for each option. Then select the option you would be most likely to choose. In the eight screens that follow, you will see three options shown on each page comparing a trip made by various methods: • Auto *[if available]* • Bus (includes MAX (Bus Rapid Transit), Express bus, and local bus) • Train (includes Frontrunner (Commuter Rail) and TRAX (Light Rail)) Please look at each option carefully because choices will change from screen to screen. All changes will be bolded.
cbcIntro2	Please review the following definitions for standard and premium on-board features below before answering the questions on the following screens. If you need to review these definitions on the following screens, put your mouse over the icon. STANDARD features include: • Transit vehicle has some air-conditioning and heating • Your trip is crowded and you may or may not have a seat • Transit vehicle is maintained, but not new PREMIUM features include: • Seats on board are ample and comfortable, with back and neck support • Transit vehicle has efficient air-conditioning and heating • There are always available seats on board and vehicle is not over-crowded • Transit vehicle is very new and clean STANDARD station/stop design features include: • Station/stop is maintained • Station/stop has some benches • Station/stop is safe MODERNIZED station/stop design features include: • Station/stop is well maintained and clean • Benches at station/stop are clean and comfortable • Station/stop is well lit and safe • Station/stop has shelter to effectively protect from bad weather • Station/stop is close to other services (coffee shop, dry cleaners, grocery, etc.) Real-time Information • STANDARD station/stop: does NOT have real-time info, but transit routes and schedules are posted • INFORMATIVE station/stop: has real-time info AND transit routes and schedules are posted

<table>
<tr><td>cbc</td><td>Which option would you prefer if you were to make your trip? ....</td></tr>
<tr><td>EXAMPLE SCREEN</td><td>
Which option are you MOST LIKELY to choose and which are you LEAST LIKELY to choose for your trip to work?
Please look at each option carefully because choices will change from screen to screen.
Please select one option in each row.
To see a definition, please put your mouse over the ⓘ.
<table>
<tr><th></th><th>Option #1:
Take the BUS</th><th>Option #2:
DRIVE</th><th>Option #3:
Take the TRAIN</th></tr>
<tr><td>Transit Service Features ⓘ</td><td>• STANDARD on-board features
• STANDARD station/stop
• REAL-TIME arrival/ departure info available</td><td></td><td>• STANDARD on-board features
• MODERNIZED station/stop
• REAL-TIME arrival/ departure info available</td></tr>
<tr><td>Travel Time</td><td>• Walk 5 mins. to station/stop
• Wait time: 10 mins.
• 10 mins. ride on bus
• 1 transfer
• 1 in 10 trips experience delay of 5 mins. or more</td><td>• 13 mins. drive
• 1 in 10 trips experience delay of 2 mins. or more</td><td>• Walk 5 mins. to station/stop
• Wait time: 20 mins.
• 10 mins. ride on train
• No transfer
• 1 in 10 trips experience delay of 10 mins. or more</td></tr>
<tr><td>Cost</td><td>• Transit: $5.50 one-way</td><td>• Parking: $11.00 a day
• Gas: $4.50 a gallon</td><td>• Transit: $9.00 one-way</td></tr>
<tr><td>MOST Likely</td><td>○</td><td>○</td><td>○</td></tr>
<tr><td>LEAST Likely</td><td>○</td><td>○</td><td>○</td></tr>
</table>
(Question 1 of 8)
</td></tr>
</table>

	Attribute	Variation		Auto	Bus	Train	3rd Transit Option (if no auto avail)
1	In-Vehicle Travel Time	Local Trip	1	10% shorter than current trip			
			2	Same as current trip			
			3	10% longer than current trip			
			4	20% longer than current trip			
		Long Trip	1	15% shorter than current trip			
			2	Same as current trip			
			3	15% longer than current trip			
			4	25% longer than current trip			
2	Parking Cost		1	Free	Free		
			2	Same as current ($5 if currently park free)	50% more ($5 if currently park free)		
			3	50% more	n/a		
			4	100% more	n/a		
3	Gas Cost		1	$1.50	n/a		
			2	$2.50	n/a		
			3	$3.50	n/a		
			4	$4.50	n/a		
4	Reliability	Local Trip	1	1 of out 10 trips takes 30%	1 out of 10 trips delayed, service is 5 minutes late		
			2	1 of out 10 trips takes 50%	1 out of 10 trips delayed, service is 10 minutes late		
			3	1 of out 10 trips takes 70%	n/a		
			4	1 of out 10 trips takes 90%	n/a		
		Long Trip	1	1 of out 10 trips takes 30%	1 out of 10 trips delayed, service is 5 minutes late		
			2	1 of out 10 trips takes 40%	1 out of 10 trips delayed, service is 10 minutes late		
			3	1 of out 10 trips takes 50%	n/a		
			4	1 of out 10 trips takes 60%	n/a		
5	Transit Fare - most respondents	Local Trip	1	n/a	20% less than current trip		
			2	n/a	Same as current ($2 if did't use transit for current trip)		
			3	n/a	20% more than current trip		
			4	n/a	30% more than current trip		
		Long Trip	1	n/a	10% less than current trip		
			2	n/a	Same as current ($6 if did't use transit for current trip)		
			3	n/a	10% more than current trip		
			4	n/a	20% more than current trip		
	Transit Fare - students/ employees with free transit pass	Local Trip	1	n/a	Free		
			2	n/a	$0.50		
			3	n/a	$1.00		
			4	n/a	$2.00		
		Long Trip	1	n/a	Free		
			2	n/a	$1.00		
			3	n/a	$2.00		
			4	n/a	$4.00		
6	Access Mode		1	n/a	Walk		
			2	n/a	Drive/get dropped off		
7	Access Time		1	n/a	5 minute <insert access mode> to station/stop		
			2	n/a	10 minute <insert access mode> walk to station/stop		
8	Wait time	Down-town	1	n/a	Wait 3 minutes		
			2	n/a	Wait 5 minutes		
			3	n/a	Wait 8 minutes		
			4	n/a	Wait 12 minutes		
		Outside Down-town	1	n/a	Wait 5 minutes		
			2	n/a	Wait 10 minutes		
			3	n/a	Wait 15 minutes		
			4	n/a	Wait 20 minutes		
9	Transfers		1	n/a	No transfer		
			2	n/a	Transfer		
10	On-Board Amenities		1	n/a	PREMIUM on-board transit amenities		
			2	n/a	STANDARD on-board transit amenities		
11	Station/Stop Design		1	n/a	MODERNIZED station/stop		
			2	n/a	STANDARD station/stop design		
12	Real Time Info		1	n/a	INFORMATIVE station/stop		
			2	n/a	STANDARD station/stop information		
13	Local/Long Trip		1	Local			
			2	Long (if current trip is < 10 miles, then only show local)			

Debrief Section

yNoTrans	*(If never chose a transit option)* What is the main reason you never selected the transit option in the previous section? Travel time too long Doesn't fit my schedule Less reliable than driving Too difficult to get to transit station/stop Not safe enough Too crowded Uncomfortable Confused about how to use transit Transit is too dirty Need car for other reasons Transit doesn't go where I need to go It would require too many transfers to make the trip by transit Other, please specify:
	Deb1 – Deb12 only asked of non-transit users
Deb1	*(If said travel time too long)* How much longer would your trip take if you used transit instead of driving? ______ minutes Don't know
Deb2	*(If doesn't fit schedule)* Please tell us a little bit more about why transit does not fit your schedule. Doesn't run early/late enough Doesn't come often enough I have to run errands/pick up my kids which makes transit too difficult to use Not flexible enough for my busy lifestyle Other, please specify:

Deb3	*(If said it's less reliable)* Please tell us a little bit more about why you consider transit unreliable. Transit is often late Don't know if I'll get a seat Bus might pass my stop if too many people are already on board Might miss my transfer Schedules are incorrect If I miss a bus or train, I have to wait too long for the next one Other, please specify:
Deb4	*(If said difficult to get to station/stop)* Please tell us a little bit more about why it is difficult to get to the transit station/stop. Too far to walk Don't want to walk/can't walk No sidewalks to get to the station/stop Need to cross major roads, making it difficult to get to the stop Only parking spaces are too far from station/stop Too expensive to park near the station/stop Other, please specify:
Deb5	*(If said unsafe)* Please tell us a little bit more about why transit isn't safe. Too much traffic on the way to the station/stop Station/stop in a bad neighborhood The walk to the stop/station goes through a dangerous area Station/stop is in a dangerous area and I don't want to wait there Lack of police/security presence at the station/stop Lack of security cameras at station/stop Worried about the type of people on the bus or at the station/stop I don't like to walk home in the dark from the station/stop Other, please specify:

Deb6	*(If said too crowded)* Please tell us a little bit more about how transit crowding affects you. Can't get a seat and have to stand Can't get a seat and crowded even when standing Can get a seat, but it's too close to other riders Other, please specify:
Deb7	*(If said uncomfortable)* Please tell us a little bit more about why transit is uncomfortable. Temperature – it's too hot or cold Seats are hard Seats are too close together Not enough seats Air-conditioning/heat don't work properly Don't like being so close to other riders Other, please specify:
Deb8	*(If said confusing)* Please tell us a little bit more about why transit is confusing to use. Don't know how to find out about how to use transit or where it goes Not sure how to find the right station/stop Not sure which route to get on to get me to my destination Don't know how long the trip will take using transit Not sure where to park I don't know how much it will cost me Not sure how to buy a ticket or what I need to do to board a bus/train Not sure where to transfer Not sure how safe the trip will be Other, please specify:

Deb9	*(If said too dirty)* Please tell us a little bit more about what you consider to be dirty about transit. Station/stop Benches Transit vehicle People on the bus/train Other, please specify:
Deb10	*(If need car)* Please tell us a little bit more about what else you need your car for. Running errands Need to pick up/drop off up kids/spouse Need car to match my flexible schedule Need car for work-related trips Need car because transit doesn't run early/late enough Can't carry what I need on transit Other, please specify: *(If said need car b/c can't carry what they need on transit)* What do you need to carry that is too big/heavy to bring on transit (e.g., too many grocery bags, something for work, stroller)? ________________________
Deb12	*(If said too many transfers)* How many transfers would you typically need to make? ___transfers How many transfers would you be willing to make? ___transfers

Available Transit Alternatives

altmode1-4	*(After the eight screens of CBC experiment…)* Thanks for considering all the transportation options shown on the previous screens. Thinking back to the trip you described using [insert mode] from your home to *[insert trip type]* that took *[insert total trip time]* minutes, did you know you had a *[insert other mode option from skims data]* option that would have taken *[insert minutes from skims data]*? Yes No *(If yes and transit user)* Why did you decide not to use the [insert other mode option from skims data]? [Open-end] ____ *(If yes and don't use transit, see debrief section)* *(If no)* If you had known you could have used the *[insert other mode option from skims data]*, would you have considered using it? Yes No *(If no and don't use transit, see debrief section)* *(If no and transit user)* Why would you not have considered using the [insert other mode option from skims data]? [Open-end] ____

MaxDiff Section (If transit users)

mdintro

(For transit users only. MaxDiff not shown to transit non-users as they will not know how to answer.)

Thank you for your answers so far. We're nearly done.

In the next section of the survey you will go through a series of 8 more screens.

You will be asked to choose the one transit option you MOST PREFER and the one that you LEAST PREFER.

Please click "Next Question" to begin.

Maxdiff

EXAMPLE SCREEN

SALT LAKE CITY TRAVEL STUDY

If these were your only choices, which transit option are you MOST LIKELY to use and which are you LEAST LIKELY to use?

Please assume all other aspects of transit service are the same across all of the options.

	Option #1	Option #2	Option #3
Time Riding on Transit	**12 mins.**	**9 mins.**	**11 mins.**
Transit Fare	**$0.80**	**$1.20**	**$1.00**
Station/Stop Distance	More than 10 mins. walk of your home/work	Within 10 mins. walk of your home/work	More than 10 mins. walk of your home/work
Station/Stop Shelter	Effectively protects you from bad weather	Effectively protects you from bad weather	Limited or no shelter
Route Name/Number Identification	Easy to immediately identify on outside of transit vehicle	Difficult to immediately identify on outside of transit vehicle	Difficult to immediately identify on outside of transit vehicle
MOST Likely	○	○	○
LEAST Likely	○	○	○

(Question 1 of 8)

Next Question

Questions or problems? Please call toll-free 1-888-774-5980 or email TCRP@surveycafe.com

	Attribute	Inverse of attribute
Travel Time	Local Trips: 5% shorter; same as current; 5% longer; 10% longer Long Trips: 10% shorter; same as current; 10% longer; 15% longer	
Transit Fare	**Most respondents:** Local Trips: 10% less; same as current (base of $2 if did not use transit for current trip); 10% more; 15% more Long Trips: 5% less; same as current (base of $6 if did not use transit for current trip); 5% more; 10% more **Students/employees with free transit pass:** Local Trips: Free, $0.50, $1.00, $1.50 Long Trips: Free, $1.00, $2.00, $3.00	
Real-Time Info About Next Transit Arrival/Departure	Real-time info available	NO real-time info available
Route Name/Number Identification	Easy to identify on outside of transit vehicle	Difficult to immediately identify on outside of transit vehicle
On-Board Seating Availability	Always available seats	Often crowded; you might not get a seat
On-Board Seating Comfort	Seats are comfortable and a good size	Seats are standard
On-Board Temperature	Effective air-conditioning and heating	Some air-conditioning and heating
Cleanliness of Transit Vehicle	Very new and clean	Maintained, but not new
Reliability	1 in 10 trips are 5 mins late or more	1 in 10 trips are 15 mins late or more
Station/Stop Security	Enhanced (e.g., emergency call-buttons, surveillance cameras, security personnel)	No added security features
Schedule Span	Transit runs from 4 AM until 11 PM	Transit runs from 6 AM until 9 PM
Transit Frequency	Arrives every 10 mins. in rush hour and every 20 mins. in non-rush hour	Arrives every 20 mins. in rush hour and every 60 mins. in off-peak
Station/Stop Lighting/Safety	Well-lit with police presence	Normal lighting and no police presence
Station/Stop Shelter	Effectively protects you from bad weather	Limited or no shelter
Proximity to Services	Close to coffee shop, dry cleaners, grocery, etc.	NOT close to coffee shop, dry cleaners, grocery, etc.
Cleanliness of Station/Stop	Well-maintained and clean	Maintained
Station/Stop Benches	Clean and comfortable	Some benches
Transfer Distance	Convenient (short walking distance or on same platform)	Several minute walk
Station/Stop Distance	Within 10 mins. walk of your home/work	NOT within 10 mins. walk of your home/work
Parking Distance	Within 10 mins walk from station/stop	NOT within 10 mins. walk from station/stop
Ease of Boarding	Easy to board; doors are level with platform/curb	Must step up to board
Fare Machines	Fast and easy to use	Slow and somewhat confusing
On-board wireless high-speed internet (Wi-Fi)	Available	Not available

Demographic Questions (All respondents)

SLCResTime	We really appreciate the time you've spent giving us your information and opinions. This is the last section, and we want to collect this last bit of information only to make sure we have a representative group of people from the Salt Lake City area. This information is being collected only to classify respondents in this study and will not be used for any other purpose. How long have you lived in the Salt Lake City area? Less than 6 months 6 months to 1 year 1–2 years 2–3 years 3–5 years More than 5 years
homedur	How long have you lived at your current home (your primary residence)? Less than 6 months 6 months to 1 year 1–2 years 2–3 years 3–5 years More than 5 years
gender	What is your gender? Female Male
age	What is your age? 16–24 25–34 35–44 45–54 55–64 65–74 75 or older

hhsize	How many people live in your household? 1 (I live alone) 2 3 4 5 or more
hhkid	*If household size is two or more:* How many of the people in your household are under age 18? 0 1 2 3 4 or more
hhlic	How many licensed drivers are there in your household? 0 1 2 3 4 or more
vehnum	How many cars, motorcycles, pick-up trucks, minivans, SUVs, etc., are there in your household? 0 (no vehicles) 1 vehicle 2 vehicles 3 vehicles 4 vehicles 5 or more vehicles

income	Which category best represents your household's annual income before taxes? *Note: this information is used only to make sure we have acquired a representative sample of the population. Less than $25,000 $25,000 – $34,999 $35,000–$49,999 $50,000–$74,999 $75,000–$99,999 $100,000–$124,999 $125,000–$149,999 $150,000–$174,999 $175,000–$199,999 $200,000 or more
mobility	Do you have a condition that substantially limits your physical activities such as walking or climbing stairs? Yes No Prefer not to answer
comment	Thank you for participating! All of your responses have now been saved. If you would like to add any suggestions for improving public transit services in and around the [Salt Lake City/Portland/Greater New Jersey and New York City] area, please type them below. Otherwise, please click "next question' to complete the survey.
end	Thank you for your participation! This survey is conducted by: Resource Systems Group, Inc. (RSG) For: The National Academies: Federal Transit Cooperative Research Program (TCRP) in conjunction with the Utah Transit Authority (UTA) ***[Show logos of RSG, Natl. Academies, and UTA]***

Chicago and Charlotte

Introduction and Background Questions

Intro	Did you know that your travel habits help shape our transportation system? It's true! The purpose of this survey is to learn from you and others about where you go and how you get there in the <city> area. The <authority> is conducting research to understand what factors are important to residents when they decide to make a local trip. You have been chosen as one of a select group of residents to take part in this study. The results of this survey will help <authority> better serve citizens' transportation needs. Please click "Next Question" to continue.
Instruct	Instructions To back up, use the browser's "back" button, which is the left-pointing arrow in the upper left corner of the screen. If you back up to change an answer, please be sure to click "Next Question" to continue forward. It is important that you do NOT use the browser's "forward" button because your new answers will not be recorded. Answering all of the questions will take about 15-20 minutes. For information: 1-888-774-5982 or tcrp@rsgsurvey.com Please click "Next Question" to continue.
(All respondents)	
Res	Are you a resident of the greater <city> area? Yes No *(terminate)*
Employ	What is your employment status? Employed full-time Employed part-time Self-employed Homemaker Retired Not currently employed
Student	Are you currently a student? Yes, a full-time student Yes, a part-time student No, not currently a student
Informed	How informed do you feel you are about the <city> area's public transit services (e.g., types of service available, routes, schedules, fare options)? Very informed Somewhat informed Neither informed nor uninformed Somewhat uninformed Very uninformed

tranUse	How often to you use the following public transit options? **[columns]** 5 or more times per week 3 - 4 times per week 1 - 2 per week 1-3 times per month 5-11 times per year 4 times or less per year Never **[rows]** CTA local bus CTA express bus Pace bus CTA train (the "L") Metra commuter rail CATS local bus (includes neighborhood shuttle) CATS express bus LYNX light rail
modePurp	In the box below, for each of the transportation options listed please select every type of trip you made in the past week that took at least 10 minutes. Select all that apply. If you used more than one transportation option on a trip, select a box for each option. **[columns]** *(If full-time, part-time, or self-employed)* Commute trips between home and work *(If full- or part-time student)* Commute trips between home and school Trips between home and a location other than work/school I did not make any trips using this transportation option **[rows]** Car *(Don't show any transit options that the respondent reported never using on tranUse)* CTA local bus CTA express bus Pace bus CTA train (the "L") Metra commuter rail CATS local bus (includes neighborhood shuttle) CATS express bus LYNX light rail Walk/Bike

Questions about Reference Trip

(All respondents)	
reference	We'd now like to ask you some questions about your **most recent** trip: • From home to work (school, somewhere other than work/school) • That took 10 minutes or more • Traveling by car (Using a CTA local bus, etc.) • From work (school, somewhere other than work/school) to home • That took 10 minutes or more • Traveling by car (Using a CTA local bus, etc.) Do you have this trip in mind? Yes No *(terminate)*
dow	What day of the week did you make your most recent trip like this? Monday Tuesday Wednesday Thursday Friday Saturday Sunday
endloc	*(If assigned reference trip is not between home and work or school)* What was your main destination on this trip? Work School Shopping location Friend's home Business location (sales call, meeting, etc.) Other place of business (restaurant, doctor's office, etc.) Other, please specify

endLocConf	*(If work or school selected)* You said that the main destination for your trip was <WORK/SCHOOL>. We would like you to think about your most recent trip: • Starting at home and going **somewhere other than work/school** • That took at least 10 minutes • Traveling by car (Using a CTA local bus, etc.) Do you remember your most recent trip like this? Yes *(branch back to dow)* No *(terminate)*
geoO	Where is the <beg loc> (where your trip began) located?* Please enter an address (with street number) or the nearest intersection in the boxes below. If you do not know this information or you would prefer to find the location on a map. Please select "I would rather use a map." • I would rather use a map Address or Intersection City State Zip Code To use the map: 1. Click on the map to zoom in on your location 2. Keep zooming until a marker appears 3. Continue to drag the map and click on the location until the marker is in the right place (the street number does not have to be exact) 4. Click "Next Question" to proceed *Note: Your information will be kept strictly confidential and will only be used for this survey. Your responses will never be linked back to your personal information.
geoD	Where is the <end loc> (where your trip ended) located?* Please enter an address (with street number) or the nearest intersection in the boxes below. If you do not know this information or you would prefer to find the location on a map. Please select "I would rather use a map." • I would rather use a map Address or Intersection City State Zip Code To use the map: 1. Click on the map to zoom in on your location 2. Keep zooming until a marker appears 3. Continue to drag the map and click on the location until the marker is in the right place (the street number does not have to be exact) 4. Click "Next Question" to proceed *Note: Your information will be kept strictly confidential and will only be used for this survey. Your responses will never be linked back to your personal information.

tranAccMode	*(If transit)* On this trip, how did you get from <beg loc> to the first transit station/stop? Drove and parked Dropped off by car Walked Biked Taxi/Limousine Other, please specify:
tranModes	*(If transit)* What type(s) of transit did you use on your trip (from <beg loc> to <end loc>)? Please tell us about all of the types of transit you used on your trip in the order you used them. When you are finished submitting ALL of the types of transit you used, please select "left transit" and click the "Submit" button. I first used: Submit My trip: **Chicago types:** CTA local bus CTA express bus Pace bus CTA train (the "L") Metra commuter rail **Charlotte types:** CATS local bus (includes neighborhood shuttle) CATS express bus LYNX light rail *(must select the option that you are meant to be thinking of for your reference trip)*
tranEgrMode	*(If transit)* After you left transit, how did you get to the <end loc>? Drove parked vehicle Picked up by car Walked Biked Taxi/Limousine Other, please specify:

<table>
<tr><td>autoAvailUsual</td><td>Do you usually have a car available to make the trip from <beg loc> to <end loc>?

Yes
No</td></tr>
<tr><td>autoAvailTrip</td><td>(If transit)
When you made your trip on <dow>, did you have a car available to make the trip from <beg loc> to <end loc>?

Yes
No</td></tr>
<tr><td>autoSpecs</td><td>(If respondent drove on ref trip, usually has a car available, or had one available this time)

(If auto)
What type of car did you drive on this trip?
(If transit and had one available)
What type of car did you have available to make this trip?
(If transit and did not have one available but usually does)
What type of car do you usually have available to make this trip?

[drop down lists]
<table>
<tr><td>Type of car:</td><td>Year:</td><td>Fuel type:</td></tr>
<tr><td>Compact</td><td>List 1985 – 2010</td><td>Gasoline</td></tr>
<tr><td>Sedan</td><td>Older than 1985</td><td>Diesel</td></tr>
<tr><td>Minivan</td><td></td><td>Hybrid</td></tr>
<tr><td>Pick-up truck</td><td></td><td>Electric</td></tr>
<tr><td>SUV</td><td></td><td></td></tr>
<tr><td>Cargo van</td><td></td><td></td></tr>
</table></td></tr>
<tr><td>tranTravTime</td><td>(If transit ref trip)
Please tell us some more about your trip.

What time did you leave <beg location>?
How long did it take to get to transit?
How long did you wait for transit (in total)?
How long did you ride on-board transit (in total)?
How long did it take to get from transit to your destination?
How long were you at any other stops along the way (e.g., coffee)?
You arrived at <end location> at _____________<adds automatically></td></tr>
</table>

autoTime	*(If auto ref trip)* Please tell us some more about your trip. What time did you leave <beg location>? How long did you spend traveling? How long did you spend at stops? Your arrived at <end location> at ________________ *(adds automatically)*
tranTicket	*(If transit ref trip)* How did you pay your fare on the <authority><transit mode used>? Cash/regular one-ride fare Weekly pass Monthly pass 10-ride local pass Senior reduced fare ADA reduced fare Chicago Card (blue card) Chicago Card Plus (blue and yellow card) Transit card 1-day pass 3-day pass 7-day pass 30-day pass Weekend pass (Metra only) Express service (Pace only) Regular 10-ride plus ticket (Pace only) Premium 10-ride plus ticket (Pace only) Pace Campus Connection (Pace only) Seniors Ride Free Military Service Pass People with Disabilities Ride Free
tranParkCost	*(If drove and parked for access or drove parked vehicle for egress)* How much did you pay to park at the transit station/stop? Please enter a zero if you did not pay to park. $______

destParkCost	*(If auto, start at home)* How much did it cost to park at <end loc>? *(If auto, start at work/school)* How much did it cost to park while at <beg loc>? *(If transit, start at home and parked car egr)* How much did it cost to park at <end loc>? *(If transit, end at home and drive and park acc)* How much did it cost to park while at <beg loc>? If you parked in a location you pay for weekly or monthly, please report the cost and duration (weekly or monthly) of your parking pass. $________ Daily Weekly Monthly I did not pay to park
destParkCostHyp	*(If transit, start at home and auto avail and not park egr)* On the day of your trip, how much would it have cost you to park at <end loc>? *(If transit, ended at home and auto avail and not park acc)* How much would it have cost you to park while at <beg loc>? I would have paid $______ I don’t know
autoTolls	*(If drove for trip, either as primary mode or access/egress mode)* Did you pay any tolls during your trip? Yes, I paid $_______ No

subsid	*(If employed)* Were the costs for this trip directly subsidized by your employer? If so, how much was the subsidy? *(Only show rows for modes used in ref trip)* Transit fare: Parking costs: **[drop down]** Fully subsidized Partially subsidized Not subsidized I don't know
Pretax	*(If employed)* Do you participate in a program (e.g., TransitChek or ADP) that allows you to pay transportation or parking costs with pre-tax dollars? Please select all that apply. *(Only show rows for modes used in ref trip)* Yes, my transit fare was paid with pre-tax dollars. Yes, my parking costs were paid with pre-tax dollars. No
Occ	How many people traveled together in your party for this trip? 1 person (I traveled alone) 2 people 3 people 4 people 5 people 6 people or more

stops	What stops did you make on your way from <beg loc> to <end loc>? Select all that apply. Pick up/drop off household member Pick up/drop off non-household member Buy groceries Stop for coffee, newspaper, etc. Get gas Make a business/school related stop Pick up/meet other carpool members Other I didn't make any stops Later, what stops did/will you make on your way from <end loc> back to <beg loc>? Select all that apply. Pick up/drop off household member Pick up/drop off non-household member Buy groceries Stop for coffee, newspaper, etc. Get gas Make a business/school related stop Pick up/meet other carpool members Other I didn't make any stops I didn't return <(to) beginning loc> this day
tripfreq	How frequently do you make this specific trip using a <authority><transit mode for ref trip>? 5 or more times per week 3 - 4 times per week 1 - 2 per week 1-3 times per month 5-11 times per year 4 times or less per year

Reference Trip Transit Awareness

(All respondents)	
willingWalk	Please continue to think about your most recent trip: • X criteria • Y criteria • Z criteria Thanks for your responses so far! Now we're going to ask you some questions about your travel decisions. Please continue to think about your trip when answering these questions. To make the trip you've been describing, what is the furthest you would be willing to walk to a station or bus stop in order to take public transportation? Please assume the weather is reasonably good – it is not raining or snowing and the temperature is comfortable. I would walk for ______ minutes. (dropdown)
willingDrive	*(If tranAccMode = drove and parked or if tranEgrMode = drove parked car, then write 1 and branch over)* *(If no car usually available, clear and branch over)* *(If trip began at home)* Would you be willing to make this trip by driving to a station or stop, parking there and taking public transportation the rest of the way to your destination? *(If trip ended at home)* Would you be willing to make this trip by taking public transportation to a station or stop, picking up a car that you parked there earlier, and driving the rest of the way home? Please assume the weather is reasonably good – it is not raining or snowing and the temperature is comfortable. Yes No
willingBus	*(Branch over if used bus during transit reference trip)* Would you be willing to make this trip by taking a bus to get to another public transportation option (El, Metra, express bus, etc.) the rest of the way to your destination? Please assume the weather is reasonably good – it is not raining or snowing and the temperature is comfortable. Yes No

willingDropped	*(If tranAccMode = drove and dropped off or tranEgrMode = picked up by car, write 1 and branch over)* Would you be willing to make this trip by being dropped off at a station or bus stop and taking public transportation to <your destination/home>? Please assume the weather is reasonably good – it is not raining or snowing and the temperature is comfortable. Yes No
tranModesConsidered	What <other *(if transit ref trip)*> types of public transit did you consider using to make your trip? Select all that apply. *(Don't list modes actually used if transit reference trip)* Chicago types: CTA local bus CTA express bus Pace bus CTA train (the "L") Metra commuter rail Charlotte types: CATS local bus (includes neighborhood shuttle) CATS express bus LYNX light rail There is no <other *(if transit ref trip)*> public transit currently available for this trip Did not consider any of these/ not sure

yThisTran	*(If transit reference trip and aware of other transit options)* Why did you make this trip by <mode> rather than by <other mode>? Please select all that apply. Time savings Better fit with my schedule Lower cost Greater comfort Better frequency Closer/more convenient station Safety concerns Less crowded Parking costs at station More reliable Fewer transfers Better amenities Other, please specify: *(Repeat for each mode respondent was aware of and did not use)*
yNoTran	*(If auto reference trip, and considered transit options)* Why did you drive instead of using <other mode> to make your trip? Please select all that apply. Travel time on <other mode> was too long <Other mode> did not run early or late enough <Other mode> does not run often enough <Other mode> is less reliable than driving Too difficult to get to <other mode> station/stop <Other mode> is not safe enough <Other mode> is too crowded <Other mode> is uncomfortable I don't know enough about <other mode> <Other mode> is too dirty It would have required too many transfers to make the trip by <other mode> I don't like taking public transportation I needed my car for other reasons *(Repeat for each mode respondent was aware of and did not use. If respondent choose "I don't like taking public transportation" or "I needed my car for other reasons" do not repeat for other transit modes, as reasoning stays the same)*

yNeedCar	*(If needed car for other reasons)* What did you need your car for on your trip? Please select all that apply. Need car for work-related trips Running errands Cannot carry what I need on transit Need car because transit doesn't run early/late enough Need to pick up/drop off my kids/spouse Need car to match my flexible schedule Other, please specify: *(On to aware or attitudes, based on whether or not skims revealed a transit option. Do not repeat yNoTran)*
aware	*(Based on skim data, determine the single best option - if any - for each mode the respondent did not report considering on trantrip. If none, branch to attitudes)* For the trip you made using <reported mode>, did you know you had a <skim mode> option that would have taken <skim time>? This trip would have required <skim transfers> transfers and cost <skim cost>. Yes, I was aware of it and I considered it Yes, I was aware of it but I did not consider it No, I was not aware of it but now that I know I would choose it No, I was not aware of it and now that I know I would not consider it *(If response 1 looped back to ythistran or ynotran, asking about that specific mode)* *(If response 2 looped back to ythistran or ynotran, asking about that specific mode)* *(If response 3 ahead to attitudes)* *(If response 4 ahead to noconsid)* *(After branching, repeat this slide for each mode the skim says is available but they did not report considering on trantrip.)*
noconsid	Why would you not consider the <skim mode> option presented on the previous screen? Please select all that apply. Travel time is too long Too many transfers Fare is too expensive Service is too infrequent I don't like taking <skim mode>

Attitudes1	Please indicate how strongly you agree or disagree with each of the following statements. 1. I am not afraid to ride transit. 2. I'm the kind of person who rides transit. 3. It's easy to plan a trip using transit. 4. Transit is often dirty. 5. More than saving time, I prefer to be productive when traveling. 6. If it would save time, I would change my form of travel. 7. As long as I am comfortable when traveling, I can tolerate delays. 8. Protecting the environment is very important to me. 9. My days of taking transit are over. *Statements will be shown in random order.*
	Please indicate how strongly you agree or disagree with each of the following statements. 1. For me, car is king! Nothing will replace my car as my main mode of transportation 2. Getting to and from transit station/stops is not pedestrian friendly and is very unpleasant 3. I have to drive to get to transit anyway, so I may as well just drive my car the whole way 4. Privacy is important to me when I travel 5. I currently make an effort to take public transit whenever I can 6. My car reflects who I am 7. If I wanted to, I could use public transit more frequently 8. I am willing to carpool or take public transit more frequently to reduce air pollution and carbon emissions from my vehicle 9. I am willing to pay higher tolls if they are used to reduce air pollution and carbon emissions *Statements will be shown in random order.*

Stated Preference for Modes

(All respondents)	
cbcintro	In the questions that follow, think about your recent one-way *"[insert triptype]"* trip you described earlier using *[insert mode]*. Please imagine that you could make your trip in any of the three ways shown on the following pages, and think about the different times, costs, etc., for each option. Then select the option you would be most likely to choose. In the eight screens that follow, you will see three options shown on each page comparing a trip made by various methods: • Auto *[if available]* • Bus • Train Please look at each option carefully because choices will change from screen to screen. All changes will be bolded.

cbcIntro2	Please review the following definitions for standard and premium on-board features below before answering the questions on the following screens. If you need to review these definitions on the following screens, put your mouse over the icon. STANDARD on-board features include: • Transit vehicle has some air-conditioning and heating • Your trip is crowded and you may or may not have a seat • Transit vehicle is maintained, but not new PREMIUM on-board features include: • Seats on board are ample and comfortable, with back and neck support • Transit vehicle has efficient air-conditioning and heating • There are always available seats on board and vehicle is not over-crowded • Transit vehicle is very new and clean STANDARD station/stop design features include: • Station/stop is maintained (but with some litter, dingy floors, and some unpleasant smells) • Station/stop has some benches • Station/stop is safe • Station/stop posted train/bus schedules and maps PREMIUM station/stop design features include: • Station/stop is well maintained and clean • Benches at station/stop are clean and comfortable • Station/stop has shelter to effectively protect from bad weather • Station/stop is well lit and has enhanced safety features (e.g., emergency call-buttons, surveillance cameras, security personnel) • Station/stop has real-time train/bus arrival information in addition to posted schedules and maps • Station/stop is close to other services (coffee shop, dry cleaners, grocery, etc.)

EXAMPLE SCREEN [Note: the Stated Preference (SP) will be reformatted a bit based on other recent survey work – the second example screenshot below.]

Which option are you MOST LIKELY to choose and which are you LEAST LIKELY to choose for your trip to work?

Please look at each option carefully because choices will change from screen to screen.

Please select one option in each row.

To see a definition, please put your mouse over the ⓘ.

	Option #1: Take the BUS	**Option #2: DRIVE**	**Option #3: Take the TRAIN**
Transit Service Features ⓘ	• **STANDARD** on-board features • **STANDARD** station/stop • **REAL-TIME arrival/ departure info available**		• **STANDARD** on-board features • **MODERNIZED** station/stop • **REAL-TIME arrival/ departure info available**
Travel Time	• **Walk 5 mins.** to station/stop • Wait time: **10 mins.** • **10 mins.** ride on bus • **1 transfer** • 1 in 10 trips experience delay of **5 mins.** or more	• **13 mins.** drive • 1 in 10 trips experience delay of **2 mins.** or more	• **Walk 5 mins.** to station/stop • Wait time: **20 mins.** • **10 mins.** ride on train • **No transfer** • 1 in 10 trips experience delay of **10 mins.** or more
Cost	• Transit: **$5.50** one-way	• Parking: **$11.00** a day • Gas: **$4.50** a gallon	• Transit: **$9.00** one-way
MOST Likely	○	○	○
LEAST Likely	○	○	○

(Question 1 of 8)

	Attribute	Variation		Auto (if available for trip)	Bus	Train	3rd Transit Option (if no auto avail)
1	In-Vehicle Travel Time	Trip < 25 minutes	1	3 minutes shorter than current trip			
			2	Same as current trip			
			3	3 minutes longer than current trip			
			4	5 minutes longer than current trip			
		Trip >=25 minutes	1	10% shorter than current trip			
			2	Same as current trip			
			3	10% longer than current trip			
			4	20% longer than current trip			
2	Parking Cost		1	Free	Free		
			2	Same as current ($5 if park free)	50% more ($5 if currently park free)		
			3	50% more	n/a		
			4	100% more	n/a		
3	Gas Cost		1	$1.50 / gallon	n/a		
			2	$2.50 / gallon	n/a		
			3	$3.50 / gallon	n/a		
			4	$4.50 / gallon	n/a		
4	Reliability	Trip < 25 minutes	1	1 in 10 trips experiences a delay of 5 min. or more			
			2	1 in 10 trips experiences a delay of 20 min. or more			
			3	3 in 10 trips experiences a delay of 5 min. or more			
			4	3 in 10 trips experiences a delay of 20 min. or more			
5	Transit Fare	Trip < 25 minutes	1	n/a	20% less than current trip		
			2	n/a	Same as current ($2.25 if didn't use transit for current trip)		
			3	n/a	20% more than current trip		
			4	n/a	30% more than current trip		
		Trip >=25 minutes	1	n/a	10% less than current trip		
			2	n/a	Same as current ($6.25 if didn't use transit for current trip)		
			3	n/a	10% more than current trip		
			4	n/a	20% more than current trip		
6	Access Mode		1	n/a	Walk/Bike		
			2	n/a	Take a bus		
			3	n/a	Drive/get dropped off		
7	Access Time		1	n/a	5 minute <access mode> to station/stop		
			2	n/a	10 minute <access mode> to station/stop		
8	Headway		1	n/a	Arrives every 5 minutes		
			2	n/a	Arrives every 10 minutes		
			3	n/a	Arrives every 15 minutes		
			4	n/a	Arrives every 20 minutes		

9	Transfers	Trip < 25 minutes	1	n/a	No transfer
			2	n/a	1 transfer taking 5 minutes
		Trip >=25 minutes	1	n/a	1 transfer taking 5 minutes
			2	n/a	2 transfers taking 5 minutes each
10	Span of service		1	n/a	Service runs all day
			2	n/a	Service runs only during rush hours
11	On-Board Amenities		1	n/a	PREMIUM on-board transit amenities
			2	n/a	STANDARD on-board transit amenities
12	Station/ Stop Design		1	n/a	MODERNIZED station/stop design
			2	n/a	STANDARD station/stop design

Relative Preference for Transit Attributes

(For transit users)

mdintro	*All respondents see the MaxDiff except for those who say they are "very unfamiliar" with transit in the question called "Familiar."* Thank you for your answers so far. We're nearly done. In the next section of the survey you will go through a series of 8 more screens. You will be asked to choose the one transit option you MOST PREFER and the one that you LEAST PREFER. Please click "Next Question" to begin.

Maxdiff EXAMPLE SCREEN

SALT LAKE CITY TRAVEL STUDY

If these were your only choices, which transit option are you MOST LIKELY to use and which are you LEAST LIKELY to use?

Please assume all other aspects of transit service are the same across all of the options.

	Option #1	Option #2	Option #3
Time Riding on Transit	12 mins.	9 mins.	11 mins.
Transit Fare	$0.80	$1.20	$1.00
Station/Stop Distance	More than 10 mins. walk of your home/work	Within 10 mins. walk of your home/work	More than 10 mins. walk of your home/work
Station/Stop Shelter	Effectively protects you from bad weather	Effectively protects you from bad weather	Limited or no shelter
Route Name/Number Identification	Easy to immediately identify on outside of transit vehicle	Difficult to immediately identify on outside of transit vehicle	Difficult to immediately identify on outside of transit vehicle
MOST Likely	○	○	○
LEAST Likely	○	○	○

(Question 1 of 8)

Next Question

Questions or problems? Please call toll-free 1-888-774-5980 or email TCRP@surveycafe.com

	Attribute	Inverse of attribute
Travel Time	Local Trips: 5% shorter; same as current; 5% longer; 10% longer Long Trips: 10% shorter; same as current; 10% longer; 15% longer	
Transit Fare	**Most respondents:** Local Trips: 10% less; same as current (base of $2 if did not use transit for current trip); 10% more; 15% more Long Trips: 5% less; same as current (base of $6 if did not use transit for current trip); 5% more; 10% more **Students/employees with free transit pass:**Local Trips: Free, $0.50, $1.00, $1.50 Long Trips: Free, $1.00, $2.00, $3.00	
Real-Time Info About Transit Arrival/Departure	Real-time info available	NO real-time info available
Route Name/Number Identification	Easy to identify on outside of transit vehicle	Difficult to immediately identify on outside of transit vehicle
On-Board Seating Availability	Always available seats	Often crowded; you might not get a seat
On-Board Seating Comfort	Seats are comfortable and a good size	Seats are standard
On-Board Temperature	Effective air-conditioning and heating	Some air-conditioning and heating
Cleanliness of Transit Vehicle	Very new and clean	Maintained, but not new
Reliability	1 in 10 trips are 5 min. late or more	1 in 10 trips are 15 min. late or more
Station/Stop Security	Enhanced (e.g., emergency call-buttons, surveillance cameras, security personnel)	No added security features
Schedule Span	Transit runs from 4 AM until 11 PM	Transit runs during rush hours only
Transit Frequency	Arrives every 10 min. in rush hour and every 20 min. in non-rush hour	Arrives every 20 min. in rush hour and every 60 min. in off-peak
Station/Stop Lighting/Safety	Well lit with police presence	Normal lighting and no police presence
Station/Stop Shelter	Effectively protects you from bad weather	Limited or no shelter
Proximity to Services	Close to coffee shop, dry cleaners, grocery, etc.	NOT close to coffee shop, dry cleaners, grocery, etc.
Cleanliness of Station/Stop	Well maintained and clean	Not well maintained
Station/Stop Benches	Clean and comfortable	Some benches
Transfer Distance	Convenient (short walking distance or on same platform)	Several minute walk
Station/Stop Distance	Within 10 min. walk of your home/work	NOT within 10 min. walk of your home/work
Parking Distance	Within 10 min. walk from station/stop	NOT within 10 min. walk from station/stop
Ease of Boarding	Easy to board; doors are level with platform/curb	Must step up to board
Fare Machines	Fast and easy to use	Slow and somewhat confusing
Productivity features	WiFi, power outlets, etc., available	Productivity features not available

Demographic Questions

(All respondents)	
ResTime	We really appreciate the time you've spent giving us your information and opinions. This is the last section, and we want to collect this last bit of information only to make sure we have a representative group of people from the <insert city> area. This information is being collected only to classify respondents in this study and will not be used for any other purpose. How long have you lived in the <insert city> area? Less than 6 months 6 months to 1 year 1–2 years 2–3 years 3–5 years More than 5 years
homedur	How long have you lived at your current home (your primary residence)? Less than 6 months 6 months to 1 year 1–2 years 2–3 years 3–5 years More than 5 years
gender	What is your gender? Female Male
age	What is your age? 16–24 25–34 35–44 45–54 55–64 65–74 75 or older

hhsize	How many people live in your household? 1 (I live alone) 2 3 4 5 or more
hhkid	*(If household size is two or more)* How many of the people in your household are under age 18? 0 1 2 3 4 or more
hhlic	How many licensed drivers are there in your household? No licensed drivers 1 –I am the licensed driver 1 – I am NOT the licensed driver 2 licensed drivers 3 licensed drivers 4 licensed drivers or more
vehnum	How many cars, motorcycles, pick-up trucks, minivans, SUVs, etc., are there in your household? 0 (no vehicles) 1 vehicle 2 vehicles 3 vehicles 4 vehicles 5 or more vehicles

income	Which category best represents your household's annual income before taxes? *Note: this information is used only to make sure we have acquired a representative sample of the population. Less than $5,000 $5,000 – $9,999 $10,000 – $24,999 $25,000 – $34,999 $35,000–$49,999 $50,000–$74,999 $75,000–$99,999 $100,000–$124,999 $125,000–$149,999 $150,000–$174,999 $175,000–$199,999 $200,000 –$249,999 $250,000 –$299,999 $300,000 or more
mobility	Do you have a condition that substantially limits your mobility or physical activities such as walking or climbing stairs? Yes No Prefer not to answer
comment	Thank you for participating! All of your responses have now been saved. If you would like to add any suggestions for improving public transit services in and around the <insert city> area, please type them below. Otherwise, please click "next question' to complete the survey.
end	Thank you for your participation! This survey is conducted by: Resource Systems Group, Inc. (RSG) For: The National Academies: Federal Transit Cooperative Research Program (TCRP) in conjunction with the <insert local transit agency> ***[Show logos of RSG, Natl. Academies, and <insert local transit agency>]***

APPENDIX C

Detailed Survey Results

Contents

Overview

Market research was conducted in three cities (Salt Lake City, Chicago, and Charlotte), representing a variety of different-sized cities with very different transit systems and different traveler characteristics. The data collected included traditional origin-destination travel data complemented by additional data on premium transit service characteristics, awareness and consideration of modal alternatives, and traveler attitudes.

A few new methods of data collection were employed to gather information desired for travel forecasting model estimation:

- Maximum Difference Scaling is a method to measure the importance of individual transit service characteristics with respondents choosing the best and worst options from a set of alternatives. There were eight maximum difference experiments in each of the three surveys.
- Choice-based Conjoint is a method to measure the stated preference of a combination of transit service characteristics with respondents choosing the best alternative. There were eight stated preference experiments in each of the three surveys.
- Attitudinal statements to the travel survey measures the attitudes of travelers on different aspects of travel. There were 15 attitudinal statements for the Salt Lake City survey (6 for transit users and 9 for non-transit users) and 18 attitudinal statements for the Chicago and Charlotte surveys.
- Questions about awareness and consideration of transit alternatives were included in the surveys for all three cities. In the initial survey for Salt Lake City, these questions were exploratory. In the second set of surveys for Charlotte and Chicago, these questions were more systematic and comprehensive to allow model estimation for awareness and consideration.

The transit service attributes collected in this research included two bundles of attributes and a series of other attributes that were not bundled:

- Station or stop design features - real-time information about the next transit arrival/departure, security, lighting/safety, shelter, cleanliness of the station, benches, and proximity to services.
- On-board features—seating availability, seating comfort, temperature, cleanliness of the transit vehicle, and productivity features (Wi-Fi, power outlets, etc.).
- Other features—identification of the transit vehicle, reliability, schedule span, transit frequency, transfer distance, walking distance and parking distance to the station, ease of boarding, and fare machines.

These attributes were included in the model estimation work for all three cities and further used in the model implementation and calibration for Salt Lake City. The market research conducted in this study collected data on mode choice behavior (attitudes, awareness and consideration, service attributes, and mode choice) as well as travel times for transit services successfully. These data were collected at a reasonable cost. The authors recommend that future data collection activities for mode choice behavior consider this template for data collection.

These survey results are provided to detail the traveler and trip characteristics represented in the survey. The survey was not designed to represent the full population, nor was it designed to be a representative sample because it was used in disaggregate modeling where behavioral differences are represented. These disaggregate models can be used in forecasting as long as the appropriate population proportions or sample weights are used to represent the population. The following survey results should not be interpreted as representative of the full population.

Market Research on Transit Service

There was no standard method for quantifying non-traditional and/or premium attributes of transit service found in the literature. One example of a challenging measure to quantify is reliability. Questions in other surveys asked about this in different ways that may have led to variation in response between surveys that merely had to do with how the question was phrased (e.g., “1 in 10 trips is 5 minutes late or more” vs. “9 out of 10 trips are on time”). Analytical techniques that are used (e.g., logit vs. other conjoint techniques, vs. simple rating/rankings) have also been found to vary in each study. In this study, the Maximum Difference Scaling (i.e., MaxDiff, also known as “Best-Worst” scaling) approach was used to measure the importance of premium transit service characteristics. In this method, the experiments are designed in such a way that respondents are required to choose their “most preferred” and “least preferred” options from a set of alternatives/items. MaxDiff is a relatively new conjoint technique, pioneered by Jordan Louviere in the early 1990s (Almquist et al. 2009). It is useful for obtaining rankings and relative preferences for a variety of different attributes, such as brand names or service benefits, which can be described in a single statement (e.g., “There are good sidewalks between the BRT stop and your home”). This technique has been used in many settings to test the attributes of transportation services, such as on-board amenities for proposed high-speed rail services in California (Outwater et al. 2010) and station amenities for upgraded New York City subway stations (Spitz et al. 2007).

Survey Administration

The survey was administered via a web-based survey to travelers in the Salt Lake City, Chicago, and Charlotte areas. Web-based surveys are more cost efficient to conduct, can report complex data more easily, and can provide a more interactive experience for the user than other surveys. There were some concerns over demographic bias in the web-based surveys but this was not a concern for our convenience sample. The major difference in administration from Salt Lake City to Chicago and Charlotte was that no in-person intercept field effort was conducted in Chicago and Charlotte and instead all administration was done online.

A sample size of 1,500 completed surveys was targeted for each city, with a minimum of 200 completed surveys within four quota cells (auto work or school trip, transit work or school trip, auto other trip, and transit other trip). The sampling plan was designed to include a sufficient range of travelers and trip types to support the statistical estimation of the coefficients of a choice model. By collecting data from a range of traveler and trip types it is possible to identify the ways in which different characteristics affect mode choice behavior. These differences can then be reflected in the structure and coefficients of the resulting choice model. The survey sample that supports choice model estimation does not need to be precisely proportional to the population as long as:

- Any behavioral differences are properly represented in the model, and
- The model is applied for forecasting using appropriate population proportions and/or sample weights.

Salt Lake City Survey

RSG administered the Salt Lake City Travel Survey from mid-July through early August 2009. The survey was made available to respondents online via email invitation containing a URL to the survey or via onsite intercepts using laptops in various locations throughout the Salt Lake City area. For the online recruiting, Utah Transit Authority's help was invaluable, as they provided 40,000 email addresses from their database which contained both UTA riders and non-riders. Additionally, the survey was administered online via business recruiting through major organizations, employers, and universities in the area, again using the email invitation method. For the onsite recruiting, the researchers surveyed over a 5-day period in Salt Lake City using laptop computers. The survey administration effort yielded an overall dataset with just over 2,000 respondents (total 2,017). This sample (TABLE C-1) provides a strong data set to conduct the analysis.

TABLE C-1. Salt Lake City trip purpose and mode of survey reported trips.

	Work /School Trips	Other Trips	Total
Auto	987	466	1,453
Transit	480	84	564
Total	1,467	550	2,017

Charlotte Survey

The Charlotte survey fielded from May 16, 2011–June 15, 2011, with a total of 1,527 respondents completing the survey. The survey was fielded first to the Charlotte Area Transit System (CATS) rider email list, from which 222 completes were obtained. Once the email list had been exhausted, the survey was fielded through a reputable online survey panel provider, which provided the remaining 1,305 completed surveys.

Respondents taking the survey were screened to ensure they qualified. Any respondents living outside the Charlotte area (Mecklenburg or Carabus counties) or who did not make a trip using auto or transit in the past week were terminated from the survey. Additionally, any respondents completing the survey in less than 7 minutes were not considered "completed" surveys, as this time was deemed too fast to have paid thorough attention to the survey. The median survey completion time was 21 minutes. TABLE C-2 presents the types of trips that were reported during the survey.

TABLE C-2. Charlotte trip purpose and mode of survey reported trips.

	Work/School Trips	Other Trips	Total
Auto	902	259	1,161
Transit	150	215	365
Total	1,052	474	1,526

Transit trips were over-sampled to ensure that this mode had enough samples for mode choice and choice set model estimation. Work trips were defined as commute trips to/from work; school trips were defined as trips to/from school; and other trips were trips that were made from home to a place other than work or school.

A mix of respondents in terms of age, income, and other demographics was surveyed. The age and income characteristics of the sample are shown in the next section.

Chicago Survey

The Chicago survey fielded from June 23, 2011–July 5, 2011, with a total of 1,515 respondents completing the survey. Respondents taking the survey were screened to ensure they qualified. Any respondents living outside the Chicago area (Cook, DeKalb, Kane, McHenry, or Will counties) or who did not make a trip using auto or transit in the past week were terminated from the survey. As with the Charlotte data, any respondents completing the survey in less than 7 minutes were removed from the dataset.

The link on Metra's website was up for 1 week and 19 completes were obtained from this source; other local transit agencies were unable to provide email lists or web links due to their own conflicting survey efforts at the time of administration. The remaining 1,496 completed surveys were obtained through a reputable online survey panel provider. The median survey completion time for Chicago was 20 minutes. TABLE C-3 presents the types of trips that were reported on during the survey.

TABLE C-3. Chicago trip purpose and mode of survey reported trips.

	Work/School Trips	Other Trips	Total
Auto	450	340	790
Transit	364	361	725
Total	814	701	1515

Transit Service Attribute Data Collection

The study's analytical approach involved a three-part survey that was conducted in Salt Lake City, UT in Phase 1 and in Chicago and Charlotte in Phase 2:

- The first part of the survey was designed to gather data on **awareness of transit options.**
- The second part of the survey presented **choice based conjoint (CBC) stated preference mode choice experiments** to travelers where they were asked to choose a mode based on different levels of attributes, including some attributes that were constructed as "bundles."
- The third part of the survey used **MaxDiff conjoint techniques**, which was used to evaluate the individual attributes that make up the bundles.

The second and third parts of the survey instrument were designed for the study to use conjoint analysis to measure preferences among transit features. The survey was intended to gather information to research awareness as well as non-traditional attributes. More detailed information on transit awareness and frequency of transit use was obtained in the Phase 2 surveys based on Phase 1 experience. The survey instrument and sampling designs were largely similar for all three cities to allow for comparisons in the data. The goal of the third part of the survey was to estimate the relative utility of a variety of transit service attributes. Confidence intervals around utilities for each attribute can be calculated to allow statistical differences between attributes to be demonstrated. MaxDiff was thought to be well suited to this exercise for the following reasons:

- MaxDiff experiments are simple for the respondent to understand and evaluate.
- MaxDiff can be used to evaluate a relatively large number of attributes (RSG has successfully tested in excess of 50 attributes, although a smaller set is reasonable for this study given the other parts of the survey and the complexity arising from having so many attributes).
- The setup produces results that show the relative importance of the items being rated, thus avoiding the problem where respondents rate most items as "important," making it more difficult to distinguish among individual items.

- In the context of studies that are similar to the current study, the values of the attributes can be expressed in terms of minutes of travel time or dollars of transit fare by including attributes in the MaxDiff experiments that represent travel time and travel cost savings.
- Further, the MaxDiff model specification can easily accommodate "bridging attributes" that may be used to link the model results with the mode choice model, allowing the analyst to evaluate the relative importance of non-traditional transit attributes (such as cleanliness of station, on-board temperature, ease of boarding, etc.) within the context of trip mode choices. This allows the results of the MaxDiff experiments to support recommendations about adjustments to standard mode choice model parameters.

As a general rule, all MaxDiff attributes, either statements or images, must be parallel in construction. For example, every attribute in these surveys is defined by both premium and standard attributes. Likewise, it is important for all attributes to be positive and as clear as possible. MaxDiff attributes may have levels (for instance, "BRT bus arrives every 10 minutes" and "BRT bus arrives every 20 minutes"); however using levels does allow for the possibility of some "no brainer" comparisons if both the statements appear in the same experiment. But this possibility does not preclude meaningful comparisons between items. RSG keeps the number of attributes with levels to a minimum to ensure that respondents are challenged as they trade off which transit service benefit is most important and which is least important to them.

FIGURE C-1 shows a screenshot of the MaxDiff experiment. Respondents were asked to indicate their "most likely" and "least likely" choices among three alternatives shown.

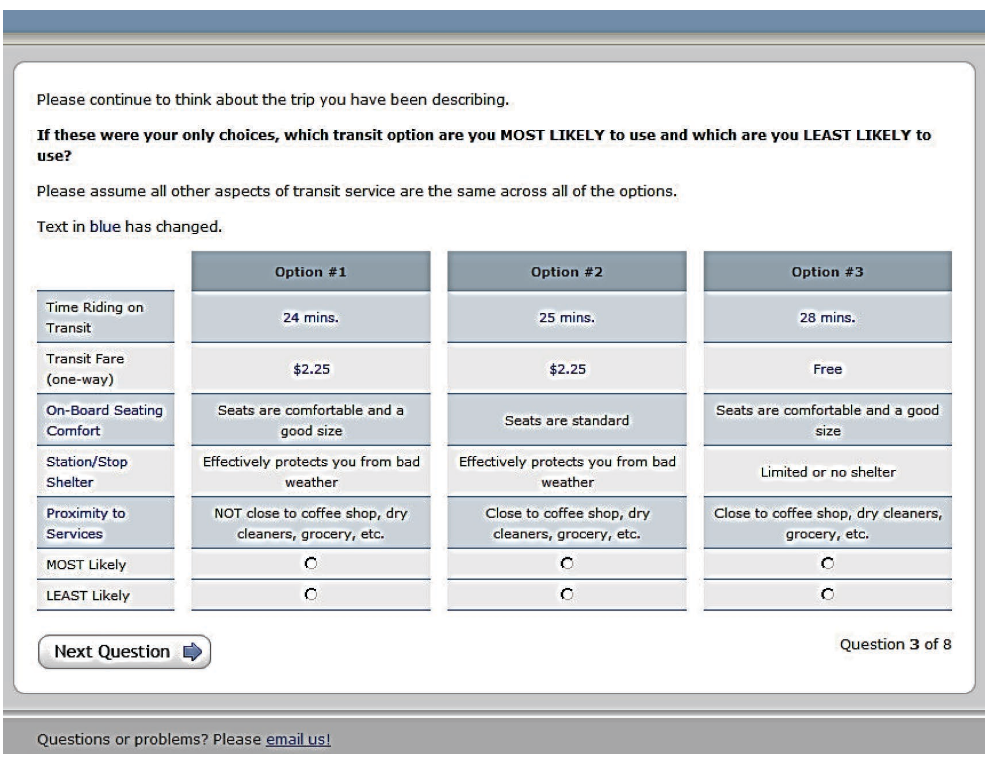
Transit Service Attributes for Market Research

A comprehensive set of attributes that affect the level of service offered by transit facilities and differentiate premium transit services from standard transit services was analyzed. For this project, using the important transit attributes identified in the literature review as a basis, RSG constructed a list of attribute statements to include in the MaxDiff and CBC sections of the survey. TABLE C-4 presents a list of the transit attributes that are analyzed in this study.

There were several considerations that went into determining the attributes list which are described in this section:

- **Length of survey and associated respondent fatigue—**The complexity of the survey and the various analysis techniques being employed necessitated breaking the survey into three parts and could make the survey quite long. In order to reduce respondent fatigue and still be able to prove the concept of this project, variables to test were carefully selected so that they would best allow measuring the most important factors that differentiate premium transit services from ordinary bus services. Certain traditional attributes that are referred to as *anchor attributes* were selected to be shown in both the MaxDiff and CBC sections in order to allow linking results from the two techniques, such as travel time and travel cost. Beyond these anchoring attributes, the overall list of MaxDiff statements was reduced from 100 to 37, focusing on non-traditional variables that were felt to be most appropriate. It is generally recommended that there be a maximum of approximately 60 statements when using simple attributes (such as images, or short phrases) or a maximum of approximately 40 statements when using more complex attributes that require a long, detailed statement.

- **Difficulty of describing certain non-traditional attributes—**Non-traditional attributes can be difficult to describe and quantify because respondents' opinions of them can be emotional and varied. For example, the researchers chose to include two safety-related statements for the MaxDiff section that have been found to be important in previous studies reviewed in the Literature Review (Chapter 2) because some respondents may feel the need for safety more acutely than other respondents, and what makes one respondent feel safe may not be the same for another. In the CBC section the researchers tested the affect of premium versus standard attributes in both on-board and station/stop amenities. Here, the researchers grouped into "bundles" various commonly accepted aspects of premium amenities and standard amenities in order to be able to reduce the number of variables to be tested. The researchers defined these groupings for the respondent to make it easy for them to understand what is meant by premium versus standard. The "bundle" attributes and definitions are shown in the following section.
- **Selection of appropriate attributes that are mode neutral and are applicable across transit services in varying geographies—**Third, the researchers selected variables not limited by transit mode or by relatively limited markets; rather, the researchers included as many variables as possible that would be applicable across many transit systems in many markets. Examples of variables that the researchers felt were not applicable across modes are queue jumping, which would pertain only to buses, or the stopping position at a platform, which would pertain to trains.
- **Consideration of whether the attribute can actually be represented with traditional modeling methods—**Finally, a few of the level-of-service features, such as queue jumping, signal priority and dedicated right-of-way can be implemented in models with specified level-of-service improvements relative to "typical" bus services. While the authors wonder whether there is intrinsic value beyond time savings for such features, the choice was made not to include these in the list of attributes in part because it would be very difficult to parse these effects in a MaxDiff experiment.



Please continue to think about the trip you have been describing.

If these were your only choices, which transit option are you MOST LIKELY to use and which are you LEAST LIKELY to use?

Please assume all other aspects of transit service are the same across all of the options.

Text in blue has changed.

	Option #1	Option #2	Option #3
Time Riding on Transit	24 mins.	25 mins.	28 mins.
Transit Fare (one-way)	$2.25	$2.25	Free
On-Board Seating Comfort	Seats are comfortable and a good size	Seats are standard	Seats are comfortable and a good size
Station/Stop Shelter	Effectively protects you from bad weather	Effectively protects you from bad weather	Limited or no shelter
Proximity to Services	NOT close to coffee shop, dry cleaners, grocery, etc.	Close to coffee shop, dry cleaners, grocery, etc.	Close to coffee shop, dry cleaners, grocery, etc.
MOST Likely	○	○	○
LEAST Likely	○	○	○

Next Question

Question 3 of 8

Questions or problems? Please email us!

FIGURE C-1. Screenshot of MaxDiff experiment.

TABLE C-4. Transit service attributes.

Category	Definition	Premium Attributes	Standard Attributes
Station/stop design features	Real-time info about next transit arrival/departure	Real-time info available	No real-time info available
	Station/stop security	Enhanced (e.g., emergency call-buttons, surveillance cameras, security personnel)	No added security features
	Station/stop lighting/safety	Well-lit with police presence	Normal lighting and no police presence
	Station/stop shelter	Effectively protects you from bad weather	Limited or no shelter
	Proximity to services	Close to coffee shop, dry cleaners, grocery, *etc.*	Not close to coffee shop, dry cleaners, grocery, *etc.*
	Cleanliness of station/stop	Well-maintained and clean	Not well maintained
	Station/stop benches	Clean and comfortable	Some benches
On-board features	On-board seating availability	Always available seats	Often crowded; you might not get a seat
	On-board seating comfort	Seats are comfortable and a good size	Seats are standard
	On-board temperature	Effective air-conditioning and heating	Some air-conditioning and heating
	Cleanliness of transit vehicle	Very new and clean	Maintained, but not new
	Productivity features	Wi-Fi, power outlets, etc. available	Productivity features not available
Other features	Route name/number identification	Easy to identify on outside of transit vehicle	Difficult to immediately identify on outside of transit vehicle
	Reliability	1 in 10 trips are 5 minutes late or more	1 in 10 trips are 15 minutes late or more
	Schedule span	Transit runs from 4 AM until 11 PM	Transit runs during rush hours only
	Transit frequency	Arrives every 10 minutes in rush hour and every 20 minutes in non-rush hour	Arrives every 20 minutes in rush hour and every 60 minutes in off-peak
	Transfer distance	Convenient (short walking distance or on same platform)	Several minute walk
	Station/stop distance	Within 10 minutes' walk of your home/work	Not within 10 minutes' walk of your home/work
	Parking distance	Within 10 minutes' walk from station/stop	Not within 10 minutes' walk from station/stop
	Ease of boarding	Easy to board; doors are level with platform/curb	Must step up to board
	Fare machines	Fast and easy to use	Slow and somewhat confusing

To ensure respondents would understand exactly what differences exist between premium transit features vs. standard transit features, a clear definition of the features was included. Respondents were first shown the definition page and could return to it at any time during the eight experiments by simply rolling over the information button (blue circle with "i") with their mouse. Examples of the definition pages for premium vs. standard on-board features, stations/stop design, and arrival/departure information are shown in FIGURE C-2.

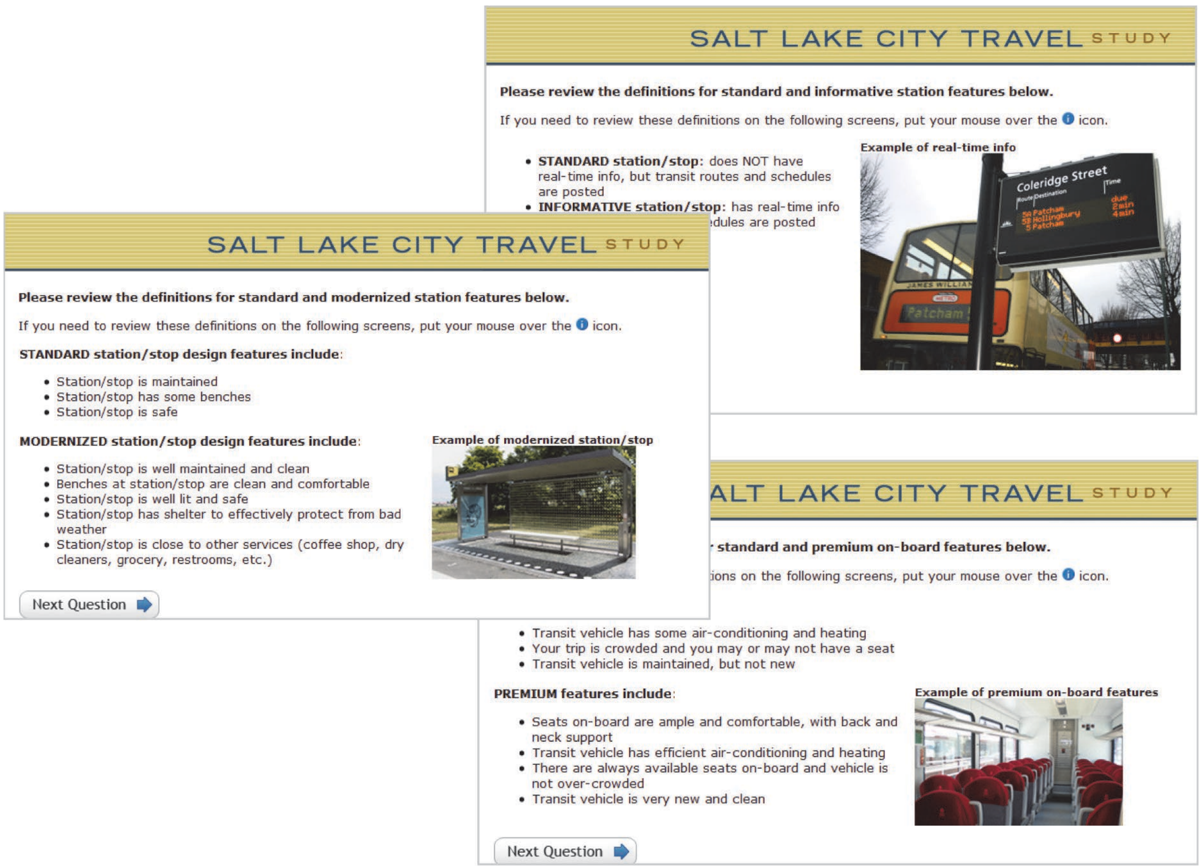


FIGURE C-2. Premium vs. standard transit feature definitions.

Traveler Attitudes

Respondents for all three surveys were asked to describe a specific, recent, home-based trip, including travel mode, access and egress modes, transfers, trip duration, cost, stops made along the way, and destination. To help understand different types of respondent segments, each respondent was shown a list of attitudinal statements, as shown in TABLE C-5. In the first survey in Salt Lake City, these differed somewhat depending on whether they were categorized as a transit user or non-user. In the second and third surveys, in Chicago and Charlotte, respectively, these statements were asked for all respondents. In addition, some changes to the attitudinal statements for Chicago and Charlotte were made to reflect the importance of the various statements in the Salt Lake City factor analysis models (i.e., some statements were dropped, other statements were added or revised).

Traveler attitudes are obtained for 18 attitudinal questions from the surveys in Charlotte and Chicago and 15 attitudinal questions from the survey in Salt Lake City. There are five ranges of responses to these attitudinal questions (strongly disagree, somewhat disagree, neutral, somewhat agree, strongly agree). FIGURE C-3, FIGURE C-4, and FIGURE C-5 show the range of responses, sorted from the least agreement with the statement to the most agreement with the statement.

In Charlotte (FIGURE C-3), travelers rate statements that are pro-transit as the ones they least agree with and several statements that are anti-transit are ones they most agree with. The one exception is the statement "I am not afraid to ride transit," which has strong agreement among Charlotte travelers. Protecting the environment has very strong agreement as well as willingness to carpool or ride transit to reduce emissions. Charlotte travelers are not willing to pay higher tolls to reduce congestion and to some degree are willing to tolerate delays if comfortable. They value saving time over choosing a particular mode.

In Chicago (FIGURE C-4), travelers are in more agreement with pro-transit statements than in Charlotte and are also not afraid to ride transit, which has very strong agreement. Protecting the environment also has very strong agreement, as well as willingness to carpool or ride transit to reduce emissions. Chicago travelers are also not willing to pay higher tolls to reduce congestion and to some degree are willing to tolerate delays if comfortable. They also value saving time over choosing a particular mode. The Salt Lake City attitudinal questions (FIGURE C-5) were completed in Phase 1 and do not match exactly those used in Charlotte and Chicago, but do have many similarities.

TABLE C-5. Traveler attitude statements from three surveys.

	Salt Lake City		Chicago and Charlotte
Attitudes Toward Travel	Transit Users	Transit Non-Users	All Users
I currently make an effort to take public transit whenever I can.	√		√
If I wanted to, I could use public transit more frequently.	√		√
I am able to take transit from my neighborhood to downtown Salt Lake City.	√		
I am able to take transit from my neighborhood to important and useful destinations (i.e., places I work, shop, go to school, run errands, etc.)	√		
The transit system makes it easy for me to purchase my fare.	√		
When waiting for transit, I know when the next bus or train is scheduled to arrive.	√		
It's easy to plan a trip using transit.		√	√
I'm the kind of person who rides transit.		√	√

TABLE C-5. (Continued).

Attitudes Toward Travel	Salt Lake City		Chicago and Charlotte
	Transit Users	Transit Non-Users	All Users
Transit is often dirty.		√	√
There's just not enough transit frequency or hours of service for transit to be convenient.		√	
I'm not afraid to ride transit.		√	√
Getting to and from transit stations/stops is not pedestrian friendly and is very unpleasant.		√	√
For me, car is king! Nothing will replace my car as my main mode of transportation.		√	√
I have to drive to get to transit anyway, so I may as well just drive my car the whole way.		√	√
I would take transit if the environment in and near the stations/stops was improved with nice lighting, benches, and convenient vendors, like coffee shops, dry cleaners, etc.		√	
More than saving time, I prefer to be productive when traveling.			√
If it would save time, I would change my form of travel.			√
As long as I am comfortable when traveling, I can tolerate delays.			√
Protecting the environment is very important to me.			√
My days of taking transit are over.			√
Privacy is important to me when I travel			√
My car reflects who I am			√
I am willing to carpool or take public transit more frequently to reduce air pollution and carbon emissions from my vehicle			√
I am willing to pay higher tolls if they are used to reduce air pollution and carbon emissions			√

Note: A check in this table indicates that the statement was included in that survey.

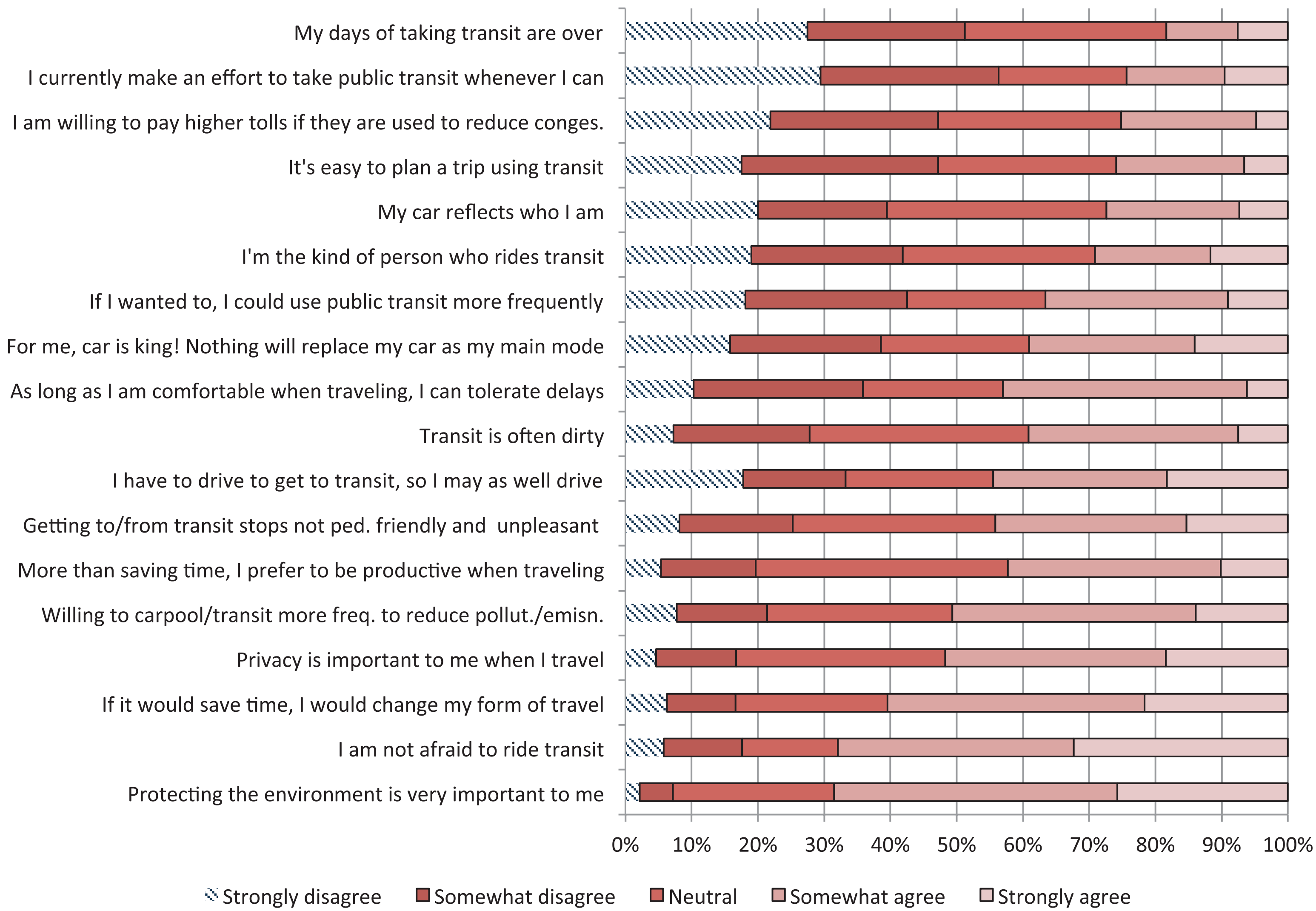


FIGURE C-3. Charlotte traveler attitudes—least to most agreement.

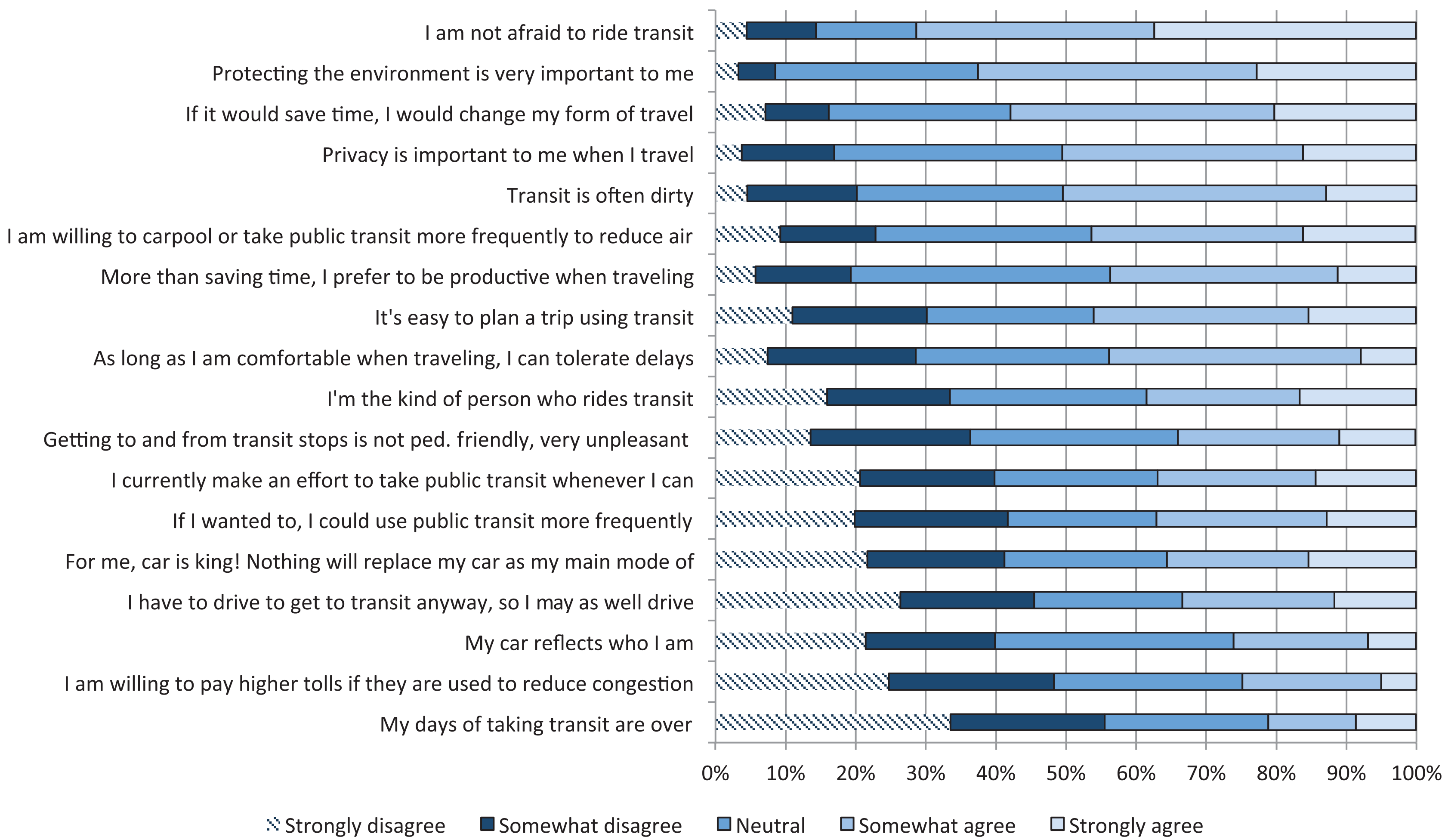


FIGURE C-4. Chicago traveler attitudes—least to most agreement.

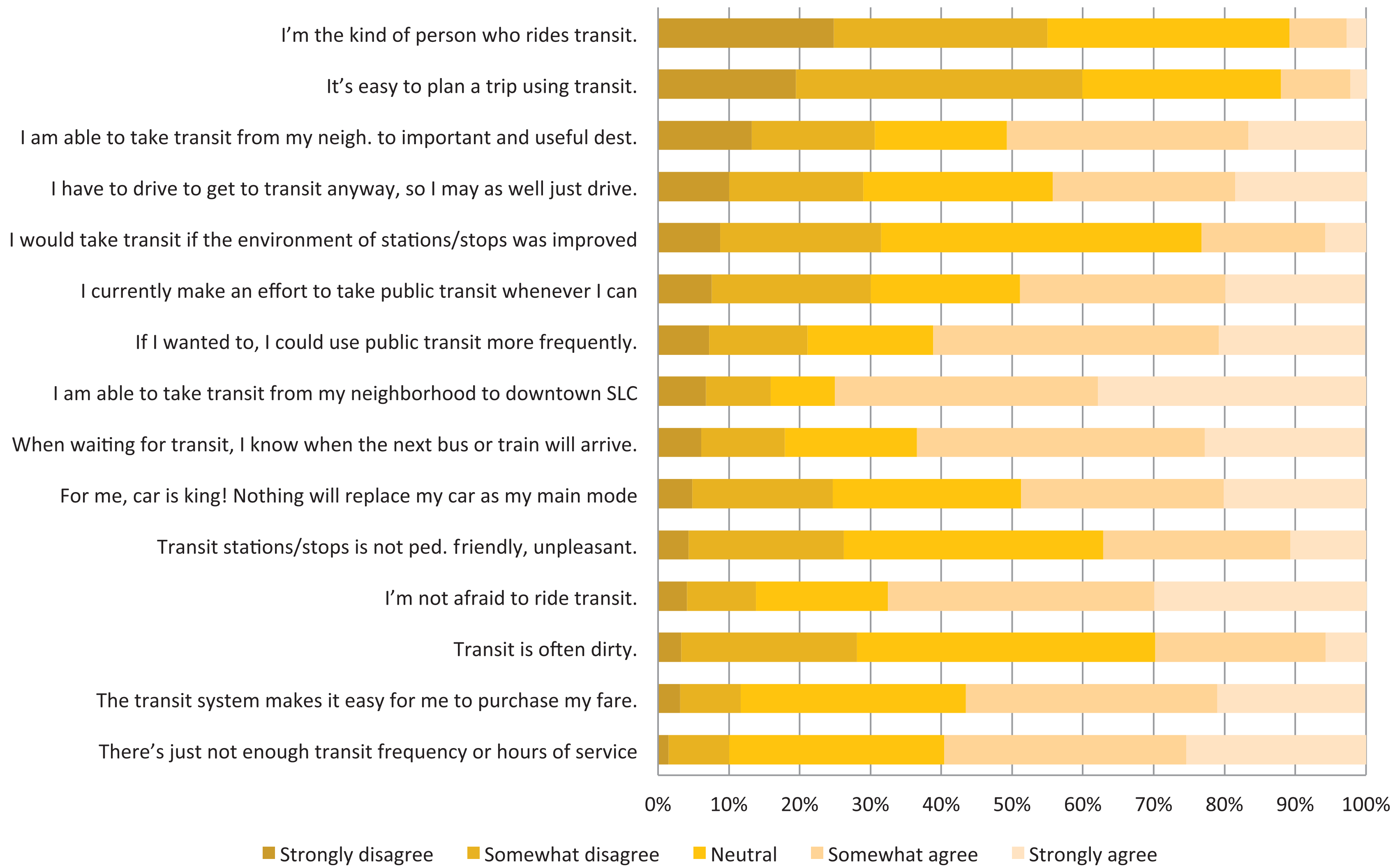


FIGURE C-5. Salt Lake City traveler attitudes—least to most agreement.

In addition to the attitudinal questions, two other questions were asked that are considered latent variables (i.e., variables that cannot be directly measured):

- Willingness to walk (how far is the respondent willing to walk for a specific trip)
- Informed about transit (how informed is the respondent about transit services)

As shown in FIGURE C-6, "20 minutes" seems to be the threshold for walk to transit. There are around 90% of respondents who are not willing to walk for 20 minutes to reach a transit stop/station. On average, people using transit mode are more willing to walk than people who drive. About 14% of respondents who drive in their reference trips are not willing to walk at all, compared to only 1% of transit riders who are not willing to walk at all. The willingness to walk question was added to the surveys for Chicago and Charlotte and was not asked in the Salt Lake City survey.

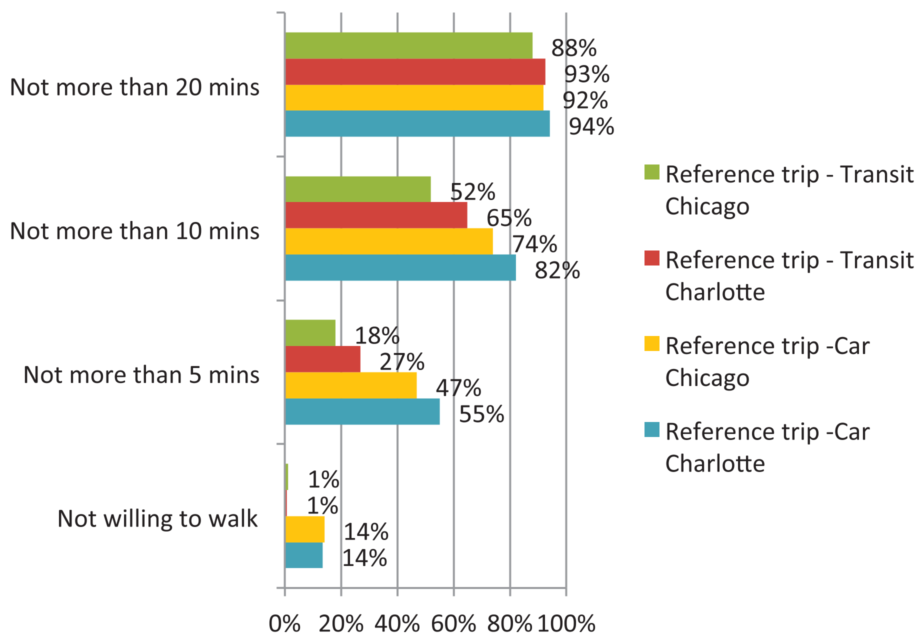


FIGURE C-6. Willingness to walk to transit for Charlotte and Chicago.

The survey respondents were asked to select how informed they are about the survey area's public transit services regarding types of service available, routes, schedules, fare options etc. (FIGURE C-7). There is no significant difference about respondents' awareness of area public transit for the three cities, except that Charlotte has slightly fewer respondents (8% percentage points) being very informed.

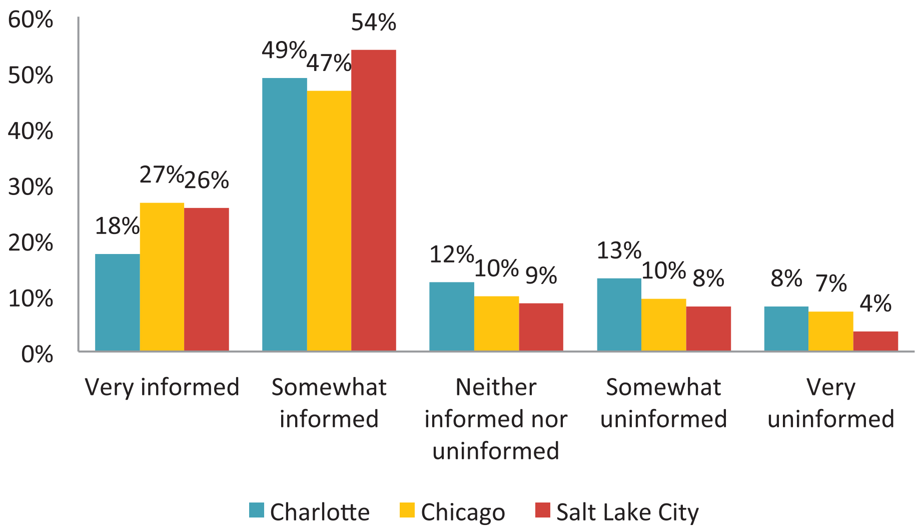


FIGURE C-7. Awareness of transit for Charlotte, Chicago, and Salt Lake City.

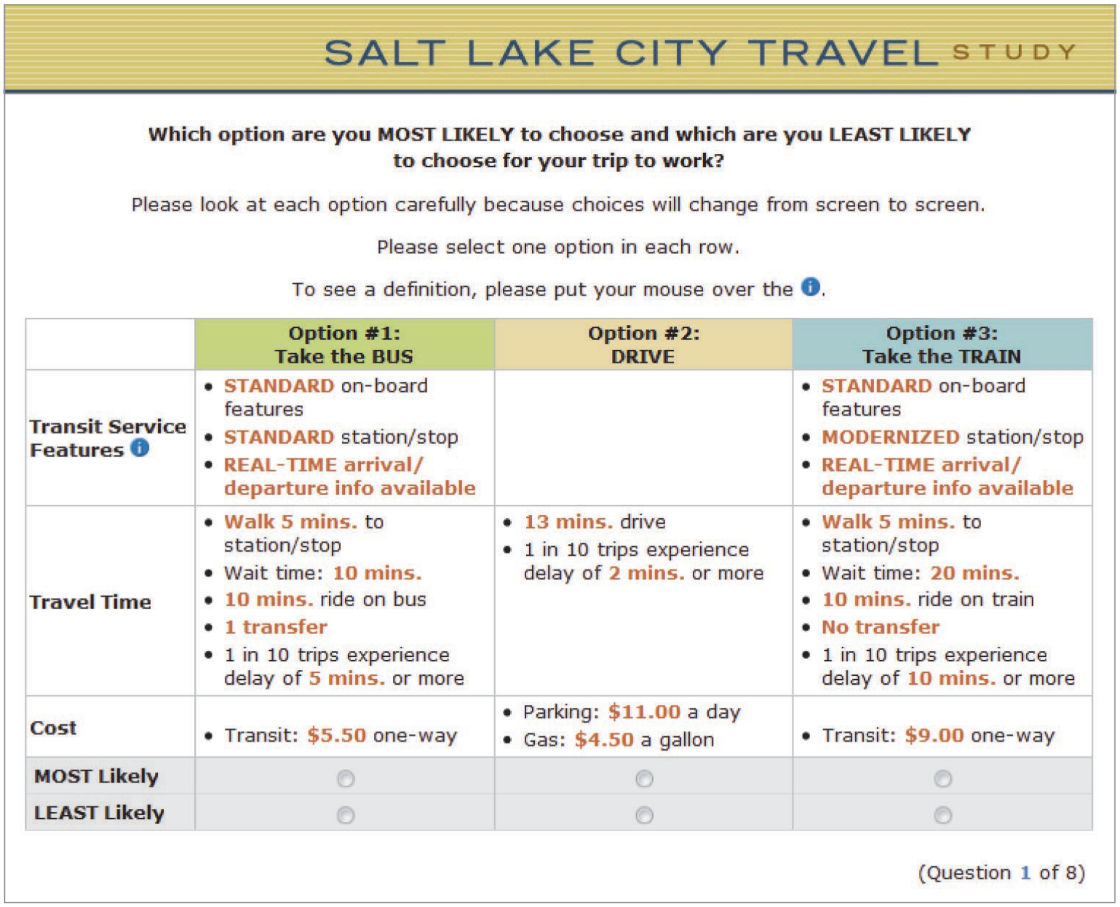
Stated Preference

Stated preference questions were included to evaluate tradeoffs travelers make when choosing a mode. Survey respondents were asked to complete eight stated preference questions with varying travel time, costs, and transit service features to force choices among three options shown in each question. An experimental design was created that would allow the calculation of value in terms of time (minutes) or in cost (dollars) for all the traditional variables used in forecast demand modeling. Additionally, because the goal of this research is to determine the effect premium vs. standard transit features have on people's choices and to improve estimations of mode choice models and transit path builders, bundles of non-traditional variables (premium transit vs. standard transit features) were included in the stated preference design to allow calculation of a specific value for each category. The values for these non-traditional bundles were to be linked to the values of their specific components generated through the MaxDiff analysis, a process that is described in Appendix E.

Respondents were shown three trip options on each page:

- Option 1a: Trip made by car (if car was available)
- Option 1b: Trip made by randomly selected transit type (bus or train, if car was not available)
- Option 2: Trip made by bus
- Option 3: Trip made by train

These options were shown in random order to prevent bias. An example of a stated preference experiment page is shown in FIGURE C-8.



SALT LAKE CITY TRAVEL STUDY

Which option are you MOST LIKELY to choose and which are you LEAST LIKELY to choose for your trip to work?

Please look at each option carefully because choices will change from screen to screen.

Please select one option in each row.

To see a definition, please put your mouse over the ⓘ.

	Option #1: Take the BUS	Option #2: DRIVE	Option #3: Take the TRAIN
Transit Service Features ⓘ	• STANDARD on-board features • STANDARD station/stop • REAL-TIME arrival/departure info available		• STANDARD on-board features • MODERNIZED station/stop • REAL-TIME arrival/departure info available
Travel Time	• Walk 5 mins. to station/stop • Wait time: 10 mins. • 10 mins. ride on bus • 1 transfer • 1 in 10 trips experience delay of 5 mins. or more	• 13 mins. drive • 1 in 10 trips experience delay of 2 mins. or more	• Walk 5 mins. to station/stop • Wait time: 20 mins. • 10 mins. ride on train • No transfer • 1 in 10 trips experience delay of 10 mins. or more
Cost	• Transit: $5.50 one-way	• Parking: $11.00 a day • Gas: $4.50 a gallon	• Transit: $9.00 one-way
MOST Likely	○	○	○
LEAST Likely	○	○	○

(Question 1 of 8)

FIGURE C-8. Example of stated preference experiment.

To ensure survey respondents would understand exactly what differences exist between premium transit features vs. standard transit features, a clear definition of the features was included. Respondents were first shown the definition page and could return to it at any time during the eight experiments by simply rolling over the information button (blue circle with “i”) with their mouse. The bundle attributes’ definitions of premium, modernized, and informative versus standard and are shown in TABLE C-6. The attribute levels for the stated preference experiments are shown in TABLE C-7 and TABLE C-8 for each mode option (auto and transit).

TABLE C-6. Definitions of premium and standard transit variables by category.

On-Board Amenities	Premium	
	1	Vinyl seats
	2	Transit has efficient air-conditioning & heating
	3	Your trip is uncrowded and you have a seat
	4	Train/bus is new & very clean
	5	Seats are comfortable with back and neck support
	6	Transit ride is smooth & quiet
	7	Clear announcements indicate next stop & any delays
	Standard	
	1	Cloth seats
	2	Transit has some air-conditioning & heating
	3	Your trip is crowded and you may or may not have a seat
	4	Train/bus is maintained, but not new.
Station/Stop Amenities - DESIGN	Modernized Station/Stop	
	1	Has bicycle storage
	2	Is well lit and safe
	3	Is well maintained & clean
	4	Has comfortable benches
	5	Is spacious, with good visibility & open sightlines
	6	Has modern looking shelter to protect from bad weather
	7	Has been recently renovated with high-quality materials
	8	Has retail services such as coffee shop, dry cleaners, etc.
	Standard	
	1	Is maintained
	2	Graffiti and vandalization are NOT present
	3	Has some benches
	4	Is safe
Station/Stop Amenities - INFORMATION	Informative Station/Stop	
	1	Signs show minutes until next arrival/departure
	2	Transit routes & schedules are clearly posted
	3	Service change information is posted & announced
	4	Posted routes & schedules are easy to understand
	5	Posted routes & schedules are always accurate
	6	Neighborhood map with streets is clearly posted
	Standard	
	1	Transit routes & schedules are posted
	2	Name of station/stop is visible

TABLE C-7. Stated preference experiment attribute levels.

<table>
<tr><th>Attribute</th><th colspan="2">Variation</th><th>Auto Option</th><th>Transit Options</th></tr>
<tr><td rowspan="8">In-vehicle travel time</td><td rowspan="4">Trip < 26 minutes</td><td>1</td><td colspan="2">3 minutes shorter than current trip</td></tr>
<tr><td>2</td><td colspan="2">Same as current trip</td></tr>
<tr><td>3</td><td colspan="2">3 minutes longer than current trip</td></tr>
<tr><td>4</td><td colspan="2">5 minutes longer than current trip</td></tr>
<tr><td rowspan="4">Trip ≥ 26 minutes</td><td>1</td><td colspan="2">10% shorter than current trip</td></tr>
<tr><td>2</td><td colspan="2">Same as current trip</td></tr>
<tr><td>3</td><td colspan="2">10% longer than current trip</td></tr>
<tr><td>4</td><td colspan="2">20% longer than current trip</td></tr>
<tr><td rowspan="4">Parking cost</td><td rowspan="4"></td><td>1</td><td>Free</td><td>Free</td></tr>
<tr><td>2</td><td>Same as current ($5 if currently park free)</td><td>50% more ($5 if currently park free)</td></tr>
<tr><td>3</td><td>50% more</td><td>n/a</td></tr>
<tr><td>4</td><td>100% more</td><td>n/a</td></tr>
<tr><td rowspan="4">Gas cost</td><td rowspan="4"></td><td>1</td><td>$1.50</td><td>n/a</td></tr>
<tr><td>2</td><td>$2.50</td><td>n/a</td></tr>
<tr><td>3</td><td>$3.50</td><td>n/a</td></tr>
<tr><td>4</td><td>$4.50</td><td>n/a</td></tr>
<tr><td rowspan="8">Reliability*</td><td rowspan="4">Local trip</td><td>1</td><td>1 out of 10 trips experiences a delay of <30% of current trip> or more</td><td>1 out of 10 trips experiences a delay of 5 minutes or more</td></tr>
<tr><td>2</td><td>1 out of 10 trips experiences a delay of <50% of current trip> or more</td><td>1 out of 10 trips experiences a delay of 10 minutes or more</td></tr>
<tr><td>3</td><td>1 out of 10 trips experiences a delay of <70% of current trip> or more</td><td>n/a</td></tr>
<tr><td>4</td><td>1 out of 10 trips experiences a delay of <90% of current trip> or more</td><td>n/a</td></tr>
<tr><td rowspan="4">Long trip</td><td>1</td><td>1 out of 10 trips experiences a delay of <30% of current trip> or more</td><td>1 out of 10 trips experiences a delay of 5 minutes or more</td></tr>
<tr><td>2</td><td>1 out of 10 trips experiences a delay of <50% of current trip> or more</td><td>1 out of 10 trips experiences a delay of 10 minutes or more</td></tr>
<tr><td>3</td><td>1 out of 10 trips experiences a delay of <50% of current trip> or more</td><td>n/a</td></tr>
<tr><td>4</td><td>1 out of 10 trips experiences a delay of <60% of current trip> or more</td><td>n/a</td></tr>
<tr><td rowspan="8">Transit fare (most respondents)</td><td rowspan="4">Local trip</td><td>1</td><td>n/a</td><td>20% less than current trip</td></tr>
<tr><td>2</td><td>n/a</td><td>Same as current ($2 if didn’t use transit for current trip)</td></tr>
<tr><td>3</td><td>n/a</td><td>20% more than current trip</td></tr>
<tr><td>4</td><td>n/a</td><td>30% more than current trip</td></tr>
<tr><td rowspan="4">Long trip</td><td>1</td><td>n/a</td><td>10% less than current trip</td></tr>
<tr><td>2</td><td>n/a</td><td>Same as current ($6 if didn’t use transit for current trip)</td></tr>
<tr><td>3</td><td>n/a</td><td>10% more than current trip</td></tr>
<tr><td>4</td><td>n/a</td><td>20% more than current trip</td></tr>
</table>

TABLE C-8. Stated preference experiment attribute levels, Continued.

Attribute	Variation		Auto Option	Transit Options
Transit fare (for those with free transit pass)	Local trip	1	n/a	Free
		2	n/a	$0.50
		3	n/a	$1.00
		4	n/a	$2.00
	Long trip	1	n/a	Free
		2	n/a	$1.00
		3	n/a	$2.00
		4	n/a	$4.00
Access mode		1	n/a	Walk
		2	n/a	Drive/get dropped off
Access time		1	n/a	5 minute <insert access mode> to station/stop
		2	n/a	10 minute <insert access mode> walk to station/stop
Wait time	Down-town	1	n/a	Wait 3 minutes
		2	n/a	Wait 5 minutes
		3	n/a	Wait 8 minutes
		4	n/a	Wait 12 minutes
	Outside down-town	1	n/a	Wait 5 minutes
		2	n/a	Wait 10 minutes
		3	n/a	Wait 15 minutes
		4	n/a	Wait 20 minutes
Transfers		1	n/a	No transfer
		2	n/a	Transfer
On-board amenities		1	n/a	PREMIUM on-board transit amenities
		2	n/a	STANDARD on-board transit amenities
Station/stop design		1	n/a	MODERNIZED station/stop
		2	n/a	STANDARD station/stop design
Real time info**		1	n/a	INFORMATIVE station/stop
		2	n/a	STANDARD station/stop information
Local/ long trip		1	Local	
		2	Long (if current trip is < 10 miles, then only show local)	

*Reliability was modified for the Chicago and Charlotte surveys to better reflect the way in which transit agencies use and communicate this information. The new definition was x% of trips delayed by y minutes or more.

**Real time information was included in the station/stop design bundle in the Chicago and Charlotte surveys because this resulted in inconsistencies in the mode choice modeling for Salt Lake City. In addition, span of service was added to the Chicago and Charlotte stated preference experiments (and tested in the models) because the attribute was deemed important to making the decision to use transit.

Demographic Characteristics

Gender composition of the Salt Lake City sample is quite different from Chicago and Charlotte (FIGURE C-9). There are about 56% of male respondents in Salt Lake City while the other two cities only have around 35%. Among the Charlotte and Chicago female respondents, 70% are workers and the remaining 30% are either homemakers, retired, or not employed during the time of the survey. A similar percentage (72%) of Salt Lake City female respondents are workers, who are either full-time (54%) or part-time (19%). Among the male respondents, about 79% are workers and the rest (21%) are either homemakers, retired, or not employed during the time of the survey. About 85% of male respondents from Salt Lake City are employed, with 74% full-time and 11% part-time.

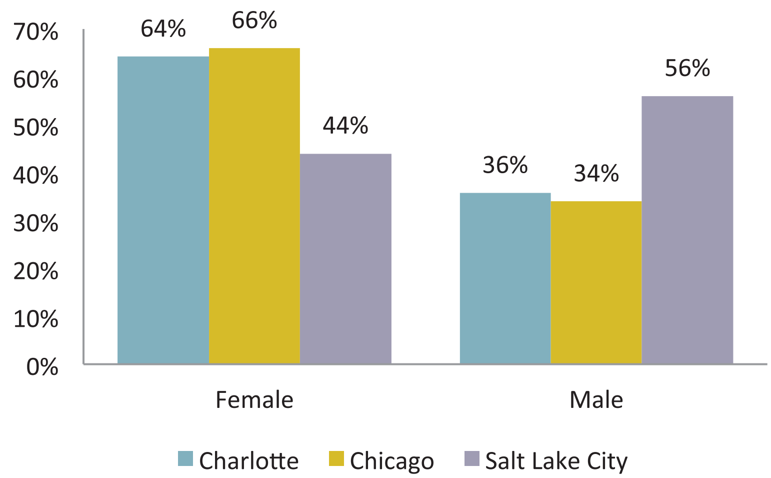


FIGURE C-9. Gender statistics for Charlotte, Chicago, and Salt Lake City.

On average, Chicago respondents are older than those of the other two cities (FIGURE C-10). The median age of Chicago respondents falls into the 45-54 yrs group, while the median age of the other cities is within the 35-44 yrs range.

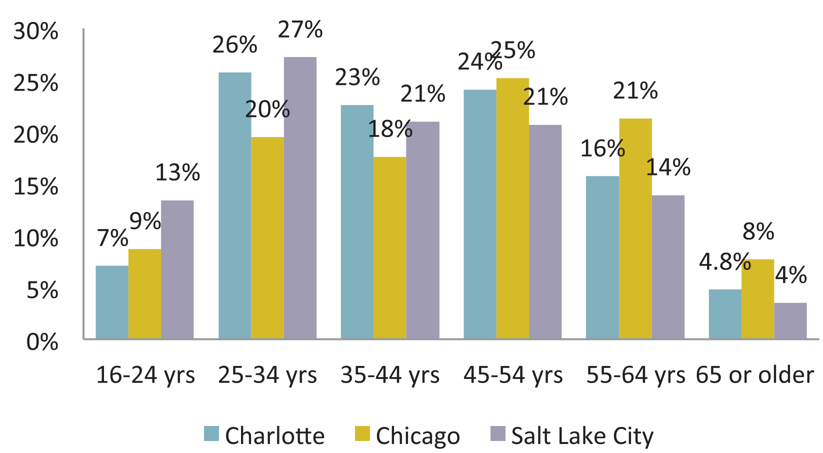


FIGURE C-10. Age statistics for Charlotte, Chicago, and Salt Lake City.

Chicago stands out as slightly different from the other two cities in terms of employment status (FIGURE C-11). Among Chicago respondents, retired persons are almost twice as many as in the other two cities, and full-time workers are more than 10% less than in other two cities. It also has higher percentage of homemaker and not-employed workers (Salt Lake City does not have the category "self employed").

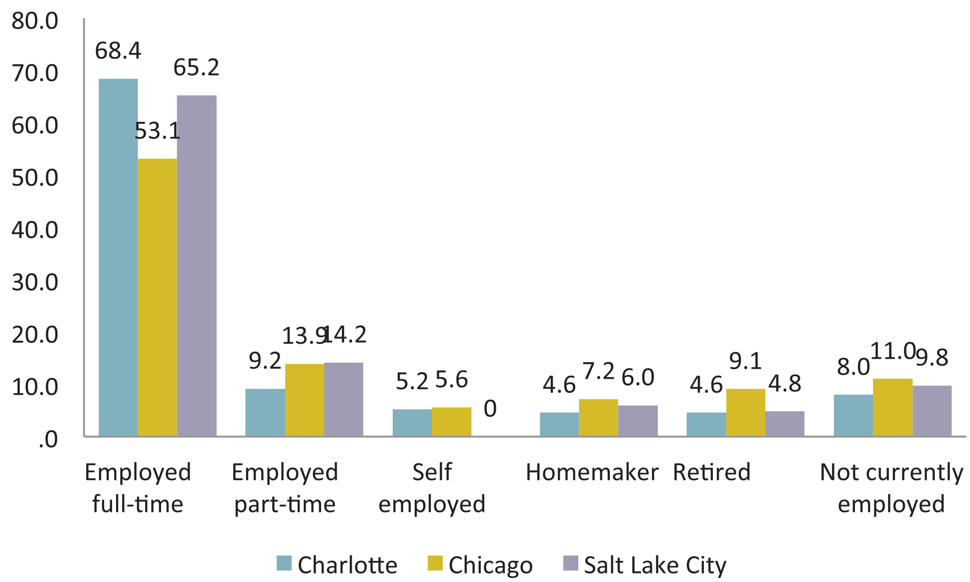
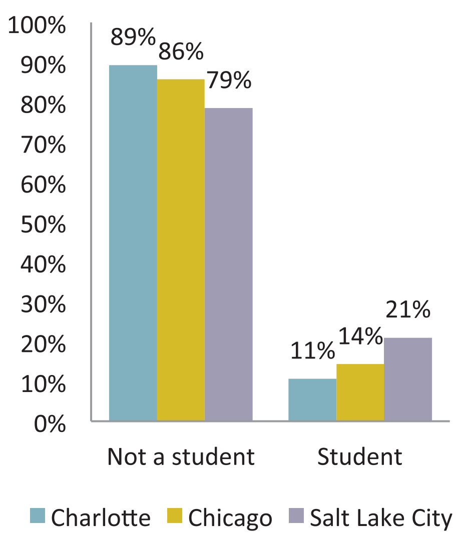


FIGURE C-11. Employment status statistics for Charlotte, Chicago, and Salt Lake City.

The characteristics of the student population are presented in FIGURE C-12. The Chicago data represents about 14% student respondents. Among the student respondents, almost 62% are full-time students and the other 38% are part-time students. Salt Lake City data has 21% student respondents and a similar full-time/part-time split as Chicago. The Charlotte data has only 11% student respondents (half that of Salt Lake City), and full-time/part-time students are half split.



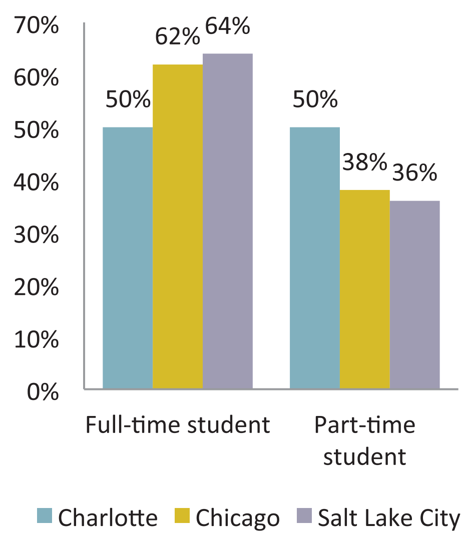


FIGURE C-12. Student status statistics for Charlotte, Chicago, and Salt Lake City.

The household size and composition characteristics are presented in FIGURE C-13. Salt Lake City respondents tend to have bigger families, with 24% of them living in households with five or more members, while the other two cities only have about 10% of respondents in households with five or more members.

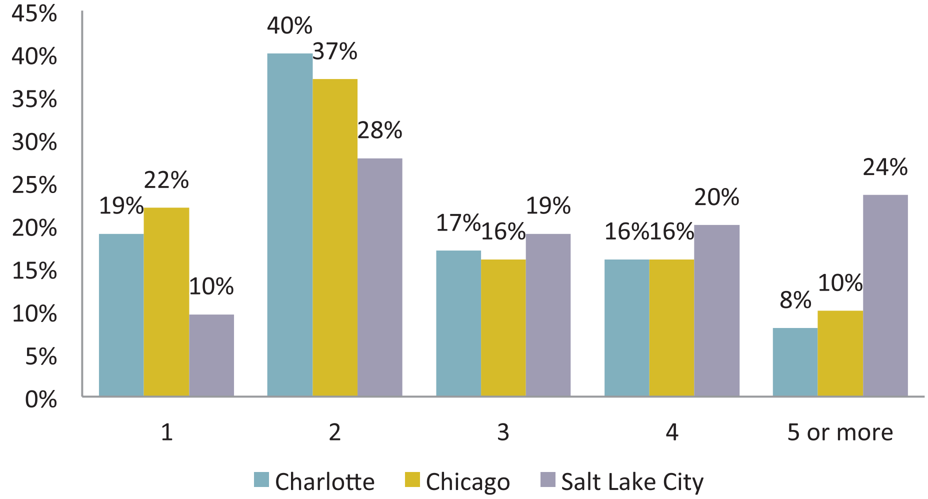


FIGURE C-13. Household size statistics for Charlotte, Chicago, and Salt Lake City.

Of the three cities, Charlotte has the highest percentage (11%) of respondents earning more than $150,000 and the smallest percentage (17%) of respondents earning less than $35,000 (FIGURE C-14).

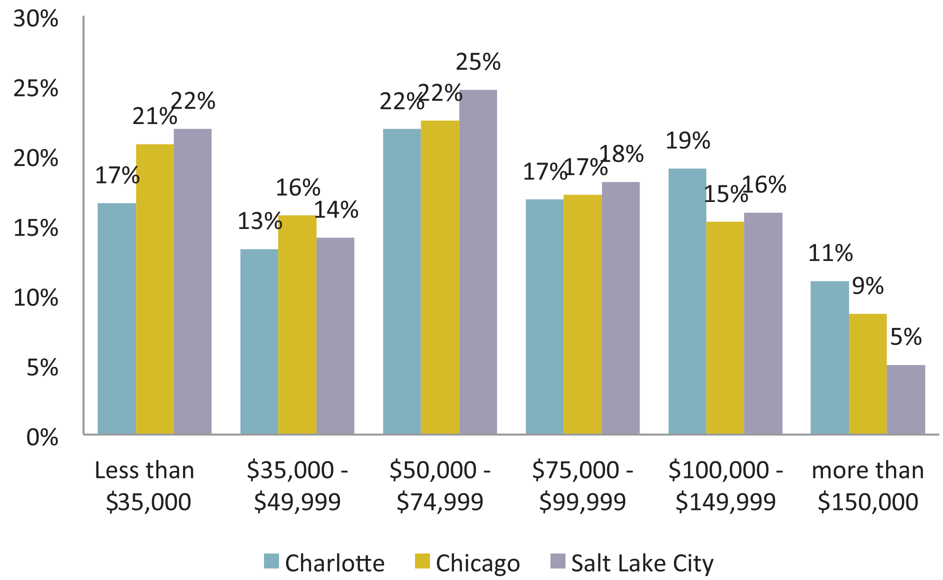


FIGURE C-14. Income statistics for Charlotte, Chicago, and Salt Lake City.

Thirty-five percent of households in the Salt Lake City sample own three, four, or five-plus cars, while the Charlotte and Chicago samples only have 22% and 19%, respectively (FIGURE C-15). This reflects the household size composition feature in Salt Lake City. The mean motorized vehicle ownership rate per household is around 1.96 (Charlotte), 1.71 (Chicago), and 2.26 (Salt Lake City).

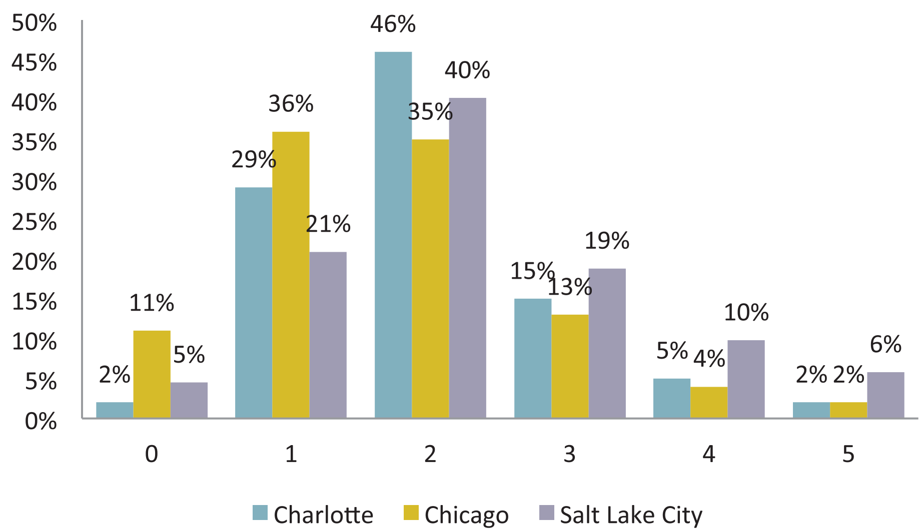


FIGURE C-15. Auto ownership statistics for Charlotte, Chicago, and Salt Lake City.

There are no dramatic differences for housing mobility among the three cities except that Chicago shows a slightly higher household mobility. The duration of respondents living in the metropolitan region of interest is shown in FIGURE C-16.

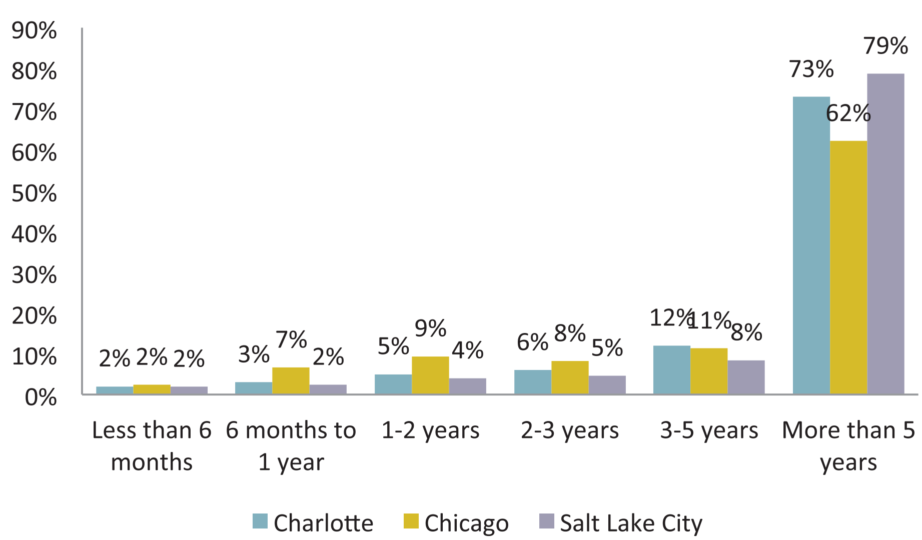


FIGURE C-16. Duration of living in the area statistics for Charlotte, Chicago, and Salt Lake City.

Transit Awareness and Use

The survey respondents were asked to select answers to indicate how informed they are about the survey area's public transit services regarding types of service available, routes, schedules, fare options, etc. There is no significant difference about respondents' awareness of area public transit for the three cities, except that Charlotte has slightly fewer respondents (8% less) indicating that they are very informed.

There is a positive relationship between usage of public transit and awareness of the transit system. People are less likely to use public transit if they are not aware of it (see FIGURE C-17). However, the causality is hard to identify because it is also reasonable to argue that the people using transit are more likely to be aware of it than the people who did not use it.

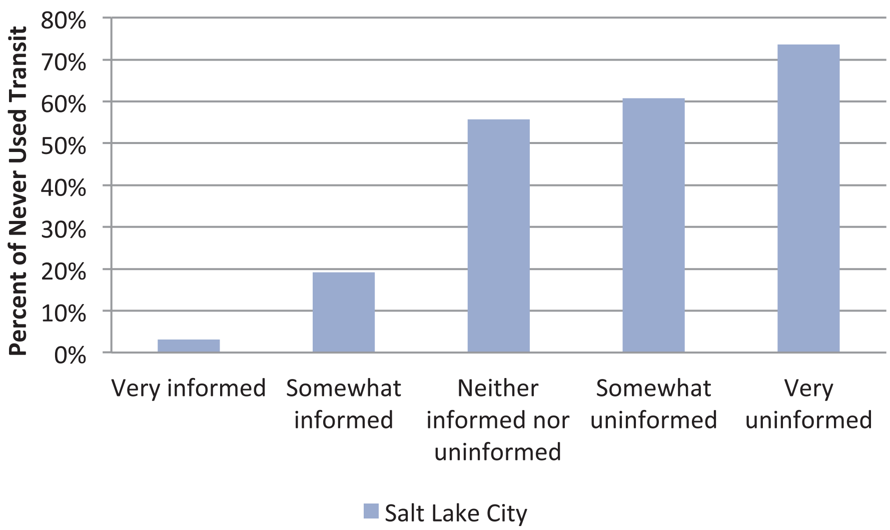


FIGURE C-17. Relationship between awareness and transit usage for Salt Lake City.

Chicago had the highest percentage of respondents who indicated they have used transit in the past 12 months, followed by Salt Lake City. Charlotte had the least (FIGURE C-18).

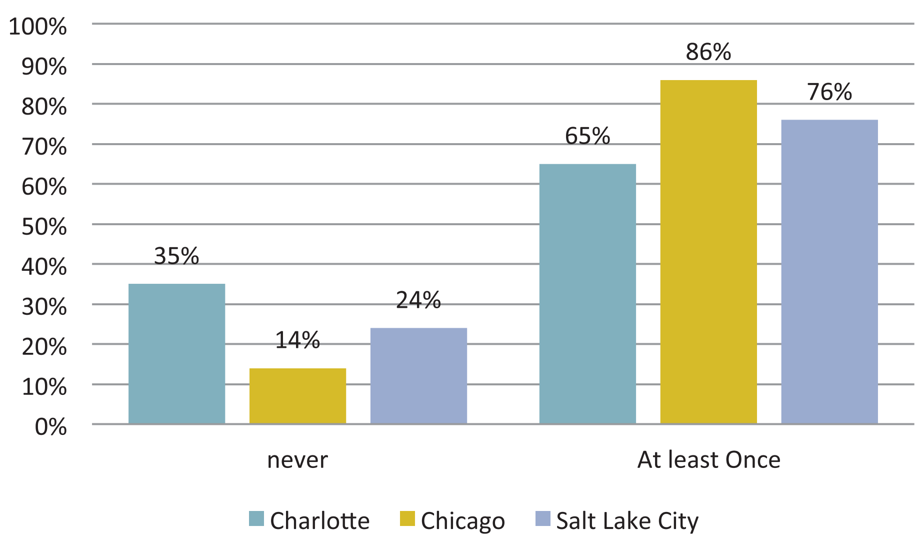


FIGURE C-18. Transit usage for Charlotte, Chicago, and Salt Lake City.

Transit use for Charlotte and Chicago are presented in TABLE C-9 and TABLE C-10, respectively. (Frequency of transit usage is not available at Salt Lake City data.) Some 35% of respondents in Charlotte never used any transit and 14% of respondents in Chicago never used any transit.

TABLE C-9. Charlotte transit usage.

Frequency of Using Transit	CATS Local Bus	CATS Express Bus	LYNX Light Rail
Never	68.60%	71.30%	46.20%
At least once	31.40%	28.70%	53.80%
4 times or less per year*	40.13%	33.45%	47.77%
5-11 times per year	13.38%	9.06%	21.00%
1-3 times per month	14.65%	8.36%	15.99%
1-2 times per week	7.96%	8.01%	5.39%
3-4 times per week	9.87%	11.85%	3.35%
5 or more times per week	14.01%	29.27%	6.51%

*Calculated as % of individuals who have taken transit "At least once."

TABLE C-10. Chicago transit usage.

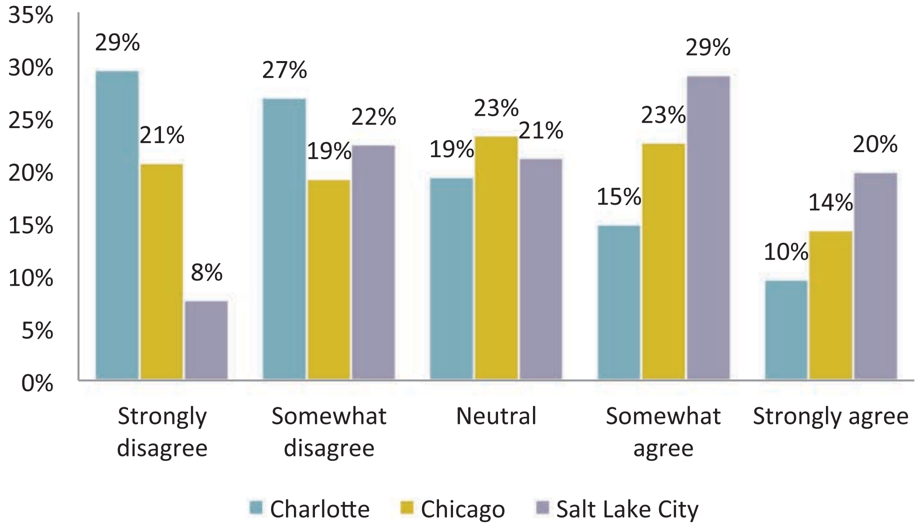
Frequency of Using Transit	CATS Local Bus	CATS Express Bus	Pace Bus	CTA train (the 'L')	Metro commuter rail
Never	43.80%	62.90%	64.00%	32.30%	30.00%
At least once	56.20%	37.10%	36.00%	67.70%	70.00%
4 times or less per year	34.70%	50.94%	51.11%	34.86%	47.86%
5-11 times per year	12.63%	11.05%	15.00%	15.51%	20.29%
1-3 times per month	12.28%	14.56%	11.67%	13.88%	12.00%
1-2 times per week	10.32%	10.24%	7.78%	9.01%	4.57%
3-4 times per week	9.07%	6.20%	6.94%	8.42%	3.29%
5 or more times per week	21.00%	7.01%	7.50%	18.17%	11.86%

*Calculated as % of individuals who have taken transit "At least once."

Traveler Attitudes

Traveler attitudes are obtained for 18 attitudinal questions from the surveys used in Charlotte and Chicago and 15 attitudinal questions from the survey used in Salt Lake City. There is a range of five responses to these attitudinal questions (strongly disagree, somewhat disagree, neutral, somewhat agree, and strongly agree).

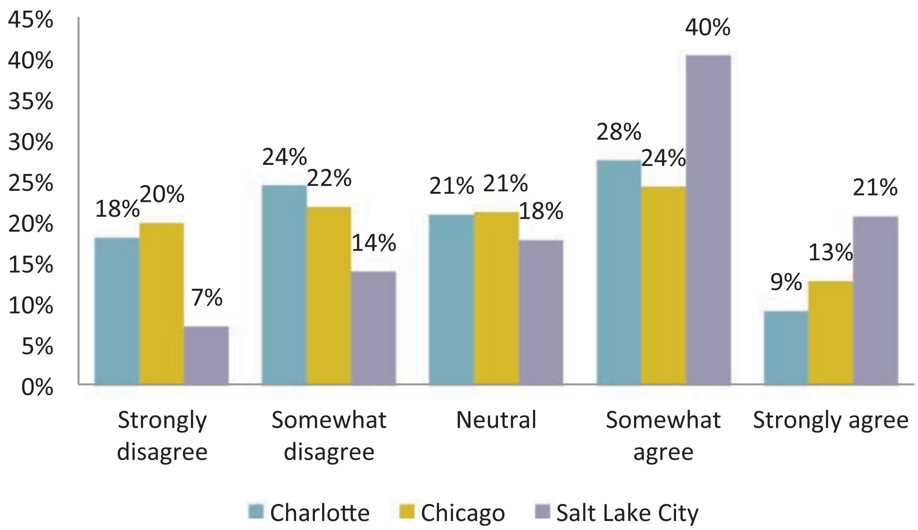
Respondents from Salt Lake City are most likely to try the transit option (FIGURE C-19), followed by those from Chicago, and respondents from Charlotte are least likely to try transit option.



Statement: I currently make an effort to take public transit whenever I can.

FIGURE C-19. Make effort to take transit for Charlotte, Chicago, and Salt Lake City.

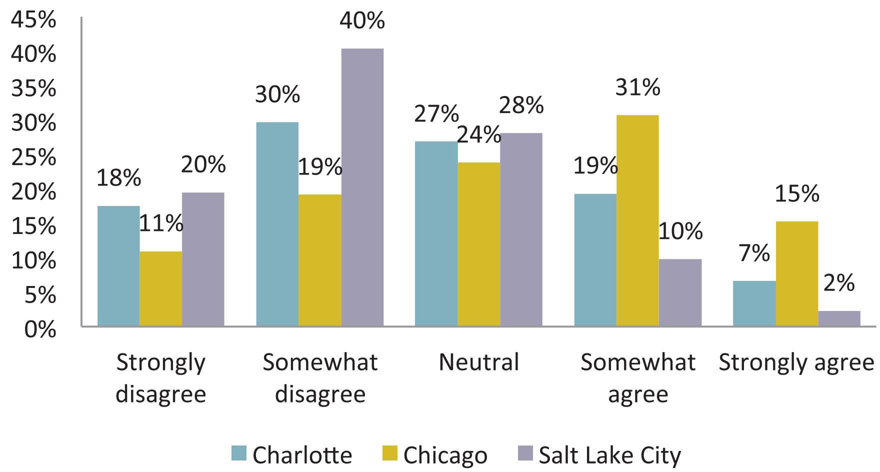
Respondents from Salt Lake City are more willing to increase the frequency of transit usage (FIGURE C-20). Respondents from Charlotte and Chicago share very similar attitudes toward the possibility of increasing transit usage.



Statement: If I wanted to, I could use public transit more frequently.

FIGURE C-20. Willingness to increase transit usage for Charlotte, Chicago, and Salt Lake City.

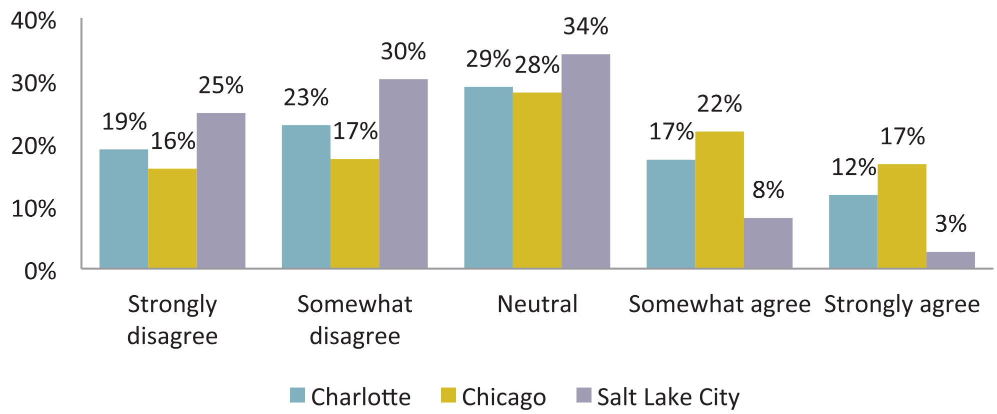
Although Salt Lake City respondents tend to be willing to take transit or use transit more frequently, they do have difficulty in planning a trip using transit (FIGURE C-21). About 60% of them disagree that it is easy to plan a trip with transit and only 12% agree. Chicago seems to have better transit coverage than other two cities, given that 46% of Chicago respondents agree that it is easy to plan transit trips.



Statement: It's easy to plan a trip using transit.

FIGURE C-21. Ease in planning a transit trip for Charlotte, Chicago, and Salt Lake City.

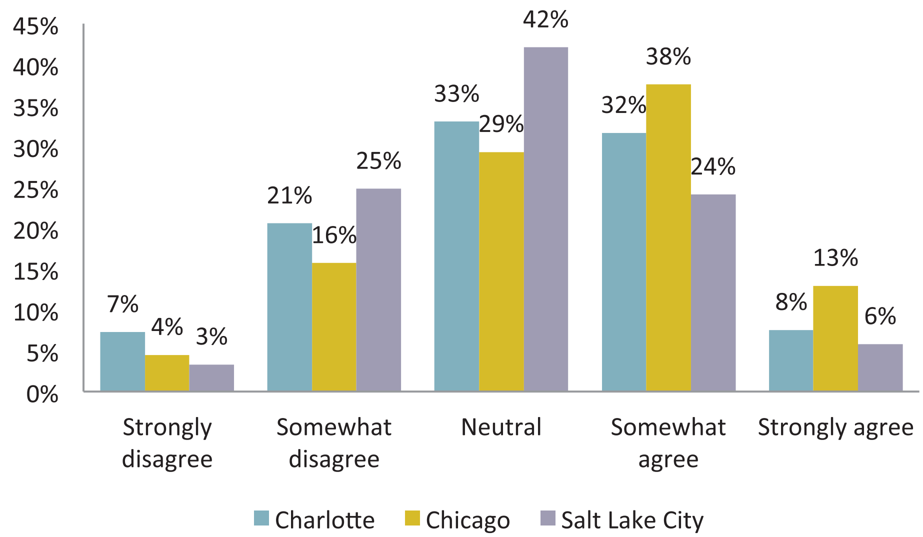
The response regarding "I am the kind of person who rides transit" is quite consistent with the question about "It is easy to plan a trip using transit." Chicago has the highest percentage (39%) of respondents who identify themselves as transit riders, while Salt Lake City has the least (only 11%) as shown in FIGURE C-22. The similarity indicates that ease in planning a trip using transit is positively related to the transit usage of the city.



Statement: I'm the kind of person who rides transit.

FIGURE C-22. Kind of person riding transit for Charlotte, Chicago, and Salt Lake City.

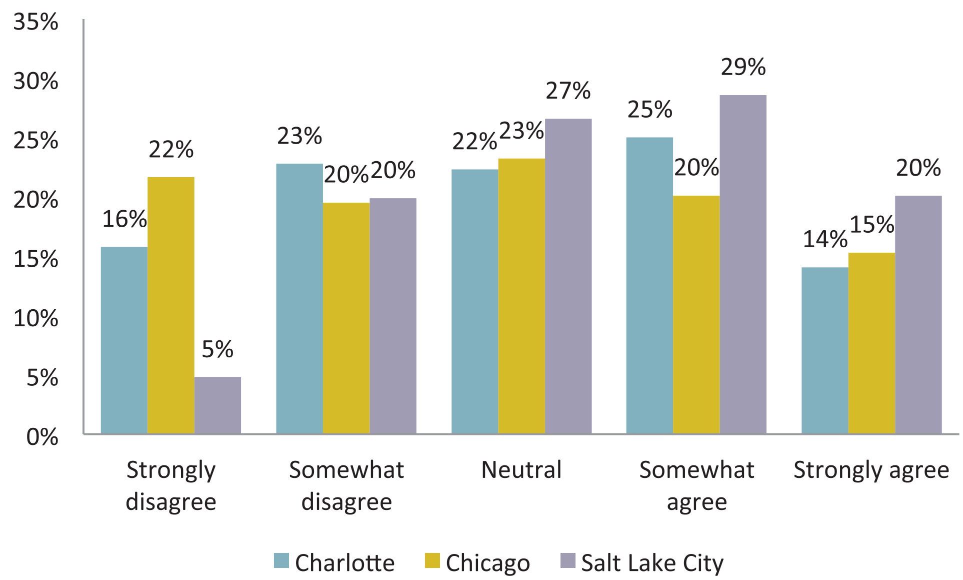
Chicago did a worse job on transit sanitation than did the other two cities, although it has the highest percentage of transit riders (FIGURE C-23). Apparently, sanitation is not a major concern for transit riders (otherwise Chicago would have smaller transit share); also a more challenging sanitation condition is likely to be a consequence of higher transit usage.



Statement: Transit is often dirty.

FIGURE C-23. Transit sanitation impression for Charlotte, Chicago, and Salt Lake City.

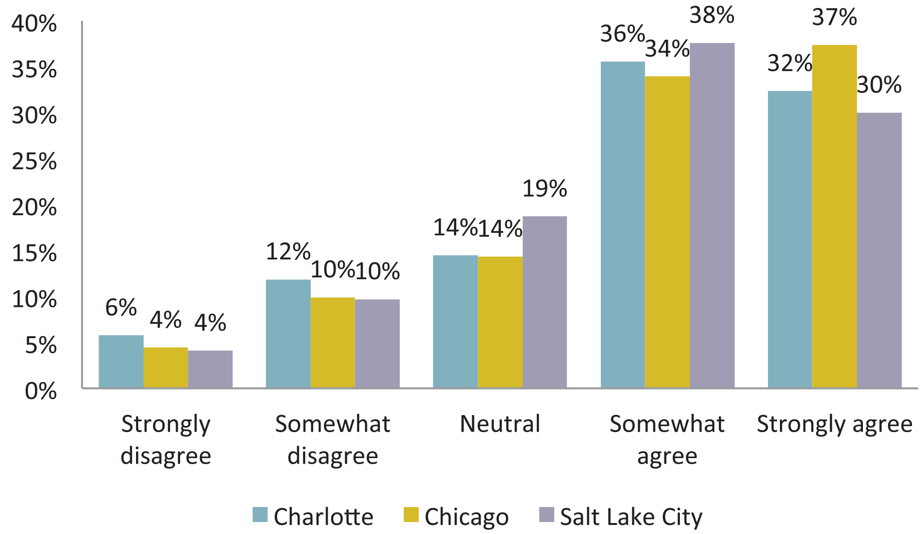
Salt Lake City has the biggest percentage of car users who are reluctant to switch to transit mode (FIGURE C-24).



Statement: For me, car is king! Nothing will replace my car as my main mode of transportation.

FIGURE C-24. Attitude toward car for Charlotte, Chicago, and Salt Lake City.

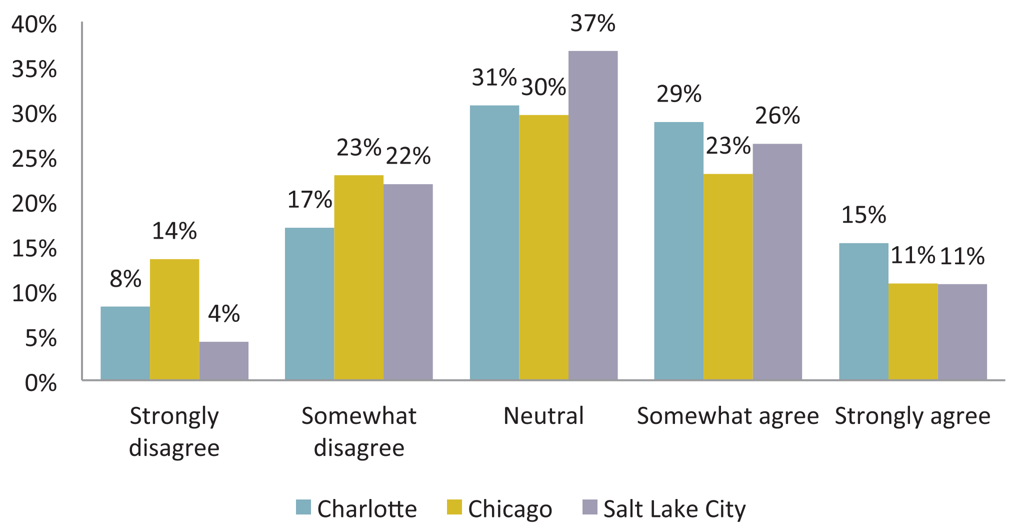
The three cities' respondents share similar attitudes regarding the feeling of riding transit (FIGURE C-25).



Statement: I'm the kind of person who rides transit.

FIGURE C-25. Feeling of transit riding for Charlotte, Chicago, and Salt Lake City.

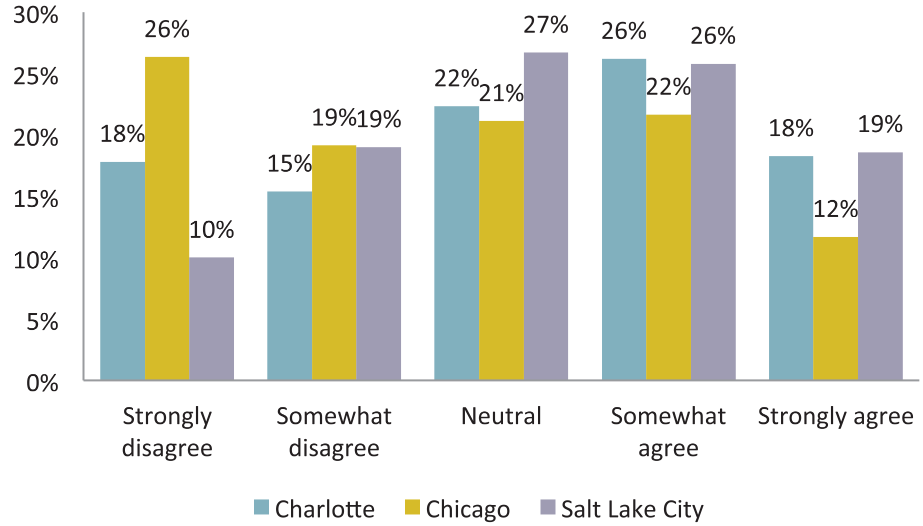
Charlotte and Salt Lake City respondents share similar feelings regarding stations' or stops' pedestrian accessibility, while a higher percentage of Chicago respondents feel that stations or stops are pedestrian friendly (FIGURE C-26).



Statement: Getting to and from transit station/stops is not pedestrian friendly and is very unpleasant.

FIGURE C-26. Station not pedestrian friendly, unpleasant for Charlotte, Chicago, and Salt Lake City.

With respect to park and ride or directly driving, more Salt Lake City respondents are likely to choose driving while more Chicago respondents are likely to choose park and ride (FIGURE C-27).



Statement: I have to drive to get to transit anyway, so I may as well just drive my car the whole way.

FIGURE C-27. Park and ride vs. drive for Charlotte, Chicago, and Salt Lake City.

Trip Characteristics

A specific trip type and mode used is picked randomly from among the trip type and mode used according to what the person said he/she made in the last week. This trip is called the *reference trip*, about which detailed questions are asked. There are more commute trips made in Charlotte and Salt Lake City, whereas Chicago is more evenly split between commuting and non-mandatory trips (FIGURE C-28).

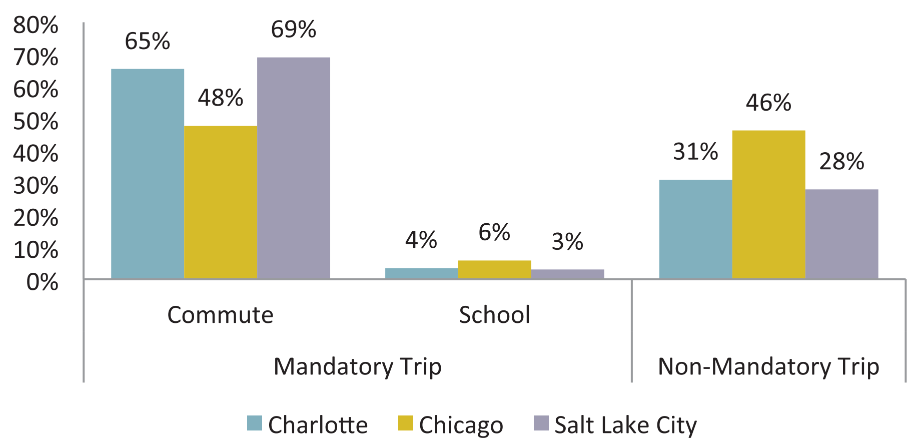


FIGURE C-28. Reference trip split by purpose for Charlotte, Chicago, and Salt Lake City.

Chicago had the highest mode share among the three cities (FIGURE C-29). As mentioned previously, these mode shares are not representative of the population, but reflect a desire to achieve an adequate number of transit trips for model estimation purposes.

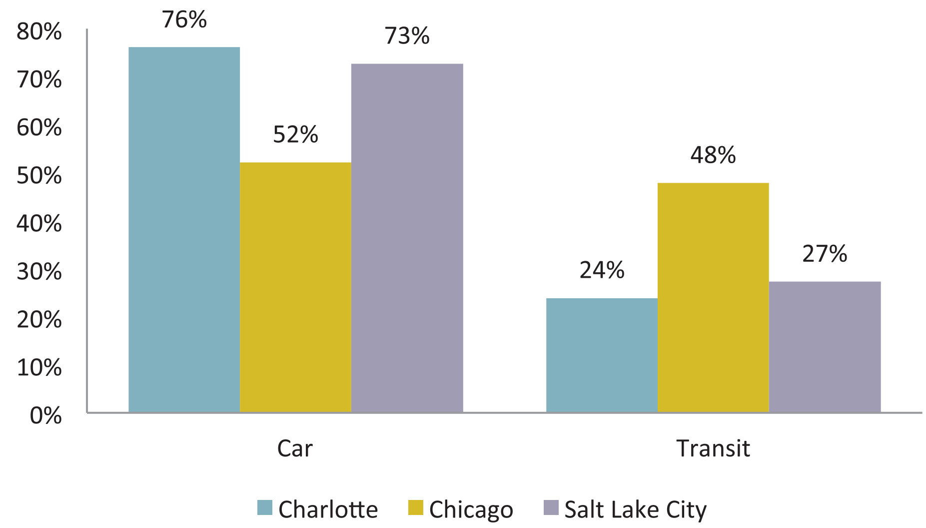


FIGURE C-29. Primary mode for Charlotte, Chicago, and Salt Lake City.

Among the three cities, Chicago respondents made more non-mandatory/transit trips than did respondents from the other two cities. In Charlotte, car is the primary mode for the commute and for school trips, while transit has a bigger share than auto for non-mandatory purposes (FIGURE C-30). In Chicago, car and transit have a similar share. In Salt Lake City, car is the primary mode for all purposes.

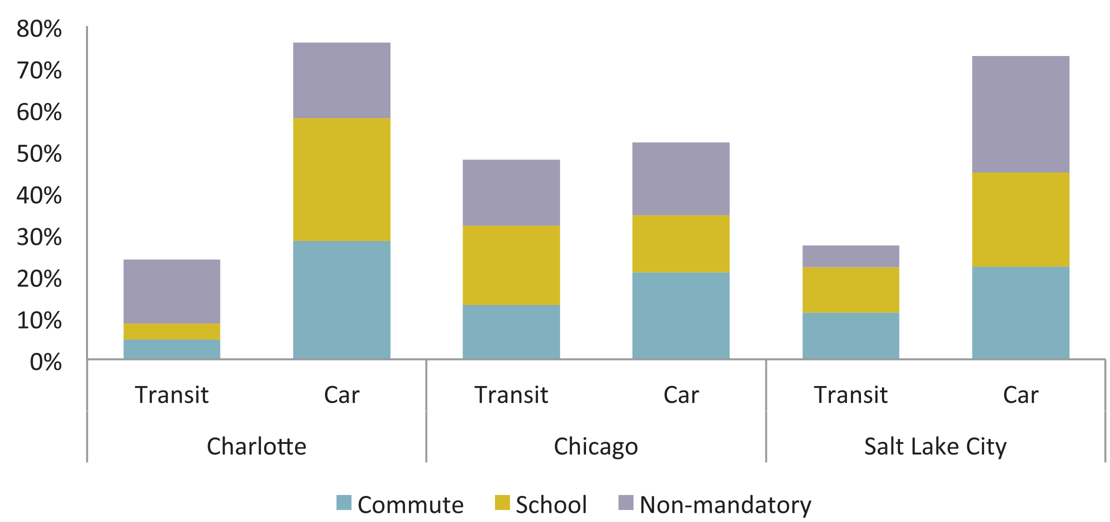


FIGURE C-30. Mode share by purpose for Charlotte, Chicago, and Salt Lake City.

FIGURE C-31 presents the number of people traveling on the reference trip for Charlotte and Chicago. Charlotte has more car trips with three or more persons than Chicago, and Chicago has a more equal split for party size by mode.

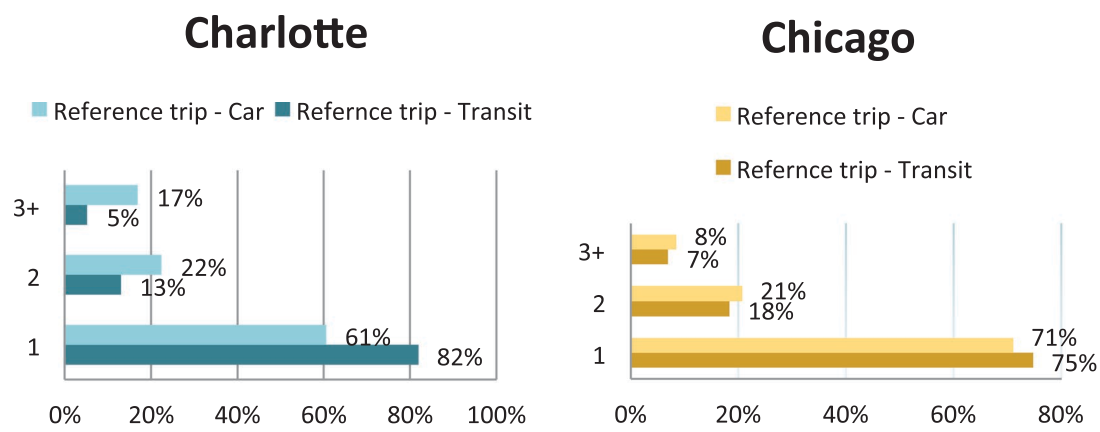


FIGURE C-31. Party size for Charlotte and Chicago.

The respondents were asked how often they make this specific trip using the same mode (FIGURE C-32). TABLE C-11 shows the responses for the people with transit and car reference trips.

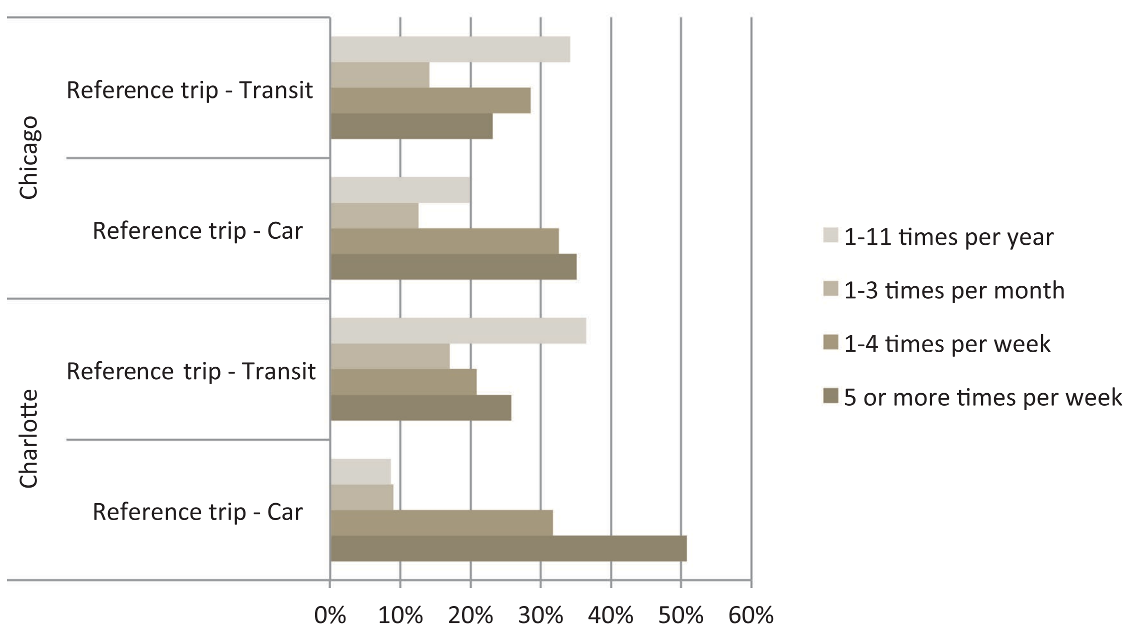


FIGURE C-32. Trip frequency for Charlotte and Chicago.

It is surprising to find that respondents mentioned stop behavior in transit mode for pick-up/drop-off purposes, because the authors expect this to be more prevalent for the car mode (TABLE C-11). Another surprising finding is that people would make a stop during a transit trip to buy coffee or newspapers. In any case, pick up/drop off is more likely to happen during mandatory trips than it is during non-mandatory trips.

TABLE C-11. Stop-making behavior for Charlotte, Chicago, and Salt Lake City.

Purpose	Mandatory						Non-mandatory					
Mode	Car			Transit			Car			Transit		
City	Cha	Chi	SLC	Cha	Chi	SLC	Cha	Chi	SLC	Cha	Chi	SLC
Pick up/drop off household member	13%	18%	18%	10%	16%	18%	5%	7%	0%	7%	6%	0%
Pick up/drop off non-household member	2%	0%	0%	3%	8%	0%	4%	10%	0%	11%	10%	0%
Buy groceries	27%	11%	11%	37%	22%	12%	29%	29%	36%	16%	21%	100%
Coffee, newspapers, etc.	13%	34%	34%	16%	26%	41%	10%	12%	14%	20%	28%	0%
Get gas	25%	13%	13%	21%	7%	0%	28%	13%	23%	10%	9%	0%
Business/school related stop	5%	4%	4%	0%	4%	6%	3%	4%	5%	4%	5%	0%
Pick up/meet other carpool members	1%	3%	3%	4%	4%	0%	0%	1%	5%	4%	4%	0%
Other reason	14%	18%	18%	9%	12%	24%	21%	23%	18%	28%	18%	0%

City Codes Cha – Charlotte; Chi – Chicago; SLC – Salt Lake City

The threshold for walk to transit seems to be "20 minutes." Around 90% of respondents are not willing to walk for 20 minutes to reach a transit stop/station. On average, people using transit mode are more willing to walk than are people who drive. About 14% of respondents who drive in their reference trips are not willing to walk at all, compared to only 1% of transit riders who are not willing to walk at all. Willingness to walk is discussed in Chapter 2 of the main report.

On average, men are more willing to walk than women are, and Chicago respondents are more willing to walk than Charlotte respondents (FIGURE C-33.).

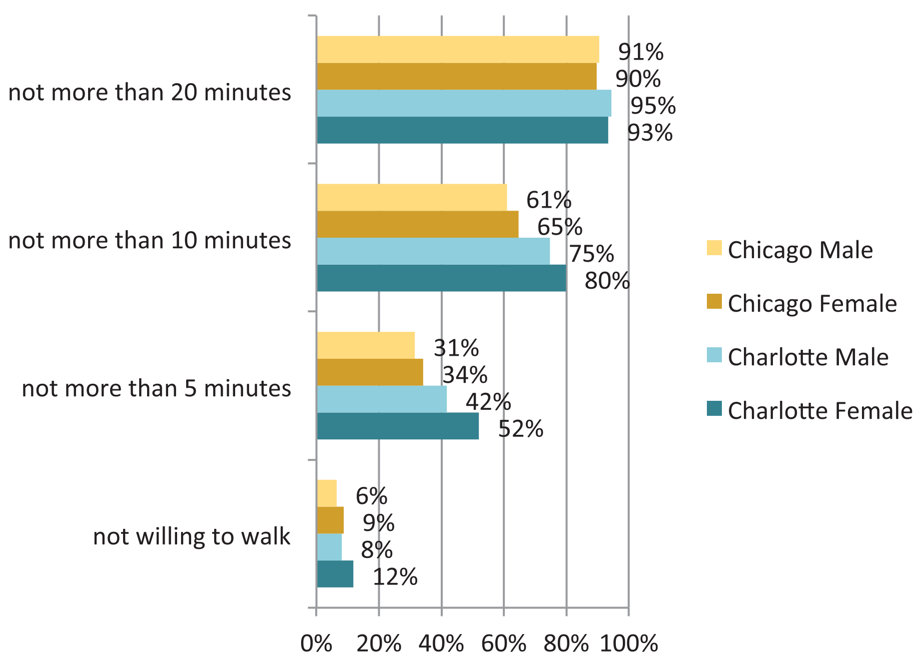


FIGURE C-33. Willingness to walk by gender for Charlotte and Chicago.

In both Charlotte and Chicago, youth are least willing to walk. In Charlotte, people ages 45-64 yrs are the most willing to walk (FIGURE C-34). In Chicago, elderly persons are the most willing to walk (FIGURE C-35).

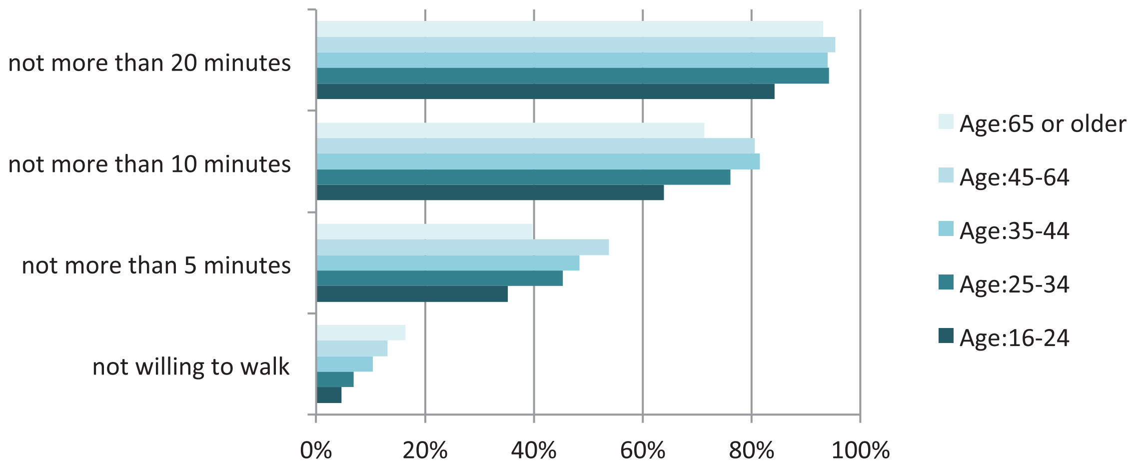


FIGURE C-34. Willingness to walk by age for Charlotte.

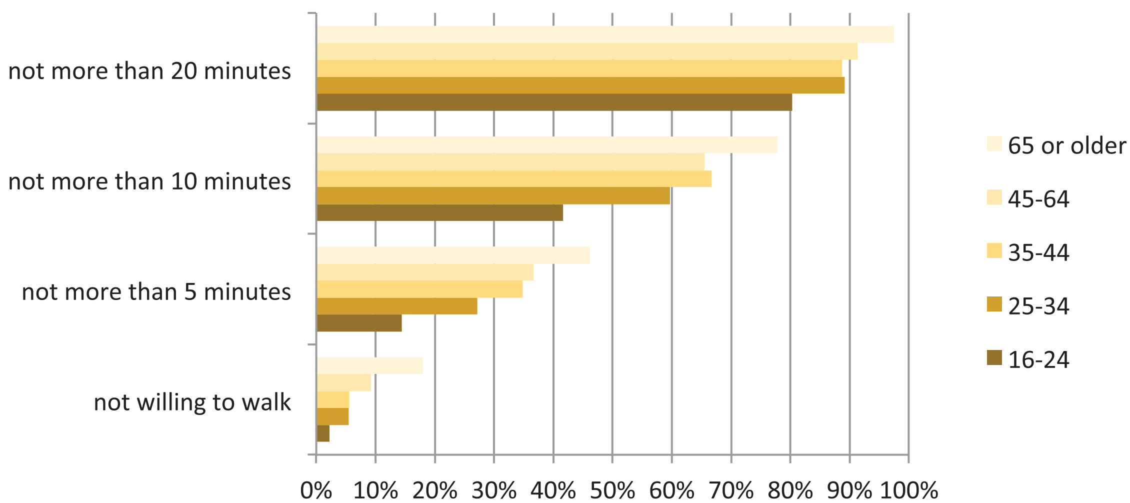


FIGURE C-35. Willingness to walk by age for Chicago.

It is not surprising to see that people using transit mode are much more willing to use various access/egress options than people who drive (FIGURE C-36). These data were not available from the Salt Lake City survey.

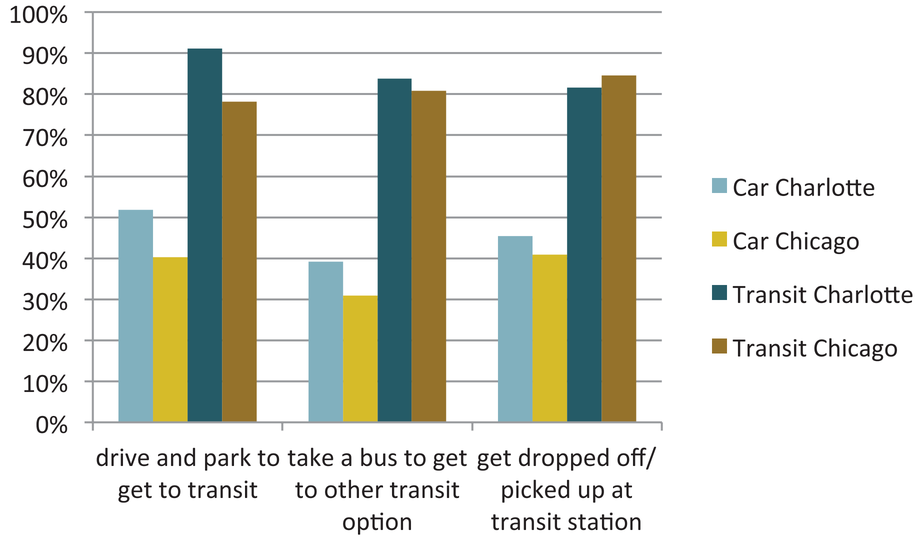


FIGURE C-36. Willingness to use various access/egress modes for Charlotte and Chicago.

No significant difference of auto type is found between Charlotte and Chicago respondents, except that Chicago respondents own a little bit higher percentage of minivans (FIGURE C-37). These data were not available from the Salt Lake City survey.

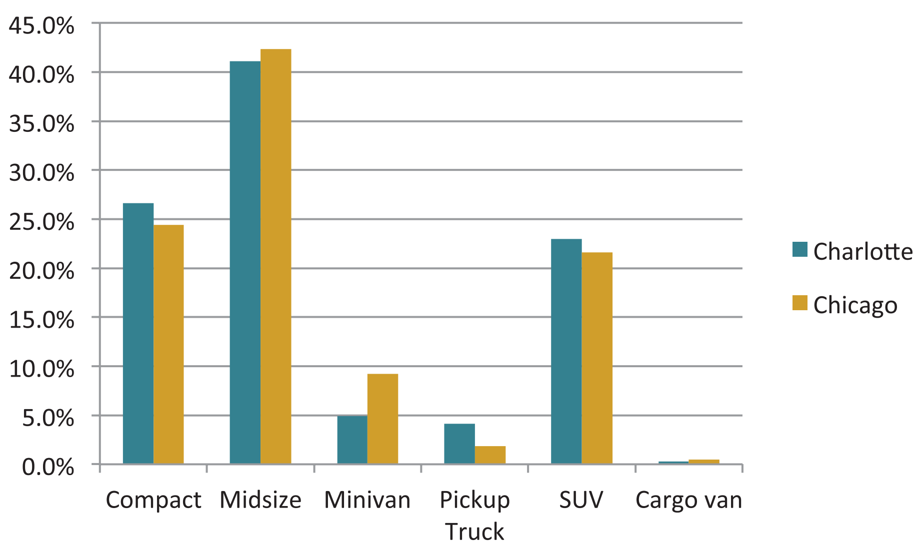


FIGURE C-37. Auto type for Charlotte and Chicago.

The characteristics of the transit reference trips are presented in TABLE C-12 and TABLE C-13 for Charlotte and Chicago, respectively. These data were not available from the Salt Lake City survey. In Charlotte, 365 individuals were asked transit reference-trip details. In Chicago, 725 individuals were asked transit reference-trip details.

TABLE C-12. Charlotte reference trips auto availability.

		Respondent usually has a car available to make reference trip	
		Yes	No
Respondent had a car available to make specific reference trip	Yes	272	13
	No	21	59

TABLE C-13. Chicago reference trips auto availability.

		Respondent usually has a car available to make reference trip	
		Yes	No
Respondent had a car available to make specific reference trip	Yes	345	39
	No	51	290

The primary access mode is walk for Salk Lake City (FIGURE C-38) and Chicago (FIGURE C-39), and park and ride for Charlotte (FIGURE C-40). The primary egress mode is walk for both Charlotte and Chicago. There is no significant difference for access and egress mode by purpose. In Salt Lake City and Charlotte, people are more likely to use park and ride for mandatory trips than for non-mandatory trips. Interestingly, people at Chicago use less park and ride for mandatory trips than for non-mandatory trips. The Salt Lake City data only have access mode.

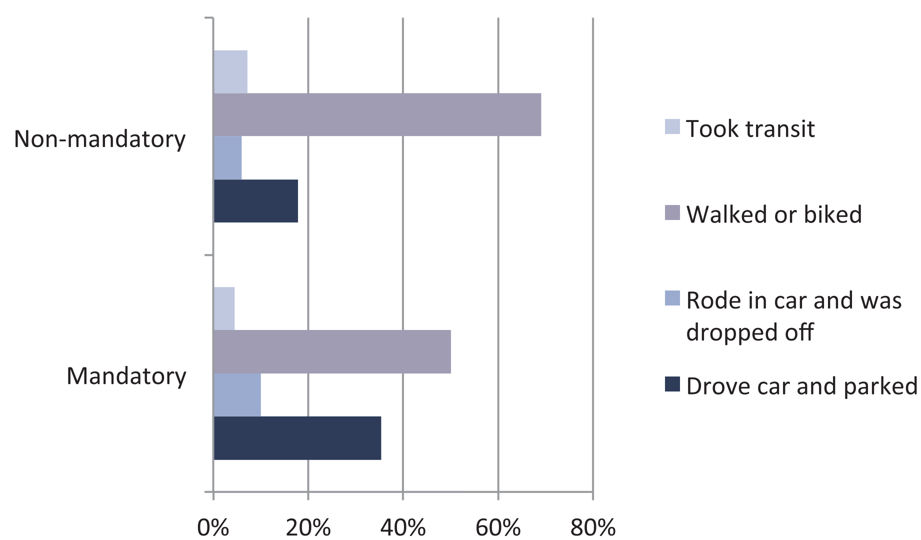


FIGURE C-38. Salt Lake City access mode by purpose.

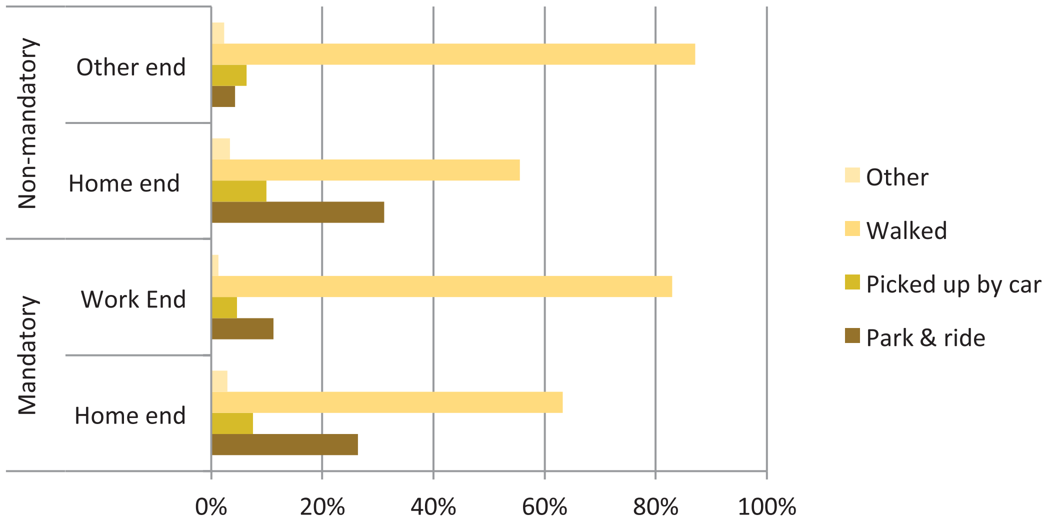


FIGURE C-39. Chicago transit access and egress mode by purpose.

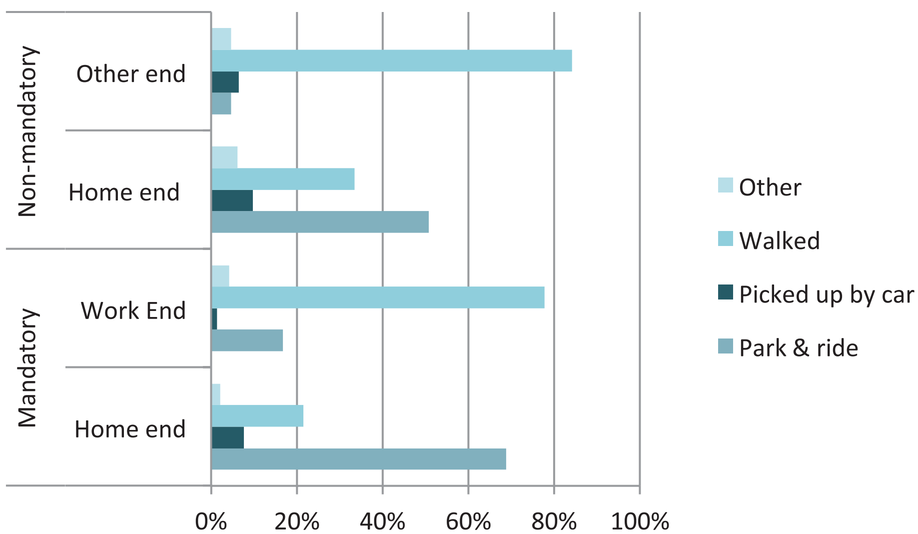


FIGURE C-40. Charlotte transit access and egress mode by purpose.

Respondents from Chicago are more likely to make chain transit trips (46% of transit trips) than respondents from the other two cities (25% for Charlotte and 6% for Salt Lake City) as shown in FIGURE C-41.

Respondents from Chicago experienced much higher total travel time, which may due to city scale (TABLE C-14).

TABLE C-15 presents the auto trip characteristics, including travelers with no car available, where Salt Lake City has the highest percentage, and average stop times, where Charlotte has the highest value (although Salt Lake City data is not available). Salt Lake City has a shorter average travel time by auto than Charlotte, even though Charlotte is a smaller city and has shorter transit travel times.

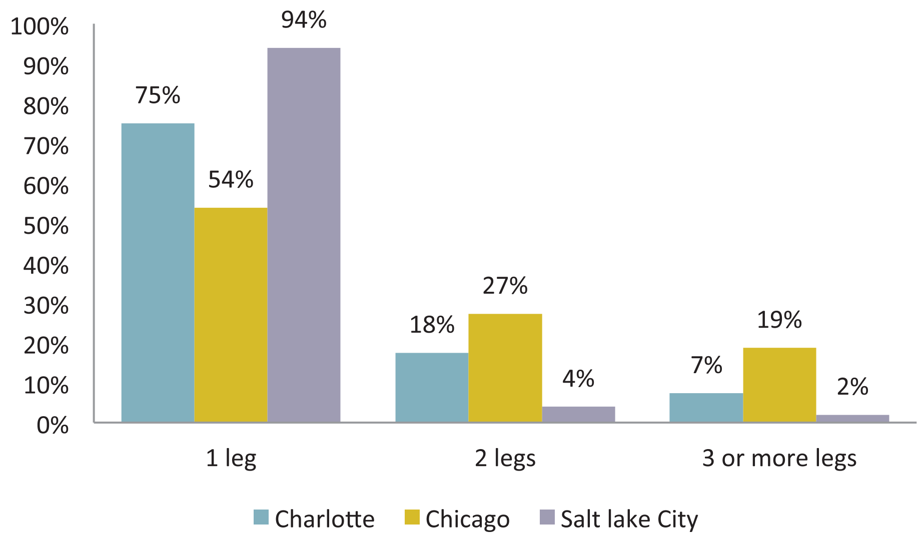


FIGURE C-41. Transit legs for Charlotte, Chicago, and Salt Lake City.

TABLE C-14. Transit travel time for Charlotte, Chicago, and Salt Lake City.

Average time (in minutes)			Charlotte	Chicago	Salt Lake City
Wait time			9	10	7
Transit in-vehicle time			26	37	31
Total travel time			65	83	54
Access/egress time	Commute	Access time	14	16	n/a
		Egress time	9	16	n/a
	Non-commute	Access time	15	16	n/a
		Egress time	15	23	n/a

TABLE C-15. Auto trips characteristics.

Characteristic	Charlotte	Chicago	Salt Lake City
Do not usually have a car	2%	2%	6%
Average travel time (min.)	26	28.4	22.4
Average stop time	6.5	5.2	n/a
Parking cost incurred by (min.)	13.30%	4.80%	7%
Tolls paid by	0.50%	12.80%	n/a

FIGURE C-42 shows the common reasons for not using transit among the three cities for respondents who considered one or more of the transit modes. The "needed my car for other reasons" is the most-cited reason for Chicago and Charlotte, while "Travel time too long" is the most-cited reason for Salt Lake City.

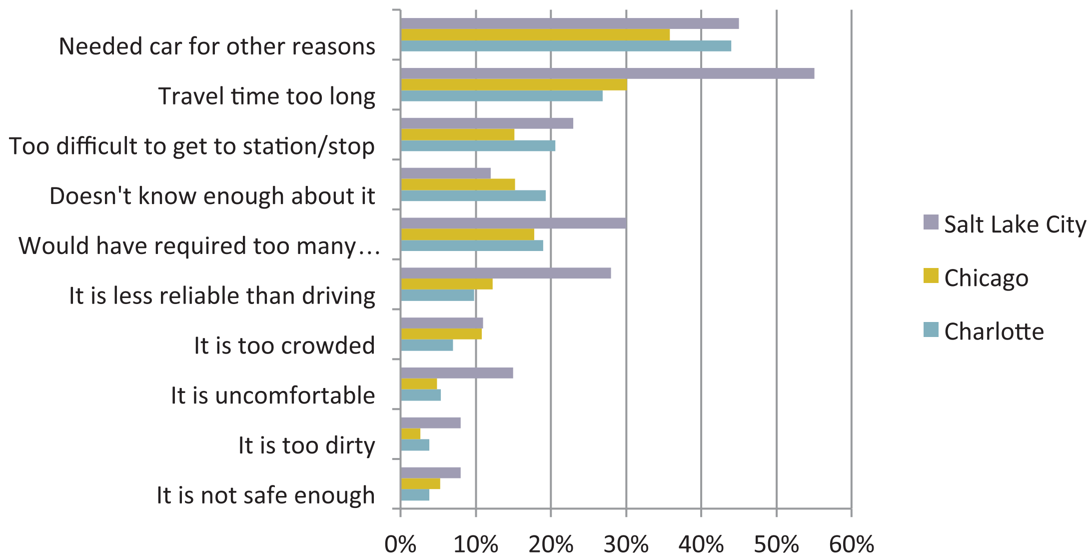


FIGURE C-42. Reasons not taking transit in Charlotte, Chicago, and Salt Lake City.

Stated Preference Survey Characteristics

Chicago has the highest percentage of scenarios where car is chosen (29%) compared to Charlotte (22%) as shown in FIGURE C-43 and FIGURE C-44 for Charlotte and Chicago, respectively. These data are presented for Charlotte and Chicago only because the stated preference experiments in Salt Lake City were different.

In the stated preference (SP) choice model the alternatives are assumed to be always considered if they are displayed to the user. This assumption is supported by the following statistics. Among 1,515 individuals, 550 individuals used bus or considered using bus. Among the remaining 965 individuals who never considered using bus in the revealed preference (RP) response, 428 actually selected bus in at least one of the eight SP scenarios. Similarly, out of 914 individuals who did not consider using train, 505 selected train in at least one of the eight SP scenarios. The usefulness of stated preference responses in logit choice modeling is to identify a wider range of options than are present in real life and therefore capture the trade-off point at which a traveler will change modes in the experiment.

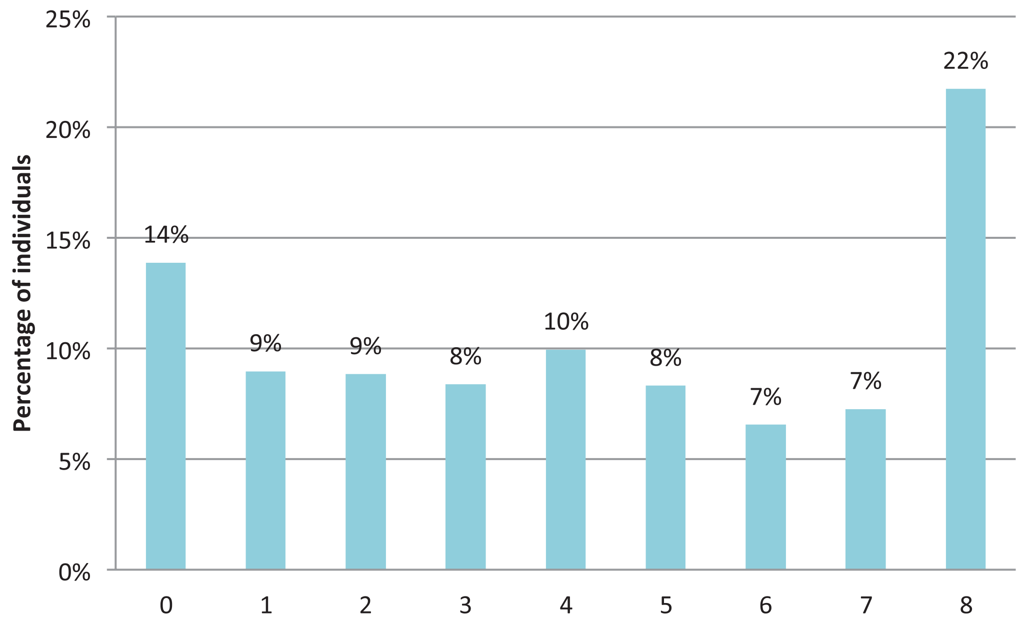


FIGURE C-43. Number of scenarios car is chosen in Charlotte.

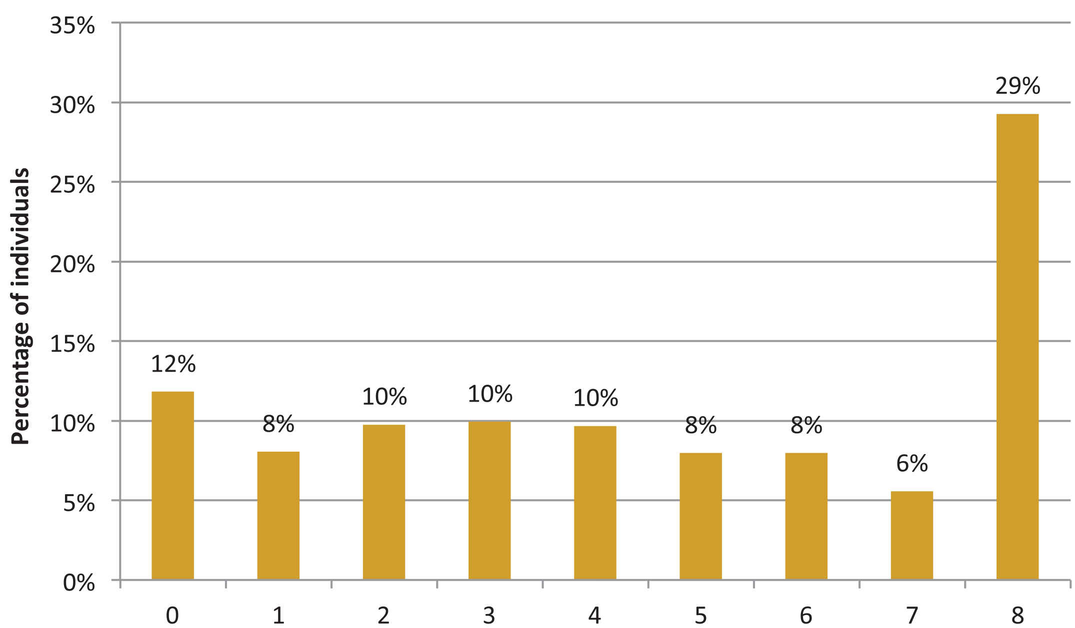


FIGURE C-44. Number of scenarios car is chosen in Chicago.

APPENDIX D

Transit Service Attribute Models

Contents

Overview

The objective of the current research effort is to evaluate the relative importance of a selected set of transit service attributes (see TABLE D-3) and to quantify their effect in the context of mode choice decision. To achieve this, we employ MaxDiff analysis on preference data collected in the surveys. The estimation of utility function in this analysis is typically performed using multinomial logit (MNL) estimation. Other algorithms that could have been used in this estimation process, included maximum likelihood, neural networks, and the Hierarchical Bayes model.

In the current study, the data from the MaxDiff experiments were used to estimate two MNL choice models for each study area: (1) a MNL model for commute trips, and (2) a MNL model for non-commute trips. All survey respondents participated in the MaxDiff experiments, except those respondents who indicated that they were "very uninformed" about the public transit system in the study area. (In Chicago, 7.2% of respondents indicated that they were "very uninformed" about the city's transit system. For Charlotte, this share is 8.1%.) Here, each respondent was asked to choose his/her "most preferred" and "least preferred" transit option from a set of three transit options, each of which included information on in-vehicle travel time, fare, and three transit attributes. This exercise was repeated eight times for each respondent. For each model, the results provide a coefficient value (or utility) for each transit attribute evaluated in the MaxDiff experiments. Then, the attributes can be ordered by their utilities to identify the relative importance of each attribute.

Two types of MaxDiff analyses were completed from the data collected in Chicago and Charlotte:

1. Estimates of unscaled coefficients, which capture the behavior of transit attributes relative to each other. These coefficients were used to estimate the marginal rates of substitution and relative importance of attributes (more on this in the next section).

2. Estimates of scaled coefficients of bundled (and not bundled) attributes. The scaled coefficients were estimated so that the effect of transit attributes on individuals' mode choice decision may be incorporated.

The purpose of scaling the coefficients is to incorporate the importance of these attributes relative to other mode choice factors (such as time and cost). The unscaled coefficients are not sufficient to use directly because the data collection method does not adequately capture the time and cost trade-offs relative to these additional service attributes (more on this in the next section). As such, the marginal rates of substitution, expressed as equivalent minutes of in-vehicle travel time, used in any planning or modeling context, should be derived only from the scaled coefficients.

Model Results of Unscaled Attributes

Two separate models were specified for commute and non-commute trips for each study area, as indicated in the previous section. Each estimated model considered travel time, travel cost, and interaction effects of the transit attributes with a number of individual demographics (such as gender, age, student status, employment status, indication of any mobility-related problem, and indicator of the length of residency in the study area), household socio-demographics (such as presence of children, family income, and number of vehicles in the household), trip characteristics (indicator of group travel and trip distance), and attitudinal variables (such as willingness to walk to access the transit system, pro-transit attitude, environment and productivity/time savings, pro-car attitude, transit averse, and low transit comfort level). The final model specification was obtained based on a systematic process of eliminating variables found to be statistically insignificant and unintuitive.

Salt Lake City

FIGURE D-1 presents marginal rates of substitution from the MaxDiff portion of the Salt Lake City survey, which evaluated the relative importance of unbundled non-traditional attributes. Results are presented as equivalent minutes of time for work and non-work trips. The marginal rates of substitution capture how much individuals are willing to pay (in terms of extra travel time) for improvements in the transit attributes. Thus, the first entry in FIGURE D-1 suggests that, on average, commuters in the Salt Lake City area would be willing to add about 15 minutes and non-commuters would be willing to add about 14 minutes to their in-vehicle travel time to always have seats available on their transit vehicle. The values for each attribute are computed (in minutes) by dividing the overall (unscaled) coefficient by the transit travel time coefficient obtained from the MaxDiff model.

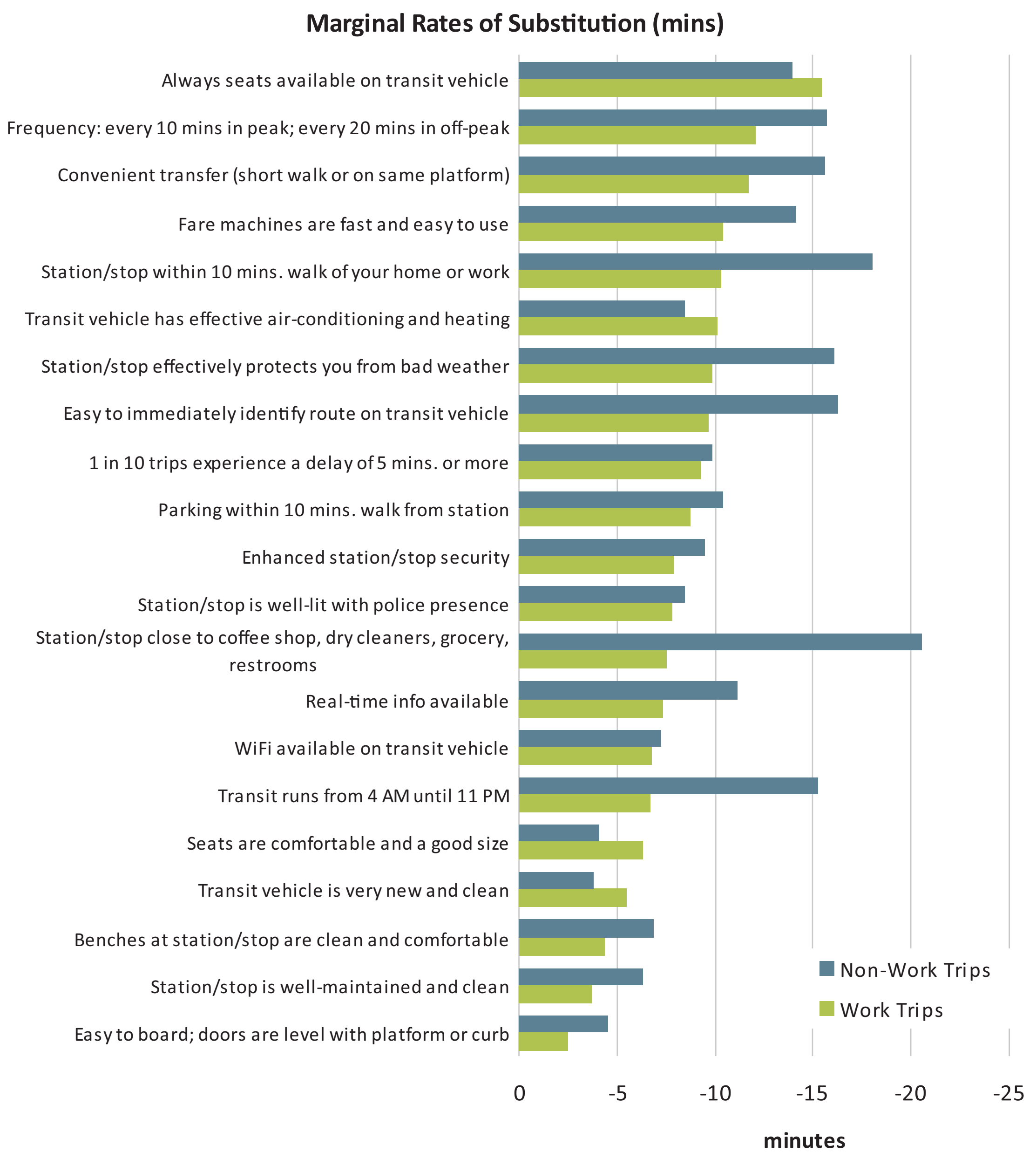


FIGURE D-1. Values of unscaled marginal rates of substitution (min. of IVT) for Salt Lake City.

Ease of use (easy to immediately identify route on transit vehicle, convenient transfers, and fast, easy-to-use fare machines) attributes are more important to non-work travelers than work travelers. This may be because non-work travelers are less familiar with the system and more likely to use different routes at different times of day. Cleanliness (station/stop is well maintained and clean, benches at station/stop are clean and comfortable, and transit vehicle is very new and clean) are among the least important attributes for both work and non-work travelers. This may reflect a tolerance among transit riders for cleanliness of public property and/or a state of good repair for the Utah Transit Authority (UTA), thus making this attribute less important than in other systems where cleanliness is not as good. Some aspects of comfort (seats are comfortable and a good size, and easy to board; doors are level with platform or curb) are also among the least important attributes for both work and non-work travelers.

FIGURE D-1 also presents average marginal rates of substitution for premium bundles of on-board amenities and modernized station/stops. The bundle values vary in importance from 7 minutes to 11 minutes depending on the bundle and the trip purpose, whereas the unscaled and unbundled values above often exceed the coefficients for the bundles. These results demonstrate that, on average, on-board amenities are more important to work travelers and modernized station/stops are more important to non-work travelers.

Chicago

FIGURE D-2 and FIGURE D-3 present the MaxDiff model results (i.e., unscaled coefficients), the marginal rates of substitution, and the relative importance of transit attributes for commute and non-commute trips for the Chicago area (the detailed model results for commute and non-commute trips are presented later in this section). In addition, FIGURE D-2. and FIGURE D-3 provide a visual representation of the (unscaled) marginal rates of substitution and relative importance of transit attributes for the Chicago area, respectively. The scaled results corresponding to this study area are discussed in the next section of this appendix.

The coefficients presented in FIGURE D-2 and FIGURE D-3 are the overall (unscaled) coefficients and not just the base coefficients. The overall coefficient for each transit attribute may be calculated by adding the contribution of each interacting variable with the corresponding base coefficient. For example, the overall coefficient for real-time information (info) for commute trips in the Chicago area was calculated as follows: $0.833 - 0.478 \times 0.114 = 0.779$, where the base coefficient is 0.833 (see TABLE D-1), the coefficient corresponding to full-time student status is -0.478, and 11.4% of individuals in the dataset are full-time students.

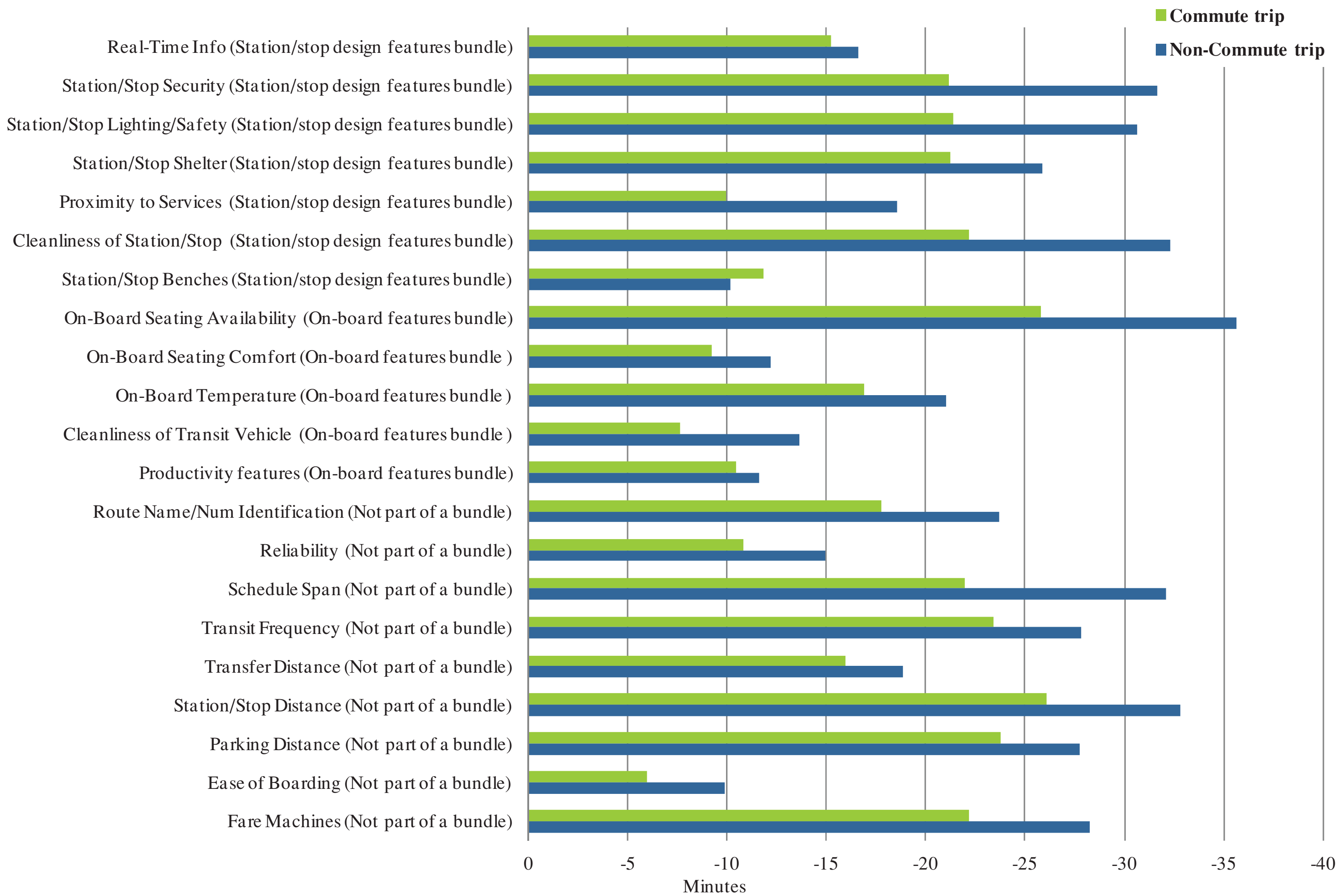


FIGURE D-2. Unscaled marginal rates of substitution (in minutes) for Chicago.

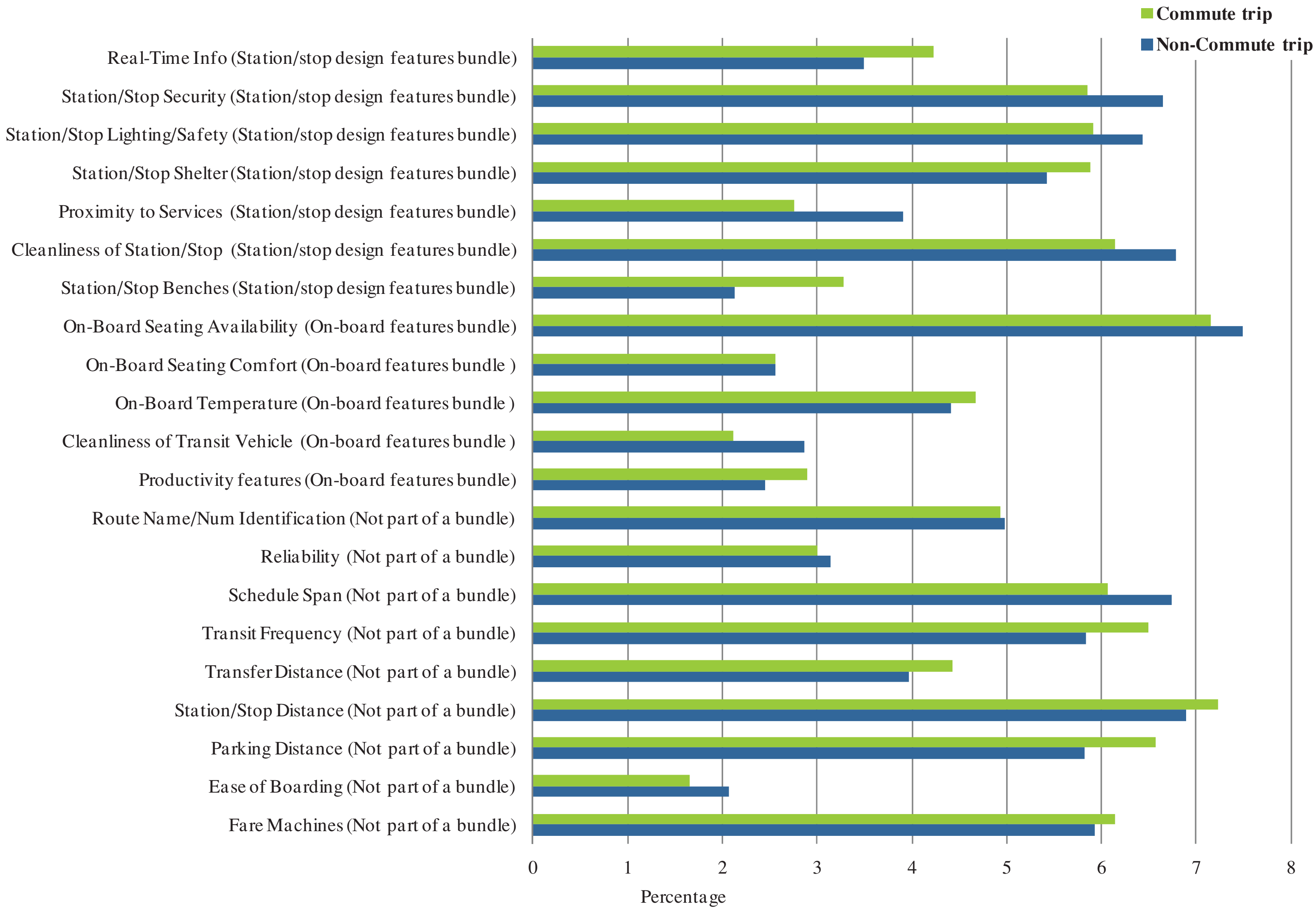


FIGURE D-3. Relative importance of transit attributes (in %) for Chicago.

Several interesting observations may be made from (FIGURE D-2 and FIGURE D-3). Overall, station/stop distance and on-board seating availability are the two most important transit attributes for both commuters and non-commuters in the Chicago area. From the viewpoint of relative rank of attributes, station/stop distance may be identified as the most important transit attribute for commuters, followed by on-board seating availability. A close inspection indicates that these two attributes have almost identical marginal rates of substitution, suggesting that station/stop distance and on-board seating availability are equally important to Chicago commuters. The non-commuters in this area, however, consider on-board seating availability slightly more important than station/stop distance feature. In addition, station/stop distance and on-board seating availability are the most important "unbundled" and "on-board feature bundle" attributes for commuters and non-commuters. In the context of on-board features, the importance of seating availability may be due to the fact that Chicago commuters and non-commuters tend to undertake long-distance trips (the average trip distances for Chicago commuters and non-commuters are 13 miles and 12 miles, respectively).

Among the attributes in the "station/stop design feature bundle," cleanliness of station/stop is the most important attribute for commuters as well as for non-commuters. In this regard, an interesting observation is that cleanliness of transit vehicle is rated as one of the less important transit attributes (cleanliness of transit vehicle is rated as the 20th and 17th most important attribute by commuters and non-commuters, respectively). This may be because unlike most stations/stops in Chicago area, the transit vehicle fleets are kept clean and well maintained (Chicago Transit Authority 2011). Ease of boarding and on-board seating comfort attributes also have low ratings, which may suggest that both commuters and non-commuters are fairly satisfied with the current conditions of these two attributes.

Though, in general, there are similarities between commuters' and non-commuters' preference levels, a number of attributes are considered more important by commuters than non-commuters. These attributes include availability of good station/stop shelter, clean and comfortable station/stop benches, productivity features, transit frequency, and parking distance. On the other hand, attributes such as station/stop security, lighting/safety, proximity to services, and longer schedule span are considered more important by non-commuters (relative to commuters). A point to note here is that the relative importance of transit attributes is not fixed but changes with travel distance, as shown in FIGURE D-4, and for commute and non-commute trips, respectively. For commuters, some transit attributes such as route name/number, station/stop lighting/safety features, cleanliness of station/stop, and transit frequency become less important while transfer distance becomes noticeably more important as commute distance increases. This may be because a longer commute distance is likely to involve one or more transfers. A convenient transfer (e.g., on the same platform or only a short walk) would reduce a commuter's total out-of-vehicle travel time as well as overall travel time. In contrast, transfer distance becomes less important for non-commute trips because the need to be at work on time is not applicable to this group of travelers (see FIGURE D-5).

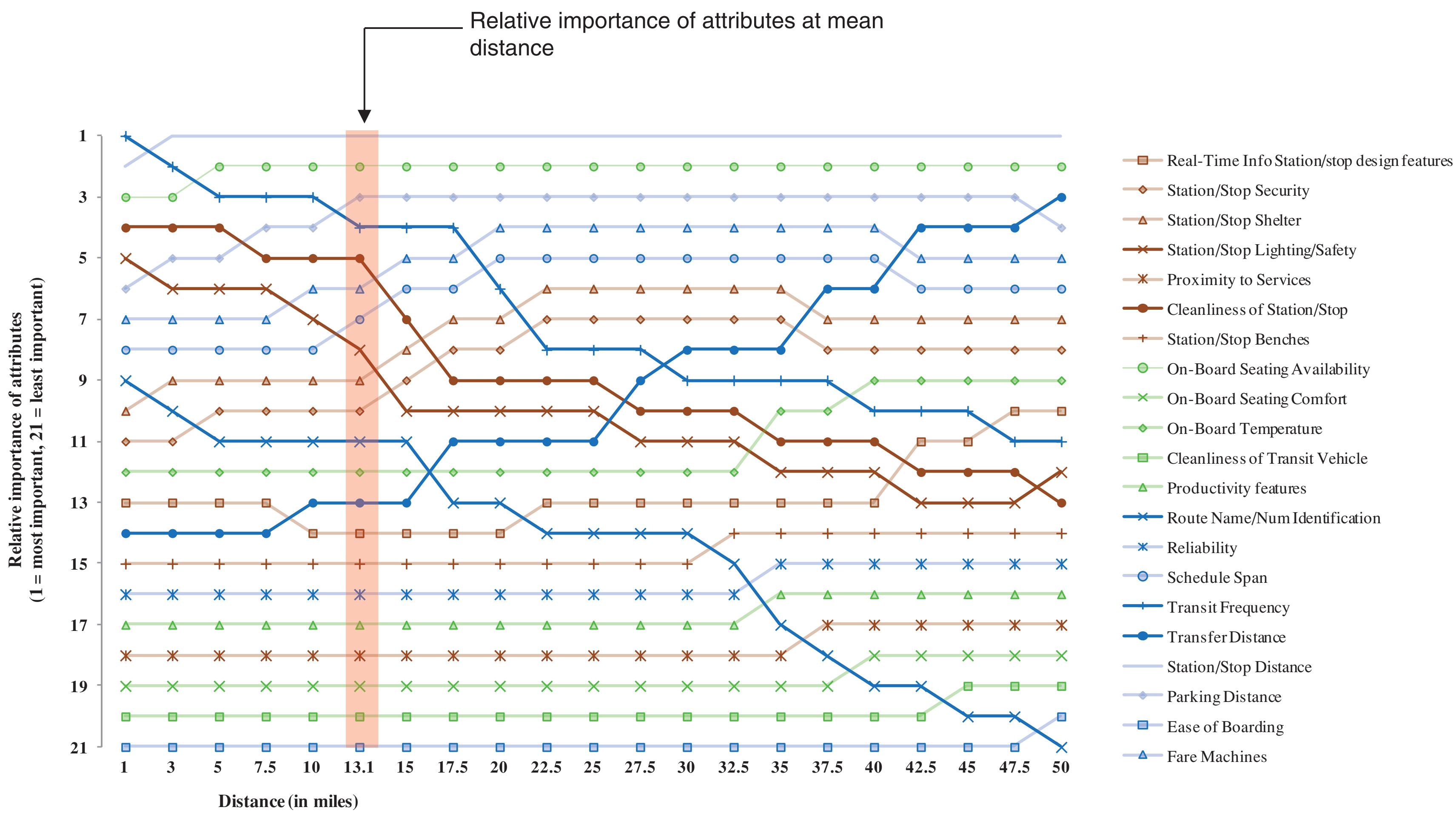


FIGURE D-4. Relative importance of transit attributes by distance for Chicago (commute trip).

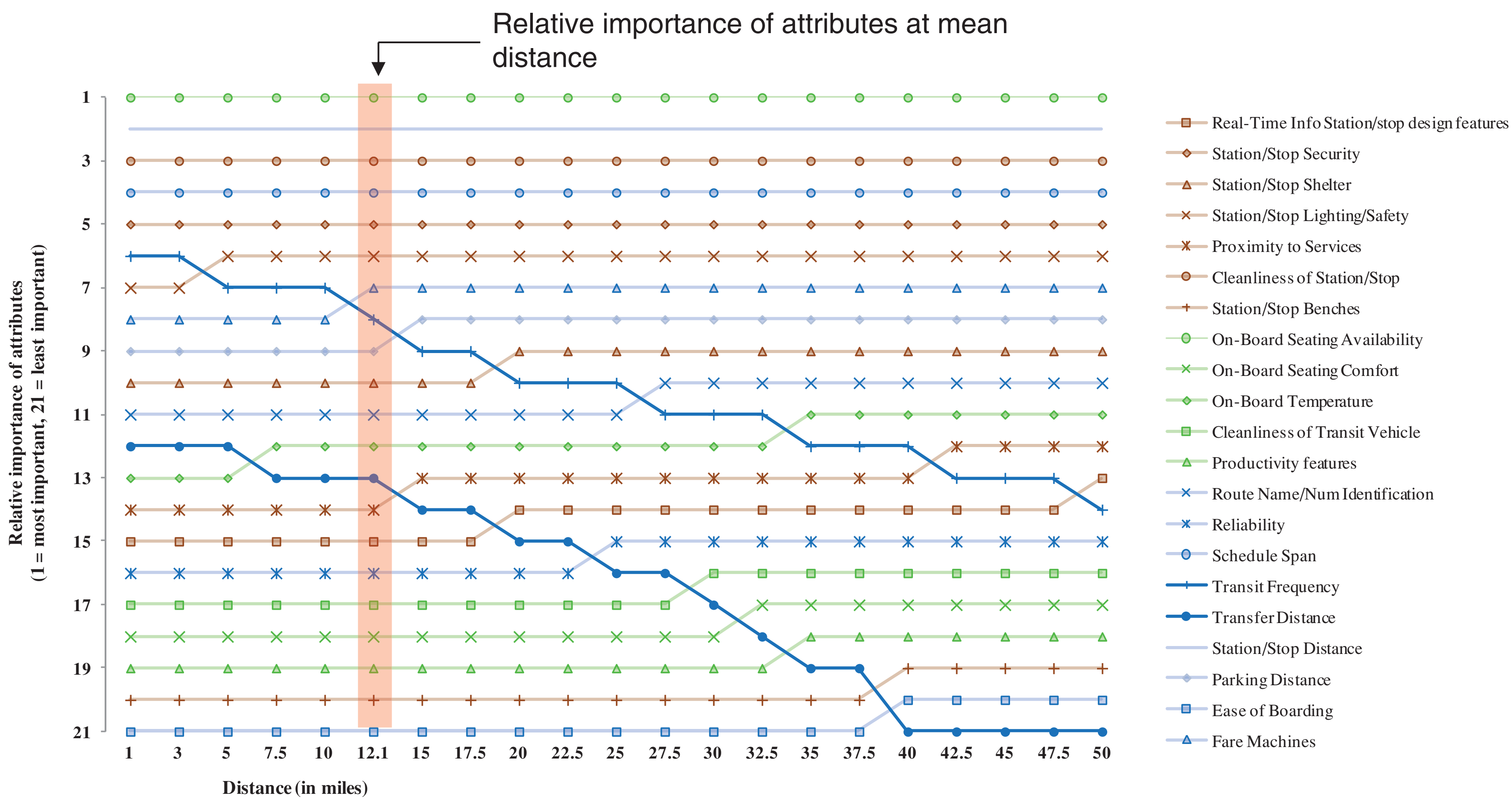


FIGURE D-5. Relative importance of transit attributes by distance for Chicago (non-commute trip).

An intuitive and interesting observation is that the level of importance of transit attributes is not the same across all strata of commuters in Chicago. For example, parking distance is regarded as the most important transit attribute by full-time employed commuters relative to self-employed/part-time employed commuters with the same characteristics. (In the interest of brevity, these results are only presented in Appendix B.) Though station/stop cleanliness has an overall ranking of five, this is the most important transit attribute for respondent commuters who are full-time students, female, long-time Chicago residents, or are traveling in a group. For non-commuting female travelers, long-time Chicago residents, or group travelers, transit frequency is the most important attribute (see Appendix E). Transit frequency is also ranked highest among other non-commuting strata, such as full-time workers, retired individuals, individuals aged 35 to 55, individuals from households with 1 or 2 vehicles, and individuals from households with at least $75,000 income. From a transit strategy formulation standpoint, these results may be useful. For example, findings from this study may be used by transit providers to formulate strategies that would provide improved service to specific demographic segments.

Charlotte

Figure D-6 shows the MaxDiff model results for Charlotte and the marginal rates of substitution. The relative importance of transit attributes is presented in FIGURE D-7 and FIGURE D-8 for commute and non-commute trips for Charlotte (see Appendix E for the model results). The scaled results corresponding to this study area are also discussed in the next section.

Commuters and non-commuters in the Charlotte area behave in a similar manner to commuters and non-commuters in Chicago, with a few exceptions (though, in general, unscaled marginal rates of substitution are higher for Charlotte non-commute trips relative to similar trips for Chicago). For example, station/stop distance and cleanliness of station/stop are the two (almost equally) important attributes for commuters in Charlotte, while on-board seating availability and cleanliness of station/stop are the most important transit attributes for non-commuters. Both commuters and non-commuters in Charlotte almost always consider station/stop security and lighting/safety to be more important than their counterpart travelers in Chicago. Relative to non-commuters, Charlotte commuters are more sensitive to attributes such as reliability and parking distance that have a direct impact on travel time, while Charlotte non-commuters are more sensitive to attributes such as schedule span and frequency that have a direct impact on trip scheduling.

An interesting contrast between Chicago and Charlotte is that the relative importance of attributes does not change with travel distance for commuters and non-commuters in Charlotte (the only exception is the station/stop benches attribute for Charlotte commuters—see FIGURE D-7). To conserve space, the figure showing relative importance of transit attributes by distance for Charlotte non-commuters has been omitted. However, like Chicago, the level of importance of attributes does vary between different segments of commuters and non-commuters (see Appendix E).

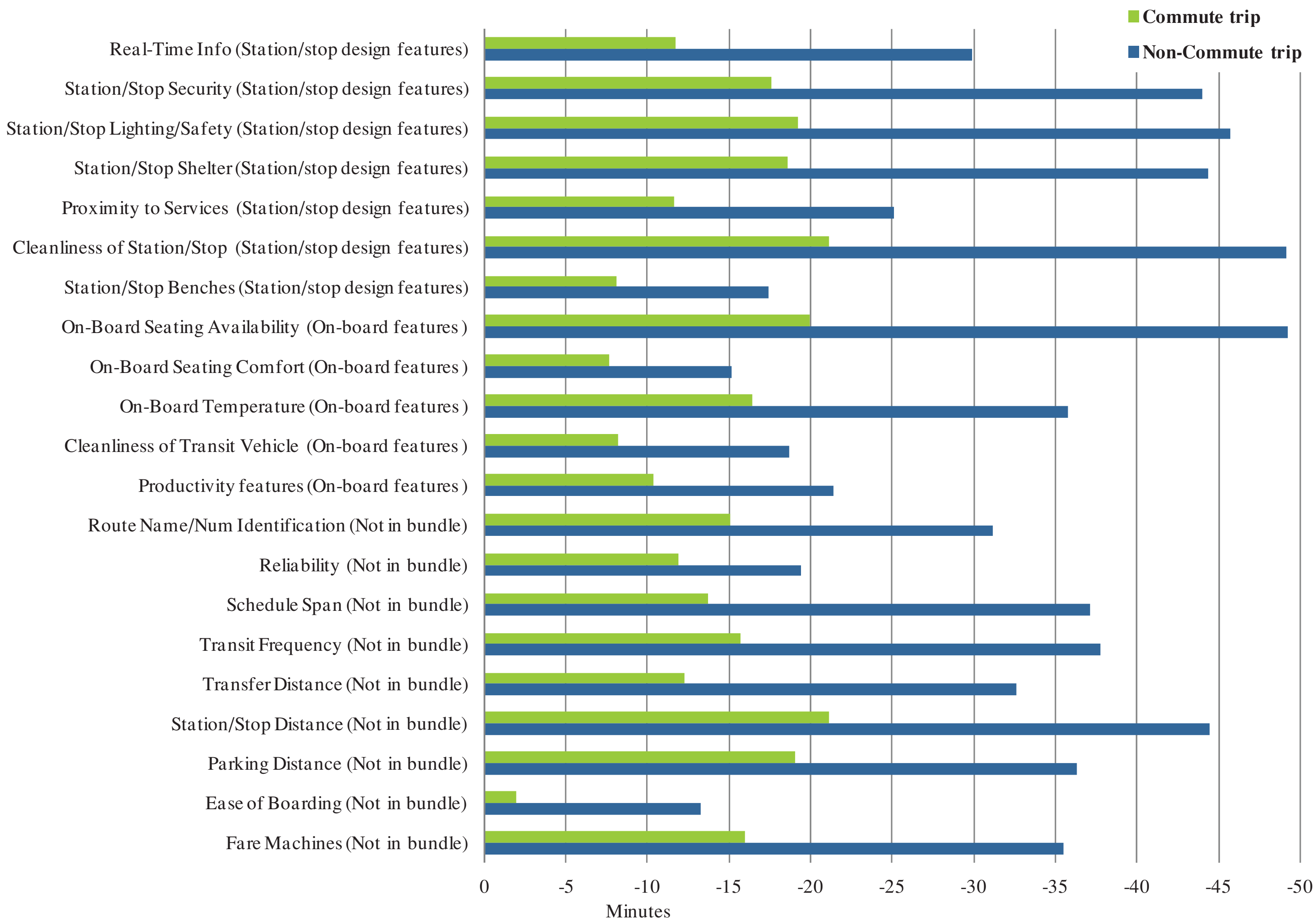


FIGURE D-6. Unscaled marginal rates of substitution (in minutes) for Charlotte.

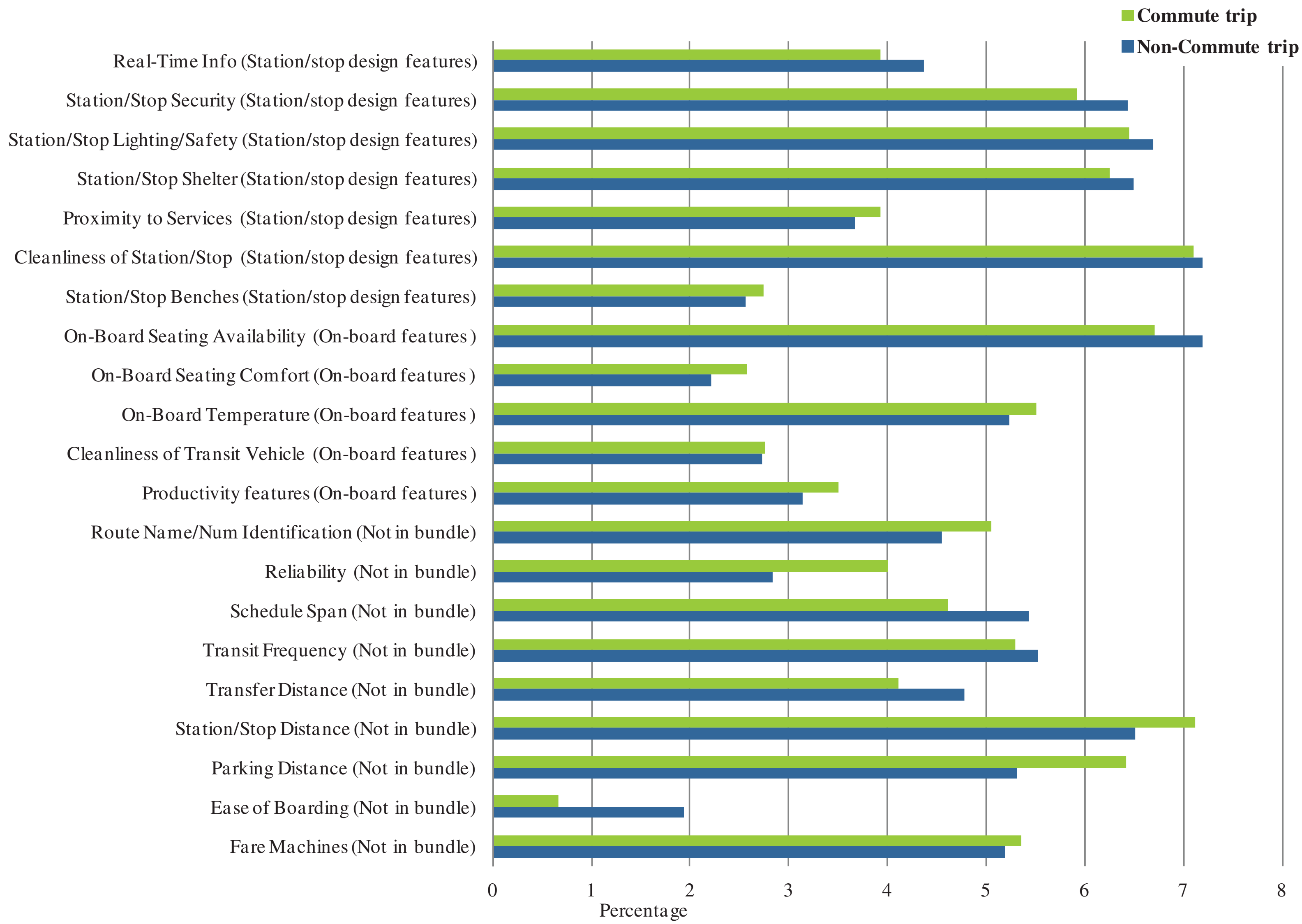


FIGURE D-7. Relative importance of transit attributes (in %) for Charlotte.

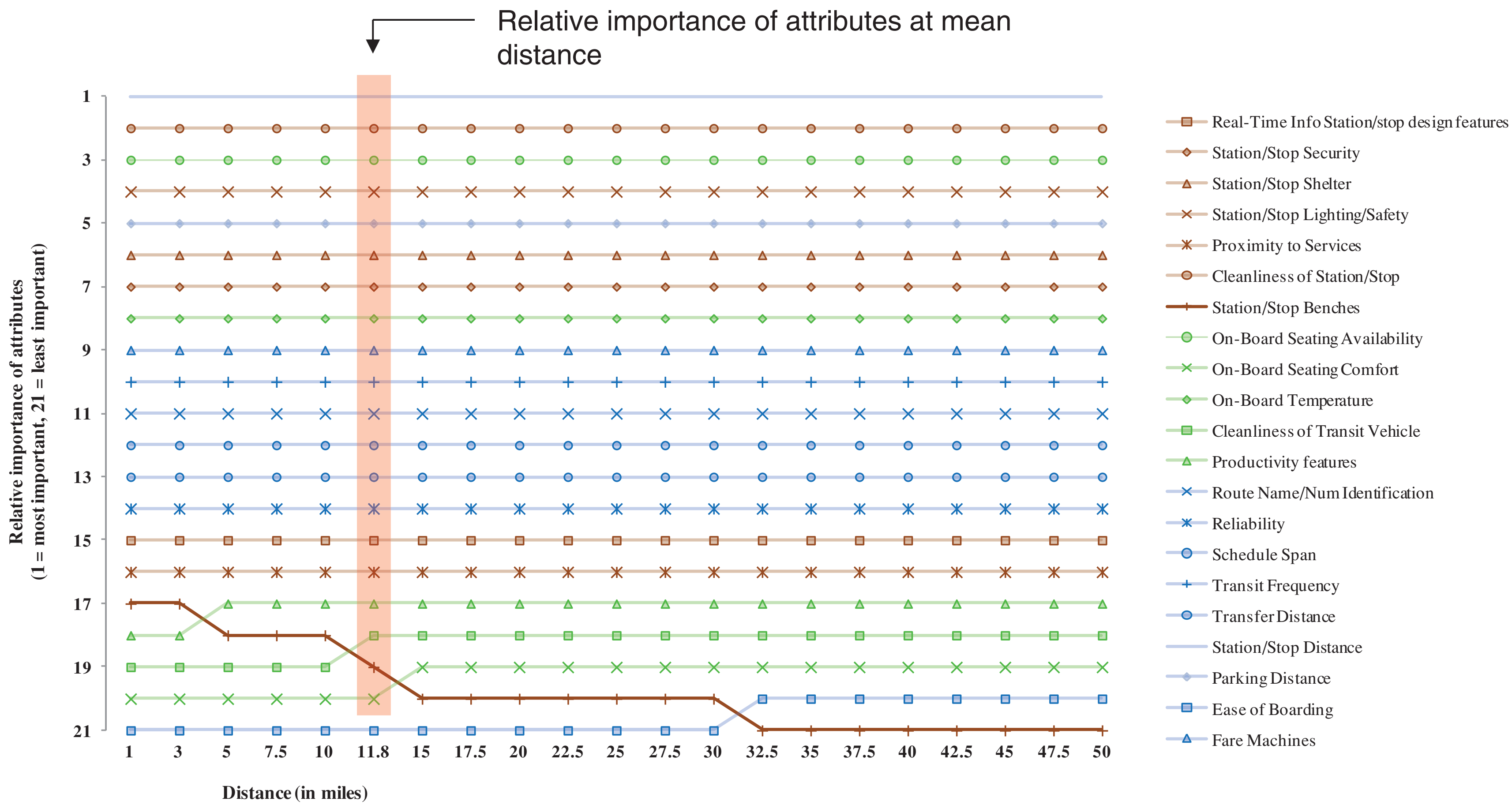


FIGURE D-8. Relative importance of transit attributes by distance for Charlotte (commute trip).

TABLE D-1. Relative importance of attributes by trip purpose—comparison of Chicago, Charlotte, and Salt Lake City.

Attribute	Attribute Bundle	Commute			Non-Commute		
		Chicago	Charlotte	Salt Lake	Chicago	Charlotte	Salt Lake
Real-time info*	Station/stop design	14	15	12	15	14	9
Station/stop security	Station/stop design	10	7	9	5	6	12
Station/stop lighting/safety	Station/stop design	8	4	10	6	3	13
Station/stop shelter	Station/stop design	9	6	5	10	5	4
Proximity to services	Station/stop design	18	16	11	14	15	1
Cleanliness of station/stop	Station/stop design	5	2	16	3	2	16
Station/stop benches	Station/stop design	15	19	15	20	19	15
On-board seating availability	On-board features	2	3	14	1	1	14
On-board seating comfort	On-board features	19	20	20	18	20	20
On-board temperature	On-board features	12	8	17	12	10	17
Cleanliness of transit vehicle	On-board features	20	18	21	17	18	21
Productivity features**	On-board features	17	17	19	19	16	19
Route name/number identification	Not part of a bundle	11	11	6	11	13	3
Reliability	Not part of a bundle	16	14	7	16	17	11
Schedule span	Not part of a bundle	7	12	13	4	8	7
Transit frequency	Not part of a bundle	4	10	1	8	7	5
Transfer distance	Not part of a bundle	13	13	2	13	12	6
Station/stop distance	Not part of a bundle	1	1	4	2	4	2
Parking distance	Not part of a bundle	3	5	8	9	9	10
Ease of boarding	Not part of a bundle	21	21	18	21	21	18
Fare machines	Not part of a bundle	6	9	3	7	11	8

*The attribute was not part of station/stop design features bundle in the survey for Salt Lake City.

**The attribute was referred to simply as "Wi-Fi" in the survey for Salt Lake City.

Finally, there are more similarities between the residents in the Chicago and Charlotte areas (in terms of their preferences regarding the transit attributes) than between the residents in Chicago and Salt Lake City or between the residents in Charlotte and Salt Lake City (see TABLE D-1). In particular, the residents in Salt Lake City rate attributes such as proximity to services, cleanliness of station/stop, on-board seating availability, reliability, and transfer distance quite differently than do the Chicago and Charlotte residents. One possible reason for these differences may be that the survey design and administration was undertaken in a slightly different manner for Salt Lake City, compared to the Chicago and Charlotte surveys. For instance, all respondents participated in the surveys for the Chicago and Charlotte areas (except for respondents who indicated that they were "very uninformed" about the local transit system), whereas only respondents who were transit users participated in the Salt Lake City survey. Also, in the Salt Lake City survey, the station/stop design feature bundle did not contain the real-time information attribute and the "productivity features" attribute was included simply as "Wi-Fi" in the on-board features bundle.

Model Results of Scaled Attributes

The MaxDiff model results need to be scaled before the coefficients can be incorporated in planning analysis. This scaling is completed to associate the bundled coefficients in the MaxDiff model with the bundled coefficients estimated in the mode choice models. This ensures that there the individual characteristics represented in the MaxDiff model are consistent with the trade-offs identified in the mode choice model estimation process (described in Appendix E).

For this exercise, depending on the coefficients that are available from the mode choice models, transit attributes are divided into two groups:

1. Bundled transit attributes include transit attributes that are part of station/stop design features and on-board features bundles. In general, for each study area/trip purpose combination, the mode choice model provides coefficients for the overall bundle. These coefficients are then used as control variables to adjust/scale the magnitude of the MaxDiff coefficients of the corresponding bundle. Specifically, assume that C_i is the overall coefficient for bundle *i* (estimated by the mode choice model) and M_{ij} is a MaxDiff model coefficient that corresponds to attribute *j* in bundle *i*. To obtain the adjusted coefficient for attribute *j*, S_{ij}, the following formula is applied:

$$S_{ij} = \frac{M_{ij}}{\sum_{j=1}^{J} M_{ij}} \times C_i$$

   where *J* is the total number of attributes in bundle *i*.

2. **Unbundled transit attributes** includes all other transit attributes. For scaling purpose, the unbundled attributes are divided into two categories as follows:
   - **Category A:** This includes attributes for which coefficients are available from the mode choice models. Reliability and schedule span attribute fall under this category. The unscaled coefficients of these two variables can be replaced by the mode choice model results in a straightforward manner.

- **Category B:** All other unbundled attributes belong to this category. The overall coefficients for the station/stop design and on-board features bundles available from the mode choice and MaxDiff models are used to scale the coefficients under this category. In particular, assume that the overall coefficients for the station/stop design and on-board features bundles from the mode choice model are a_1 and a_2, and from the MaxDiff model are A_1 and A_2, respectively. Also, assume that the overall coefficient for Category B from the MaxDiff model is A_3. The overall mode choice coefficient for Category B, a_3, is predicted as follows:

  $$a_3 = e + m \times A_3$$

  where

  $$m = \frac{a_1 - a_2}{A_1 - A_2}, e = a_1 - m \times A_1.$$

  Then, using the formula presented above, the value of a_3 may be distributed among its component attributes. To illustrate, for Chicago commuters (transit mode = bus), $a_1 = 0.124$, $a_2 = 0.146$, $A_1 = 6.275$, $A_2 = 3.570$, and $A_3 = 6.897$. Using these values, we obtain m = -0.008, e = 0.175, and a_3 = 0.119. Now, using these values, the adjusted coefficient, for example, for route name/number identification attribute $= \frac{0.908}{6.897} \times 0.119 = 0.016.$

The mode choice coefficients used in scaling the MaxDiff model coefficients are provided in TABLE D-2 for reference. These are described more fully in Appendix E.

Salt Lake City

TABLE D-3 and TABLE D-4 present the coefficients for the stop design and on-board amenity bundles from mode choice models, respectively, for work and non-work travel from Salt Lake City data. The tables also show the corresponding scaled coefficients and marginal rates of substitution for the attributes in the two bundles. These results demonstrate that there is a wide variation in stop design attributes for work and non-work travel, and that there is much less variation in on-board attributes for work and non-work travel.

TABLE D-2. Coefficients from the mode choice model used in the MaxDiff models.

Variable		Commute		Non-Commute	
	City	Bus	Train	Bus	Train
In-vehicle travel time (minutes)	Salt Lake City	-0.034	-0.034	-0.049	-0.049
	Chicago	-0.025	-0.025	-0.019	-0.019
	Charlotte*	-0.022	-0.022	-0.008	-0.008
Premium stop design amenities	Salt Lake City	0.166	0.166	0.061	0.061
	Chicago	0.124	0.124	0.084	0.084
	Charlotte	0.103	0.060	0.172	0.172
Premium on-board amenities	Salt Lake City	0.127	0.127	0.148	0.148
	Chicago	0.146	0.146	0.205	0.205
	Charlotte	0.101	0.101	0.180	0.180
Reliability**	Salt Lake City	-0.024	-0.024	-0.025	-0.025
	Chicago	0.147	0.135	0.088	0.088
	Charlotte	0.101	0.101	0	0

*The In-Vehicle Travel Time Coefficient for non-commute trips in Charlotte is lower than what is considered reasonable and so, for the purposes of the MaxDiff model scaling, the Chicago non-commute in-vehicle travel time coefficient was used instead.

**The definition of the reliability coefficient and the estimation for this variable changed for Chicago and Charlotte and the coefficients are not directly comparable, because the stated preference questions were refined to reflect values closer to transit agency definitions (x% of trips delayed by y minutes or more) rather than the original (x in 10 trips experience delay of y minutes or more).

TABLE D-3. Scaled coefficients of bundled attributes for work travel: Salt Lake City.

Attribute	Mode	Coefficient	Std. Err	t-stat	Value	Notes
Stop design (0 = standard, 1 = modern)	Bus,train	0.166	0.043	3.843	4.628	times IVTT
Station/Stop Lighting/Safety		0.032	N/A	N/A	0.878	times IVTT
Station/Stop Shelter		0.040	N/A	N/A	1.099	times IVTT
Proximity to Services		0.030	N/A	N/A	0.842	times IVTT
Cleanliness of Station/Stop		0.015	N/A	N/A	0.419	times IVTT
Station/Stop Benches		0.018	N/A	N/A	0.489	times IVTT
Station/Stop Security		0.032	N/A	N/A	0.884	times IVTT
On-board amenities (0 = standard, 1 = modern)	Bus,train	0.127	0.051	2.478	3.552	times IVTT
WiFi *		0.019	N/A	N/A	0.540	times IVTT
On-Board Seating Availability		0.044	N/A	N/A	1.230	times IVTT
On-Board Seating Comfort		0.018	N/A	N/A	0.507	times IVTT
On-Board Temperature		0.029	N/A	N/A	0.810	times IVTT
Cleanliness of Transit Vehicle		0.016	N/A	N/A	0.442	times IVTT

TABLE D-4. Scaled coefficients of bundled attributes for non-work travel: Salt Lake City.

Attribute	Mode	Coefficient	Std. Err	t-stat	Value	Notes
Stop design Bundle (0 = standard, 1 = modern)	Bus,train	0.061	0.075	0.809	1.55	times IVTT
Station/Stop Lighting/Safety		0.008	N/A	N/A	0.196	times IVTT
Station/Stop Shelter		0.014	N/A	N/A	0.371	times IVTT
Proximity to Services		0.019	N/A	N/A	0.474	times IVTT
Cleanliness of Station/Stop		0.006	N/A	N/A	0.145	times IVTT
Station/Stop Benches		0.006	N/A	N/A	0.159	times IVTT
Station/Stop Security		0.009	N/A	N/A	0.219	times IVTT
On-board amenities (0 = standard, 1 = modern)	Bus,train	0.148	0.075	1.978	3.754	times IVTT
WiFi		0.029	N/A	N/A	0.735	times IVTT
On-Board Seating Availability		0.055	N/A	N/A	1.411	times IVTT
On-Board Seating Comfort		0.016	N/A	N/A	0.409	times IVTT
On-Board Temperature		0.033	N/A	N/A	0.853	times IVTT
Cleanliness of Transit Vehicle		0.015	N/A	N/A	0.388	times IVTT

TABLE D-5 and TABLE D-6 present adjusted MaxDiff model results and the corresponding marginal rates of substitution for the Chicago and Charlotte areas, respectively. A comparison indicates that, at aggregate level, Chicago commuters value unbundled attributes most and station/stop design features least (though these features still add value), regardless of the mode of transit, while Chicago non-commuters value on-board amenities the most, with the unbundled attributes a close second. A similar trend can also be observed among Charlotte commuters, but Charlotte non-commuters valued the on-board, station, and unbundled attributes almost equally. In the mode choice models, the aggregate-level bundle variables (and their coefficients) may be replaced by the corresponding component attributes (and adjusted coefficients) in a straightforward manner. For the unbundled attributes, the alternative specific constants for bus and train modes should be adjusted before the scaled coefficients are included in the mode choice models. One way to adjust the mode-specific constants is to run the mode choice models with and without the "anchor" variables. The differences in the magnitude of the mode-specific constants between the two models may then be used to make suitable adjustments to the mode-specific constants of the final mode choice models that include all unbundled attributes.

Once the transit attributes are incorporated, the mode choice models may be used to analyze future scenarios such as testing the effects of improving one or a set of attributes on transit mode share. TABLE D-5 and TABLE D-6 also provide information on how much additional time the commuters and non-commuters in the study areas may be willing to add to their in-vehicle travel time to include the corresponding attributes on the route (see the "Scaled Marginal Rates of Substitution" column). For example, Chicago commuters would be willing to increase their transit travel time by about 5 minutes to have all the station/stop design-related attributes on their routes. The results in the tables indicate that time values are very similar for station/stop design and on-board attributes for commuters in Chicago and Charlotte (except that the train mode for Charlotte commuters is valued less). The non-commuters are, in general, willing to pay more than commuters to have these attributes on their routes. A "-" entry in the tables indicates that either the coefficient is not statistically significant or the coefficient is constrained to zero to avoid a negative value.

Chicago and Charlotte

TABLE D-5 and TABLE D-6 present adjusted MaxDiff model results and the corresponding marginal rates of substitution for the Chicago and Charlotte areas, respectively. FIGURE D-9 and FIGURE D-10 present the same information cumulatively for Chicago and Charlotte, respectively. A visual comparison indicates that, at an aggregate level, both Chicago commuters value unbundled attributes most and station/stop design features least (though, these features still add value), regardless of the mode of transit, while Chicago non-commuters value on-board amenities the most, with the unbundled attributes a close second. A similar trend can also be observed among Charlotte commuters, but Charlotte non-commuters valued the on-board, station and unbundled attributes almost equally. In the mode choice models, the aggregate-level bundle variables (and their coefficients) may be replaced by the corresponding component attributes (and adjusted coefficients) in a straightforward manner. For the unbundled attributes, the alternative specific constants for bus and train modes should be adjusted before the scaled coefficients are included in the mode choice models.

Once the transit attributes are incorporated, the mode choice models may be used to analyze future scenarios, such as testing the effects of improving one or a set of attributes on transit mode share. TABLE D-5 and TABLE D-6 also provide information on how much additional time the commuters and non-commuters in the study areas may be willing to add to their in-vehicle travel time to include the corresponding attributes on the route (see the "Scaled Marginal Rates of Substitution" column). For example, Chicago commuters would be willing to increase their transit travel time by about 5 minutes to have all the station/stop design-related attributes on their routes. The results in the tables indicate that time values are very similar for station/stop design and on-board attributes for commuters in Chicago and Charlotte (except that the train mode for Charlotte commuters is valued less). The non-commuters are, in general, willing to pay more than commuters to have these attributes on their routes. A "-" entry in the tables indicates that either the coefficient is not statistically significant or the coefficient is constrained to zero to avoid a negative value.

TABLE D-5. Scaled MaxDiff model results and marginal rates of substitution for Chicago.

Attribute	Scaled Coefficient (t-stat)				Scaled Marginal Rates of Substitution (with respect to IVTT, in minutes)			
	Commute trips		**Non-commute trips**		**Commute trips**		**Non-commute trips**	
	Bus	**Train**	**Bus**	**Train**	**Bus**	**Train**	**Bus**	**Train**
Station/stop design features bundle	**0.124 (2.5)**	**0.124 (2.5)**	**0.084 (2.3)**	**0.084 (2.3)**	**-4.96**	**-4.96**	**-4.42**	**-4.42**
Real-time info	0.015	0.015	0.008	0.008	-0.62	-0.62	-0.44	-0.44
Station/stop security	0.021	0.021	0.016	0.016	-0.85	-0.85	-0.84	-0.84
Station/stop lighting/safety	0.022	0.022	0.016	0.016	-0.86	-0.86	-0.82	-0.82
Station/stop shelter	0.021	0.021	0.013	0.013	-0.86	-0.86	-0.69	-0.69
Proximity to services	0.010	0.010	0.009	0.009	-0.40	-0.40	-0.50	-0.50
Cleanliness of station/stop	0.022	0.022	0.016	0.016	-0.90	-0.90	-0.86	-0.86
Station/Stop Benches	0.012	0.012	0.005	0.005	-0.48	-0.48	-0.27	-0.27
On-board features bundle	**0.146 (2.5)**	**0.146 (2.5)**	**0.205 (3.5)**	**0.205 (3.5)**	**-5.88**	**-5.88**	**-10.79**	**-10.79**
On-board seating availability	0.054	0.054	0.078	0.078	-2.15	-2.15	-4.09	-4.09
On-board seating comfort	0.019	0.019	0.026	0.026	-0.77	-0.77	-1.39	-1.39
On-board temperature	0.035	0.035	0.046	0.046	-1.41	-1.41	-2.41	-2.41
Cleanliness of transit vehicle	0.016	0.016	0.030	0.030	-0.64	-0.64	-1.56	-1.56
Productivity features	0.022	0.022	0.025	0.025	-0.87	-0.87	-1.34	-1.34
Unbundled features	**0.285**	**0.273**	**0.181**	**0.190**	**-11.41**	**-10.93**	**-9.55**	**-10.00**
Route name/number Identification	0.016	0.016	0.011	0.012	-0.63	-0.63	-0.58	-0.63
Reliability	0.147 (2.1)	0.135 (2.1)	0.088 (1.6)	-	-5.88	-5.40	-4.63	-
Schedule span*	0.019	0.019	0.015	0.016	-0.77	-0.77	-0.78	-0.86
Transit frequency	0.021	0.021	0.013	0.014	-0.82	-0.82	-0.68	-0.74
Transfer distance	0.014	0.014	0.009	0.010	-0.56	-0.56	-0.46	-0.50
Station/stop distance	0.023	0.023	0.015	0.017	-0.92	-0.92	-0.80	-0.88
Parking distance	0.021	0.021	0.013	0.014	-0.84	-0.84	-0.68	-0.74
Ease of boarding	0.005	0.005	0.005	0.005	-0.21	-0.21	-0.24	-0.26
Fare machines	0.019	0.019	0.013	0.014	-0.78	-0.78	-0.69	-0.75

*Note: Schedule span was included as a separate variable in the Max Diff experiments, but the coefficients estimated separately for this variable were unreasonably high, so these were estimated along with the remaining unbundled features, relative to the reliability measure, which was also included as a separate variable in the Max Diff experiments.

TABLE D-6. Scaled MaxDiff model results and marginal rates of substitution for Charlotte.

Attribute	Scaled Coefficient (t-stat)				Scaled Marginal Rates of Substitution (with respect to IVTT, in minutes)			
	Commute Trips		Non-Commute Trips		Commute Trips		Non-Commute Trips**	
	Bus	Train	Bus	Train	Bus	Train	Bus	Train
Station/stop design features bundle	**0.103 (2.4)**	**0.060 (1.6)**	**0.172 (2.1)**	**0.172 (2.1)**	**-4.68**	**-2.73**	**-9.05**	**-9.05**
Real-time info	0.011	0.006	0.020	0.020	-0.51	-0.30	-1.06	-1.06
Station/stop security	0.017	0.010	0.030	0.030	-0.76	-0.44	-1.56	-1.56
Station/stop lighting/safety	0.018	0.011	0.031	0.031	-0.83	-0.48	-1.62	-1.62
Station/stop shelter	0.018	0.010	0.030	0.030	-0.81	-0.47	-1.57	-1.57
Proximity to services	0.011	0.006	0.017	0.017	-0.51	-0.29	-0.89	-0.89
Cleanliness of station/stop	0.020	0.012	0.033	0.033	-0.92	-0.53	-1.74	-1.74
Station/Stop Benches	0.008	0.005	0.012	0.012	-0.35	-0.21	-0.62	-0.62
On-board features bundle	**0.101 (2.1)**	**0.101 (2.1)**	**0.180 (3.1)**	**0.180 (3.1)**	**-4.59**	**-4.59**	**-9.47**	**-9.47**
On-board seating availability	0.032	0.032	0.063	0.063	-1.46	-1.46	-3.32	-3.32
On-board seating comfort	0.012	0.012	0.019	0.019	-0.56	-0.56	-1.02	-1.02
On-board temperature	0.026	0.026	0.046	0.046	-1.20	-1.20	-2.42	-2.42
Cleanliness of transit vehicle	0.013	0.013	0.024	0.024	-0.60	-0.60	-1.26	-1.26
Productivity features	0.017	0.017	0.027	0.027	-0.76	-0.76	-1.45	-1.45
Unbundled features	**0.548**	**0.410**	**0.741**	**0.864**	**-9.89**	**-8.01**	**-10.61**	**-9.50**
Route name/number Identification	0.015	0.010	0.023	0.040	-0.69	-0.45	-1.23	-1.10
Reliability	0.101 (2.3)	0.101 (2.3)	-	-	-4.59	-4.59	-	-
Schedule span*	0.014	0.009	0.028	0.025	-0.63	-0.41	-1.47	-1.31
Transit frequency	0.016	0.010	0.028	0.048	-0.73	-0.47	-1.49	-1.34
Transfer distance	0.012	0.008	0.025	0.042	-0.56	-0.36	-1.29	-1.15
Station/stop distance	0.021	0.014	0.033	0.057	-0.98	-0.63	-1.76	-1.58
Parking distance	0.019	0.012	0.027	0.047	-0.88	-0.57	-1.44	-1.28
Ease of boarding	0.002	0.001	0.010	0.017	-0.09	-0.06	-0.52	-0.47
Fare machines	0.016	0.010	0.027	0.046	-0.74	-0.47	-1.40	-1.26

*Note: Schedule span was included as a separate variable in the Max Diff experiments, but the coefficients estimated separately for this variable were unreasonably high, so these were estimated along with the remaining unbundled features, relative to the reliability measure, which was also included as a separate variable in the Max Diff experiments

** These non-commute trips have been scaled to an in-vehicle travel time coefficient of -0.0019 from Chicago because the Charlotte in-vehicle travel time coefficient was too low to be reasonable.

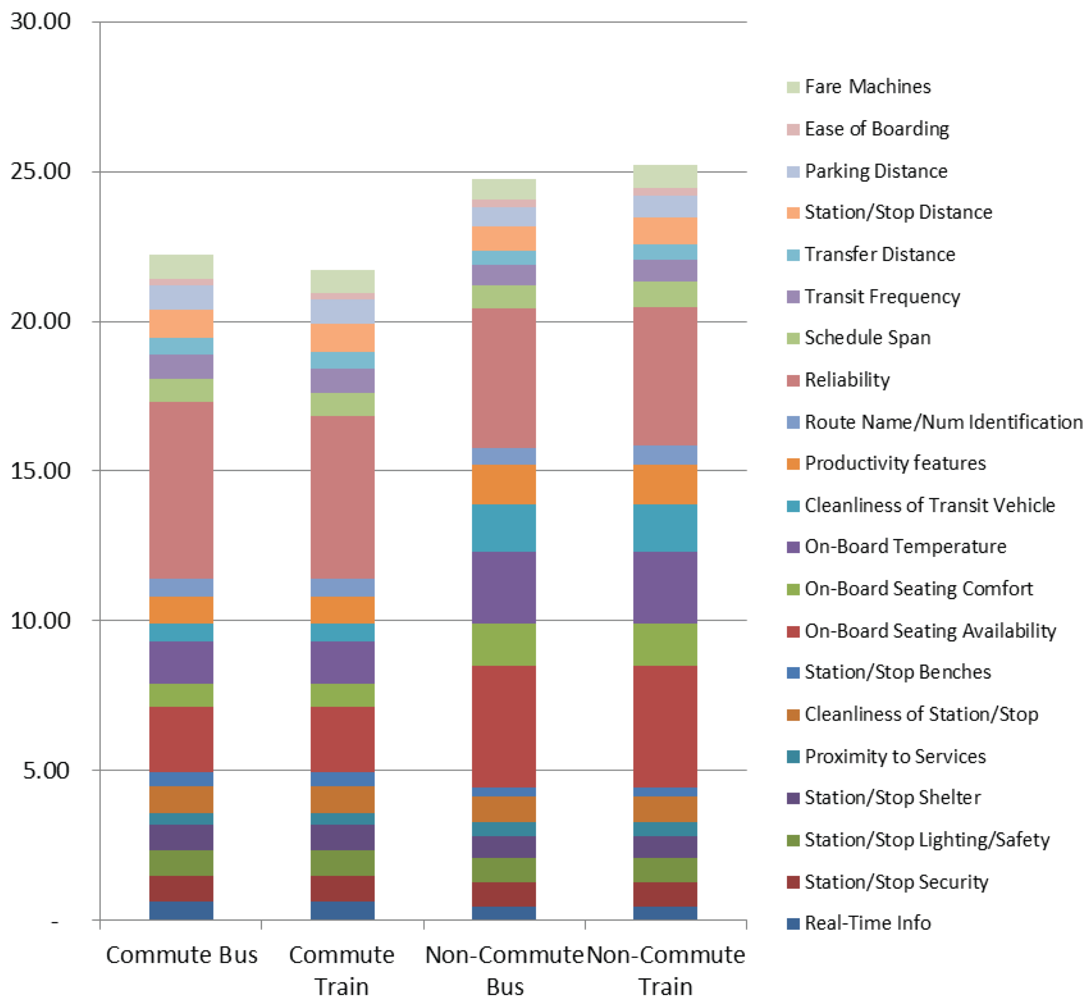


FIGURE D-9. Cumulative scaled equivalent minutes of in-vehicle travel time for Chicago.

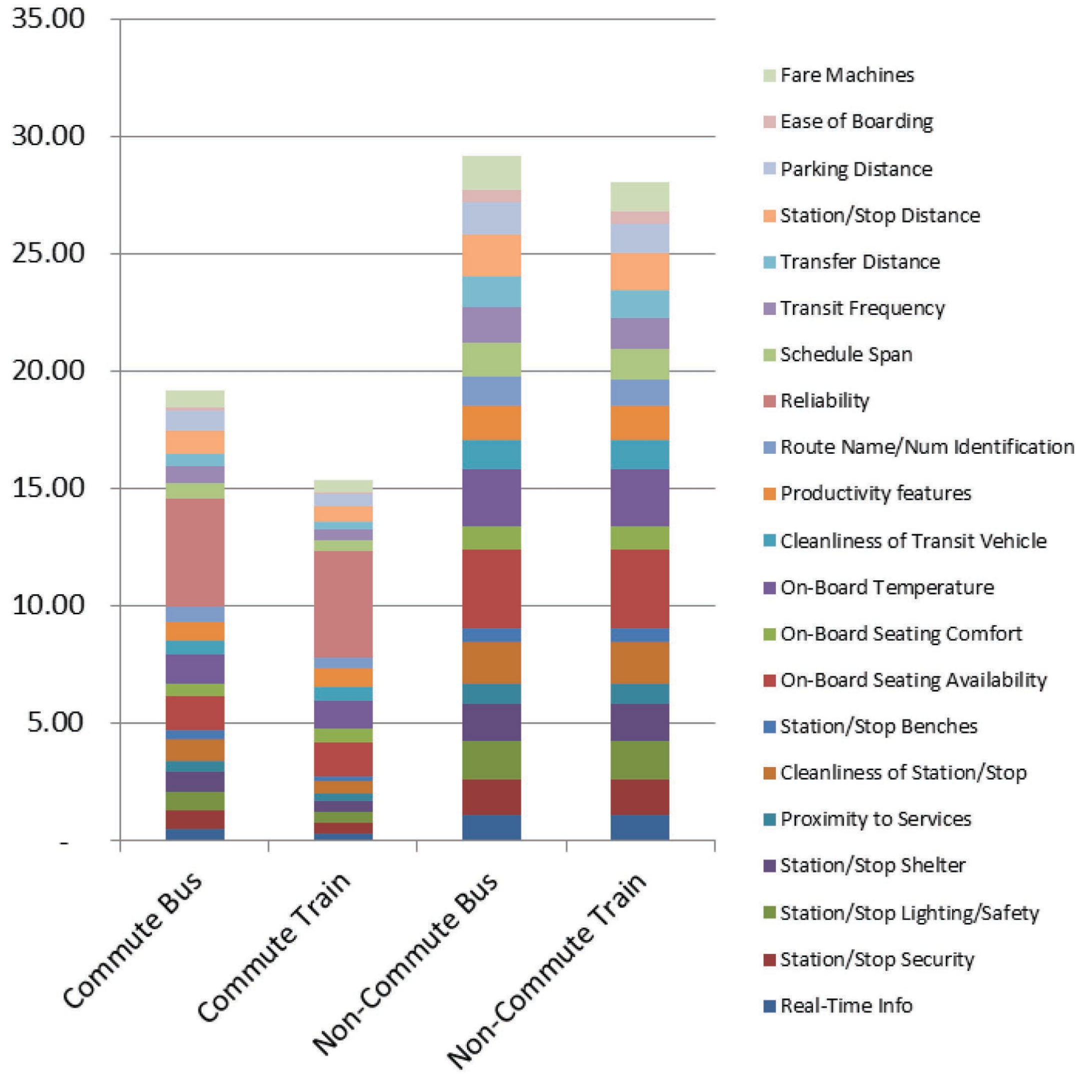


FIGURE D-10. Cumulative scaled equivalent minutes of in-vehicle travel time for Charlotte.

Details of the Transit Attribute Models

The following tables provide more detailed model results for the Maximum Difference Scaling models presented in Chapter 3 of *TCRP Report 166*:

- TABLE D-7. MaxDiff model estimation results for commute trips (t-stat) – Chicago
- TABLE D-8. MaxDiff model estimation results for non-commute trips (t-stat) – Chicago
- TABLE D-9. Relative rank of attributes by individual demographics, household demographics, trip characteristics, and attitudinal variables (relative importance in %) – Chicago (commute trips)
- TABLE D-10. Relative rank of attributes by individual demographics, household demographics, trip characteristics, and attitudinal variables (relative importance in %) – Chicago (non-commute trips)
- TABLE D-11. MaxDiff model estimation results for commute trips (t-stat) – Charlotte
- TABLE D-12. MaxDiff model estimation results for non-commute trips (t-stat) – Charlotte
- TABLE D-13. Relative rank of attributes by individual demographics, household demographics, trip characteristics, and attitudinal variables (relative importance in %) – Charlotte (commute trips)
- TABLE D-14. Relative rank of attributes by individual demographics, household demographics, trip characteristics, and attitudinal variables (relative importance in %) – Charlotte (non-commute trips)

TABLE D-7. MaxDiff model estimation results for commute trips (t-stat)—Chicago.

LOS/Attribute	Attribute Bundle	Coefficient (t-stat)	Individual Demographics Variables								Household Demographics Variables								Trip Characteristics		Attitude						
			Full-time student (base: part-time student/not student)	Employment status (base: self-employed/part-time employed/ not employed)		Female (base: male)	Long-time resident (> 5 years, base: short-time resident)	Has mobility problem (base: no mobility problem)	Age (base: age < 35)		Number of vehicles in the HH (base: no vehicles)			Family income (base: income < 35k)				Presence of kid(s) in the HH (base: no kids in the HH)	Group travel	(Actual distance /mean distance)	Pro-Transit Attitude	Environment, Productivity, and Time Savings	Pro-Car Attitude	Transit Averse	Low Transit Comfort Level	Willingness to walk	
				Full-time employed	Retired				35 ≤ Age < 55	Age ≥ 55	Number of vehs in the HH = 1	Number of vehs in the HH = 2	Number of vehs in the HH = 3+	35k ≤ Income < 50k	50k ≤ Income < 75k	75k ≤ Income < 100k	Income ≥ 100k									Willing to walk ≤ 2 min.	Willing to walk ≥ 10 min.
IVTT	-	-0.051 (-10.2)																									
Fare	-	-1.17 (-16.87)																		0.107 (3)							
Real-Time Info	Station/stop design features	0.833 (11.22)	-0.478 (-2.27)																								
Station/Stop Security	Station/stop design features	0.51 (3.66)				0.616 (4.08)			0.447 (2.99)				0.445 (2.35)					-0.411 (-2.59)									
Station/Stop Lighting/Safety	Station/stop design features	1.16 (10.46)														0.551 (2.64)				-0.148 (-1.89)				0.259 (2.44)	-0.284 (-2.45)		
Station/Stop Shelter	Station/stop design features	0.691 (5.37)							0.431 (2.63)	0.523 (2.56)					0.348 (1.98)												
Proximity to Services	Station/stop design features	0.516 (7.3)																							-0.213 (-1.95)		
Cleanliness of Station/Stop	Station/stop design features	1.31 (11.93)																		-0.164 (-2.13)	-0.17 (-1.91)						
Station/Stop Benches	Station/stop design features	0.427 (4.81)	0.654 (2.75)									0.309 (2.03)															
On-Board Seating Availability	On-board features	1.02 (9.93)							0.425 (2.89)				0.49 (2.48)														
On-Board Seating Comfort	On-board features	0.572 (6.73)																-0.31 (-2.09)									
On-Board Temperature	On-board features	0.7 (6.04)								0.408 (2.21)		0.408 (2.43)	0.491 (2.53)					-0.472 (-2.97)									
Cleanliness of Transit Vehicle	On-board features	0.711 (5.47)		-0.361 (-2.37)																			0.261 (2.97)		0.216 (1.99)	-0.641 (-3)	
Productivity features	On-board features	0.651 (8.17)								-0.339 (-2.05)																-0.45 (-2.02)	
Route Name/Num Identification	Not part of a bundle	0.92 (6.31)				0.326 (2.21)							0.401 (2.16)							-0.226 (-3.03)						-0.761 (-3.47)	
Reliability	Not part of a bundle	0.552 (7.82)																									
Schedule Span	Not part of a bundle	0.778 (5.31)							0.328 (1.97)	0.411 (1.98)	-0.296 (-1.93)				0.399 (2.15)	0.613 (2.8)							-0.223 (-2.38)				
Transit Frequency	Not part of a bundle	0.794 (5.04)				0.482 (3.17)										0.681 (3.2)	0.49 (2.83)			-0.167 (-2.15)			-0.19 (-2.04)				
Transfer Distance	Not part of a bundle	0.669 (6.49)																		0.147 (1.83)							
Station/Stop Distance	Not part of a bundle	0.77 (5.27)		0.301 (1.91)								0.347 (2.17)			0.597 (3.22)	0.512 (2.44)							-0.228 (-2.43)				
Parking Distance	Not part of a bundle	1.1 (5.67)		0.358 (2.24)								0.292 (1.72)	0.687 (3.31)					-0.412 (-2.54)									-0.373 (-2.4)
Ease of Boarding	Not part of a bundle	0.378 (4.88)											-0.37 (-2.1)														
Fare Machines	Not part of a bundle								0.582 (3.91)	0.83 (4.21)	0.764 (5.09)	0.685 (4.47)	0.92 (4.88)														

TABLE D-8. MaxDiff model estimation results for non-commute trips (t-stat)—Chicago.

LOS/Attribute	Attribute Bundle	Coefficient (t-stat)	Individual Demographics Variables: Full-time student (base: part-time student/ not student)	Employment status (base: self-employed/part-time employed/ not employed): Full-time employed	Employment status: Retired	Female (base: male)	Long-time resident (> 5 years, base: short-time resident)	Has mobility problem (base: no mobility problem)	Age (base: age < 35): 35 ≤ Age < 55	Age: Age ≥ 55	Household Demographics Variables: Number of vehicles in the HH (base: no vehicles): Number of vehs in the HH = 1	Number of vehs in the HH = 2	Number of vehs in the HH = 3+	Family income (base: income < 35k): 35k ≤ Income < 50k	50k ≤ Income < 75k	75k ≤ Income < 100k	Income ≥ 100k	Presence of kid(s) in the HH (base: no kids in the HH)	Trip Characteristics: Group travel	Trip Characteristics: (Actual distance /mean distance)	Attitude: Pro-Transit Attitude	Environment, Productivity, and Time Savings	Pro-Car Attitude	Transit Averse	Low Transit Comfort Level	Willingness to walk: Willing to walk ≤ 2 min.	Willing to walk ≥ 10 min.
IVTT	-	-0.056 (-5.6)																		0.011 (3.27)							
Fare	-	-1.46 (-21.09)															0.42 (4.82)			0.156 (6.93)							
Real-Time Info	**Station/stop design features**	0.748 (9.47)																									
Station/Stop Security		0.791 (4.75)				0.498 (2.73)				0.751 (4.01)			0.595 (2.3)	-0.427 (-1.9)													
Station/Stop Lighting/Safety		1.04 (8.31)			0.413 (1.81)								0.693 (2.79)						0.331 (1.95)								
Station/Stop Shelter		1.16 (13.82)																					-0.18 (-1.86)				
Proximity to Services		0.744 (8.2)													0.447 (2.18)												
Cleanliness of Station/Stop		0.963 (5.84)				0.485 (2.65)				0.443 (2.42)																	
Station/Stop Benches		0.458 (5.71)																									
On-Board Seating Availability	**On-board features**	1.32 (7.62)				0.337 (1.79)		0.752 (2.54)			-0.429 (-2.4)				0.499 (2.19)							0.412 (3.67)					
On-Board Seating Comfort		0.783 (5.44)																									-0.347 (-2)
On-Board Temperature		0.946 (11.25)																									
Cleanliness of Transit Vehicle		0.544 (6.16)											0.456 (1.97)														
Productivity features		0.646 (4.67)					-0.359 (-2.16)									0.649 (2.95)						0.256 (2.55)					
Route Name/Num Identification	**Not part of a bundle**	0.462 (3)				0.564 (3.28)				0.42 (2.43)												0.263 (2.48)		0.262 (2.13)		0.575 (2.04)	
Reliability		0.673 (8.38)																									
Schedule Span		1.31 (11.73)								0.357 (1.97)													-0.238 (-2.28)				
Transit Frequency		1.66 (12.2)												-0.6 (-2.71)				-0.5 (-2.71)		-0.169 (-2.3)			-0.326 (-3.22)				
Transfer Distance		0.456 (2.61)		0.424 (2.44)		0.408 (2.35)												0.52 (2.85)		-0.18 (-2.51)							
Station/Stop Distance		1.08 (6.56)	0.88 (2.49)	0.384 (2.08)			0.33 (1.84)																	-0.412 (-3.32)	0.395 (2.82)		
Parking Distance		0 (0)									1.41 (9.64)	1.15 (7.63)	1.58 (6.79)			0.463 (1.96)											
Ease of Boarding		0 (0)					0.508 (4.89)	0.876 (3.59)																			
Fare Machines		0 (0)				0.589 (4.09)								0.791 (3.39)	0.961 (4.28)	0.695 (2.89)	0.671 (3.34)										0.424 (2.78)

TABLE D-9. Relative rank of attributes by individual demographics, household demographics, trip characteristics, and attitudinal variables (relative importance in %)—Chicago (commute trips).

Attribute	Attribute Bundle	Variables: Individual Demographics								Household Demographics								Trip Characteristics		Attitude					Willingness to Walk	
		Full-time student (base: part-time student/ not student)	Employment status (base: self-employed/part-time employed/ not employed)		Female (base: male)	Long-time resident (> 5 years, base: short-time resident)	Has mobility problem (base: no mobility problem)	Age (base: age < 35)		Number of vehicles in the HH (base: no vehicles)			Family income (base: income < 35k)				Presence of kid(s) in the HH (base: no kids in the HH)	Group travel	(Actual distance /mean distance)	Pro-Transit Attitude	Environment, Productivity, and Time Savings	Pro-Car Attitude	Transit Averse	Low Transit Comfort Level	Willing to walk ≤ 2 min.	Willing to walk ≥ 10 min.
			Full-time employed	Retired				35 ≤ Age < 55	Age ≥ 55	Number of vehs in the HH = 1	Number of vehs in the HH = 2	Number of vehs in the HH = 3+	35k ≤ Income < 50k	50k ≤ Income < 75k	75k ≤ Income < 100k	Income ≥ 100k										
Real-time info		20 (2.33%)	7 (5.42%)	6 (5.53%)	8 (5.05%)	6 (5.53%)	6 (5.53%)	9 (4.82%)	9 (4.93%)	6 (5.36%)	8 (4.87%)	9 (4.60%)	6 (5.53%)	9 (5.08%)	9 (4.78%)	7 (5.36%)	5 (6.19%)	6 (5.53%)	5 (5.74%)	6 (5.59%)	6 (5.53%)	7 (5.67%)	6 (5.44%)	7 (5.64%)	5 (6.31%)	5 (5.67%)
Station/stop security	Station/stop design features	18 (3.35%)	17 (3.32%)	18 (3.39%)	5 (6.83%)	18 (3.39%)	18 (3.39%)	7 (5.54%)	18 (3.02%)	18 (3.28%)	20 (2.98%)	7 (5.27%)	18 (3.39%)	18 (3.11%)	18 (2.93%)	18 (3.28%)	20 (0.74%)	18 (3.39%)	18 (3.52%)	18 (3.42%)	18 (3.39%)	18 (3.47%)	18 (3.33%)	17 (3.45%)	15 (3.86%)	18 (3.47%)
Station/stop lighting/safety	Station/stop design features	2 (7.61%)	3 (7.55%)	2 (7.70%)	4 (7.04%)	2 (7.70%)	2 (7.70%)	3 (6.71%)	4 (6.87%)	2 (7.47%)	3 (6.78%)	6 (6.40%)	2 (7.70%)	4 (7.07%)	1 (9.82%)	3 (7.46%)	2 (8.62%)	2 (7.70%)	4 (6.98%)	1 (7.79%)	2 (7.70%)	2 (7.90%)	1 (9.26%)	6 (5.93%)	2 (8.78%)	2 (7.90%)
Station/stop shelter	Station/stop design features	12 (4.53%)	11 (4.50%)	12 (4.59%)	13 (4.19%)	12 (4.59%)	12 (4.59%)	4 (6.49%)	2 (7.19%)	12 (4.45%)	13 (4.04%)	14 (3.81%)	12 (4.59%)	6 (6.33%)	12 (3.97%)	12 (4.44%)	10 (5.13%)	12 (4.59%)	12 (4.76%)	12 (4.64%)	12 (4.59%)	9 (4.71%)	12 (4.51%)	12 (4.67%)	10 (5.23%)	12 (4.70%)
Proximity to services	Station/stop design features	17 (3.39%)	16 (3.36%)	17 (3.43%)	18 (3.13%)	17 (3.43%)	17 (3.43%)	19 (2.99%)	17 (3.05%)	17 (3.32%)	19 (3.02%)	19 (2.85%)	17 (3.43%)	17 (3.15%)	17 (2.96%)	17 (3.32%)	15 (3.83%)	17 (3.43%)	17 (3.56%)	17 (3.46%)	17 (3.43%)	17 (3.51%)	17 (3.37%)	20 (2.05%)	14 (3.91%)	17 (3.51%)
Cleanliness of station/stop	Station/stop design features	1 (8.60%)	2 (8.53%)	1 (8.70%)	1 (7.95%)	1 (8.70%)	1 (8.70%)	2 (7.58%)	1 (7.75%)	1 (8.44%)	2 (7.66%)	4 (7.23%)	1 (8.70%)	2 (7.98%)	4 (7.52%)	1 (8.42%)	1 (9.73%)	1 (8.70%)	1 (7.90%)	2 (7.66%)	1 (8.70%)	1 (8.92%)	2 (8.55%)	1 (8.86%)	1 (9.92%)	1 (8.92%)
Station/stop benches	Station/stop design features	4 (7.09%)	18 (2.78%)	19 (2.83%)	19 (2.59%)	19 (2.83%)	19 (2.83%)	20 (2.47%)	19 (2.53%)	20 (2.75%)	11 (4.30%)	20 (2.36%)	19 (2.83%)	19 (2.60%)	19 (2.45%)	19 (2.75%)	16 (3.17%)	19 (2.83%)	19 (2.94%)	19 (2.87%)	19 (2.83%)	19 (2.91%)	19 (2.79%)	18 (2.89%)	16 (3.23%)	19 (2.91%)
On-board seating availability	On-board features	5 (6.69%)	5 (6.64%)	4 (6.77%)	7 (6.19%)	4 (6.77%)	4 (6.77%)	1 (8.36%)	7 (6.04%)	4 (6.57%)	6 (5.96%)	2 (8.33%)	4 (6.77%)	7 (6.22%)	7 (5.86%)	5 (6.56%)	3 (7.58%)	4 (6.77%)	3 (7.03%)	4 (6.85%)	4 (6.77%)	4 (6.95%)	4 (6.66%)	3 (6.90%)	4 (7.72%)	3 (6.94%)
On-board seating comfort	On-board features	15 (3.75%)	14 (3.72%)	15 (3.80%)	16 (3.47%)	15 (3.80%)	15 (3.80%)	17 (3.31%)	15 (3.39%)	15 (3.68%)	17 (3.34%)	17 (3.16%)	15 (3.80%)	15 (3.49%)	15 (3.28%)	15 (3.68%)	18 (1.95%)	15 (3.80%)	15 (3.94%)	15 (3.84%)	15 (3.80%)	13 (3.90%)	15 (3.73%)	15 (3.87%)	12 (4.33%)	15 (3.89%)
On-board temperature	On-board features	11 (4.59%)	10 (4.56%)	11 (4.65%)	12 (4.25%)	11 (4.65%)	11 (4.65%)	13 (4.05%)	5 (6.56%)	11 (4.51%)	5 (6.48%)	5 (6.57%)	11 (4.65%)	12 (4.27%)	11 (4.02%)	11 (4.50%)	19 (1.69%)	11 (4.65%)	10 (4.83%)	11 (4.70%)	11 (4.65%)	8 (4.77%)	11 (4.57%)	11 (4.74%)	9 (5.30%)	11 (4.77%)
Cleanliness of transit vehicle	On-board features	10 (4.67%)	20 (2.28%)	10 (4.72%)	11 (4.31%)	10 (4.72%)	10 (4.72%)	12 (4.12%)	13 (4.21%)	10 (4.58%)	12 (4.16%)	13 (3.92%)	10 (4.72%)	11 (4.33%)	10 (4.08%)	10 (4.57%)	9 (5.28%)	10 (4.72%)	9 (4.90%)	10 (4.77%)	10 (4.72%)	5 (6.62%)	10 (4.64%)	4 (6.27%)	20 (0.53%)	10 (4.84%)
Productivity features	On-board features	14 (4.27%)	13 (4.24%)	14 (4.32%)	15 (3.95%)	14 (4.32%)	14 (4.32%)	15 (3.77%)	21 (1.85%)	14 (4.19%)	16 (3.81%)	16 (3.59%)	14 (4.32%)	14 (3.97%)	14 (3.74%)	14 (4.19%)	13 (4.84%)	14 (4.32%)	13 (4.49%)	14 (4.37%)	14 (4.32%)	11 (4.43%)	14 (4.25%)	14 (4.40%)	18 (1.52%)	14 (4.43%)
Route name/num. identification		6 (6.04%)	6 (5.99%)	5 (6.11%)	3 (7.56%)	5 (6.11%)	5 (6.11%)	8 (5.33%)	8 (5.45%)	5 (5.92%)	7 (5.38%)	3 (7.29%)	5 (6.11%)	8 (5.61%)	8 (5.28%)	6 (5.92%)	4 (6.84%)	5 (6.11%)	11 (4.78%)	5 (6.18%)	5 (6.11%)	6 (6.27%)	5 (6.00%)	5 (6.22%)	19 (1.20%)	4 (6.26%)
Reliability		16 (3.62%)	15 (3.59%)	16 (3.66%)	17 (3.35%)	16 (3.66%)	16 (3.66%)	18 (3.20%)	16 (3.27%)	16 (3.55%)	18 (3.23%)	18 (3.05%)	16 (3.66%)	16 (3.36%)	16 (3.17%)	16 (3.55%)	14 (4.10%)	16 (3.66%)	16 (3.81%)	16 (3.71%)	16 (3.66%)	15 (3.76%)	16 (3.60%)	16 (3.73%)	13 (4.18%)	16 (3.76%)
Schedule span	Not part of a bundle	8 (5.11%)	9 (5.07%)	8 (5.17%)	9 (4.72%)	8 (5.17%)	8 (5.17%)	5 (6.40%)	3 (7.04%)	19 (3.10%)	10 (4.55%)	11 (4.29%)	8 (5.17%)	3 (7.17%)	3 (7.99%)	8 (5.00%)	7 (5.78%)	8 (5.17%)	7 (5.36%)	8 (5.22%)	8 (5.17%)	14 (3.78%)	8 (5.08%)	9 (5.26%)	7 (5.89%)	7 (5.30%)
Transit frequency	Not part of a bundle	7 (5.21%)	8 (5.17%)	7 (5.27%)	2 (7.74%)	7 (5.27%)	7 (5.27%)	10 (4.60%)	11 (4.70%)	7 (5.11%)	9 (4.64%)	10 (4.38%)	7 (5.27%)	10 (4.84%)	2 (8.47%)	2 (8.26%)	6 (5.90%)	7 (5.27%)	14 (4.32%)	7 (5.33%)	7 (5.27%)	12 (4.11%)	7 (5.18%)	8 (5.37%)	6 (6.01%)	6 (5.41%)
Transfer distance	Not part of a bundle	13 (4.39%)	12 (4.36%)	13 (4.44%)	14 (4.06%)	13 (4.44%)	13 (4.44%)	14 (3.87%)	14 (3.96%)	13 (4.31%)	15 (3.91%)	15 (3.69%)	13 (4.44%)	13 (4.08%)	13 (3.84%)	13 (4.30%)	12 (4.97%)	13 (4.44%)	6 (5.63%)	13 (4.49%)	13 (4.44%)	10 (4.56%)	13 (4.37%)	13 (4.53%)	11 (5.06%)	13 (4.55%)
Station/stop distance	Not part of a bundle	9 (5.05%)	4 (6.97%)	9 (5.11%)	10 (4.67%)	9 (5.11%)	9 (5.11%)	11 (4.46%)	12 (4.56%)	8 (4.96%)	4 (6.53%)	12 (4.25%)	9 (5.11%)	1 (8.33%)	5 (7.36%)	9 (4.95%)	8 (5.72%)	9 (5.11%)	8 (5.31%)	9 (5.17%)	9 (5.11%)	16 (3.69%)	9 (5.03%)	10 (5.21%)	8 (5.83%)	8 (5.24%)
Parking distance	Not part of a bundle	3 (7.22%)	1 (9.49%)	3 (7.30%)	6 (6.67%)	3 (7.30%)	3 (7.30%)	6 (6.37%)	6 (6.51%)	3 (7.08%)	1 (8.14%)	1 (9.86%)	3 (7.30%)	5 (6.70%)	6 (6.31%)	4 (7.07%)	11 (5.11%)	3 (7.30%)	2 (7.58%)	3 (7.39%)	3 (7.30%)	3 (7.49%)	3 (7.18%)	2 (7.44%)	3 (8.33%)	9 (4.95%)
Ease of boarding		19 (2.48%)	19 (2.46%)	20 (2.51%)	20 (2.29%)	20 (2.51%)	20 (2.51%)	21 (2.19%)	20 (2.24%)	21 (2.43%)	21 (2.21%)	21 (0.04%)	20 (2.51%)	20 (2.30%)	20 (2.17%)	20 (2.43%)	17 (2.81%)	20 (2.51%)	20 (2.61%)	20 (2.54%)	20 (2.51%)	20 (2.57%)	20 (2.47%)	19 (2.56%)	17 (2.86%)	20 (2.57%)
Fare machines		-	-	-	-	-	-	16 (3.37%)	10 (4.91%)	9 (4.92%)	14 (4.01%)	8 (5.08%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE D-10. Relative rank of attributes by individual demographics, household demographics, trip characteristics, and attitudinal variables (relative importance in %)—Chicago (non-commute trips).

Attribute	Attribute Bundle	Variables: Individual Demographics								Household Demographics								Trip Characteristics		Attitude					Willingness to Walk	
		Full-time student (base: part-time student/not student)	Employment status (base: self-employed/part-time employed/ not employed)		Female (base: male)	Long-time resident (> 5 years, base: short-time resident)	Has mobility problem (base: no mobility problem)	Age (base: age < 35)		Number of vehicles in the HH (base: no vehicles)			Family income (base: income < 35k)				Presence of kid(s) in the HH (base: no kids in the HH)	Group travel	(Actual distance/ mean distance)	Pro-Transit Attitude	Environ-ment, Produc-tivity, and Time Savings	Pro-Car Attitude	Transit Averse	Low Transit Comfort Level	Willing to walk ≤ 2 min.	Willing to walk ≥ 10 min.
			Full-time employed	Retired				35 ≤ Age < 55	Age ≥ 55	Number of vehs in the HH = 1	Number of vehs in the HH = 2	Number of vehs in the HH = 3+	35k ≤ Income < 50k	50k ≤ Income < 75k	75k ≤ Income < 100k	Income ≥ 100k										
Real-time info		11 (4.49%)	12 (4.51%)	11 (4.62%)	13 (4.01%)	11 (4.60%)	12 (4.30%)	11 (4.74%)	12 (4.21%)	12 (4.46%)	12 (4.42%)	13 (3.91%)	11 (4.81%)	13 (4.23%)	12 (4.25%)	11 (4.55%)	12 (4.73%)	11 (4.64%)	11 (4.85%)	11 (4.74%)	12 (4.48%)	11 (4.97%)	10 (4.78%)	11 (4.62%)	12 (4.57%)	10 (4.72%)
Station/stop security	Station/stop design features	9 (4.75%)	10 (4.77%)	9 (4.88%)	5 (6.91%)	9 (4.86%)	10 (4.54%)	9 (5.01%)	3 (8.68%)	10 (4.72%)	10 (4.67%)	4 (7.25%)	19 (2.34%)	11 (4.47%)	10 (4.50%)	9 (4.81%)	10 (5.01%)	9 (4.91%)	9 (5.12%)	9 (5.01%)	10 (4.73%)	9 (5.26%)	8 (5.06%)	9 (4.89%)	10 (4.84%)	9 (4.99%)
Station/stop Lighting/safety		6 (6.24%)	6 (6.27%)	2 (8.97%)	8 (5.57%)	6 (6.39%)	6 (5.97%)	6 (6.59%)	8 (5.86%)	6 (6.20%)	7 (6.14%)	1 (9.07%)	6 (6.69%)	7 (5.88%)	7 (5.91%)	6 (6.32%)	6 (6.58%)	2 (8.51%)	6 (6.74%)	6 (6.59%)	6 (6.22%)	5 (6.91%)	5 (6.65%)	6 (6.43%)	6 (6.36%)	6 (6.56%)
Station/stop shelter		5 (6.96%)	5 (6.99%)	5 (7.16%)	6 (6.21%)	5 (7.13%)	4 (6.66%)	4 (7.35%)	6 (6.53%)	4 (6.92%)	4 (6.85%)	7 (6.07%)	3 (7.46%)	5 (6.56%)	5 (6.59%)	4 (7.05%)	3 (7.34%)	5 (7.20%)	4 (7.52%)	4 (7.35%)	4 (6.94%)	6 (6.52%)	4 (7.42%)	5 (7.17%)	4 (7.09%)	4 (7.31%)
Proximity to services		12 (4.46%)	13 (4.48%)	12 (4.59%)	14 (3.99%)	12 (4.57%)	13 (4.27%)	12 (4.71%)	13 (4.19%)	13 (4.44%)	13 (4.39%)	14 (3.89%)	12 (4.79%)	4 (6.73%)	13 (4.23%)	12 (4.52%)	13 (4.71%)	12 (4.62%)	12 (4.82%)	12 (4.71%)	13 (4.45%)	12 (4.95%)	11 (4.76%)	12 (4.60%)	13 (4.55%)	11 (4.69%)
Cleanliness of station/stop		7 (5.78%)	7 (5.80%)	7 (5.95%)	3 (7.76%)	7 (5.92%)	7 (5.53%)	7 (6.10%)	4 (7.92%)	7 (5.74%)	8 (5.69%)	10 (5.04%)	7 (6.19%)	8 (5.44%)	8 (5.47%)	7 (5.85%)	8 (6.09%)	7 (5.98%)	7 (6.24%)	7 (6.10%)	7 (5.76%)	7 (6.40%)	6 (6.16%)	7 (5.95%)	8 (5.89%)	7 (6.07%)
Station/stop benches		17 (2.75%)	18 (2.76%)	17 (2.83%)	19 (2.45%)	17 (2.82%)	18 (2.63%)	17 (2.90%)	17 (2.58%)	18 (2.73%)	18 (2.70%)	18 (2.40%)	17 (2.95%)	18 (2.59%)	19 (2.60%)	18 (2.78%)	18 (2.90%)	17 (2.84%)	17 (2.97%)	17 (2.90%)	17 (2.74%)	17 (3.05%)	17 (2.93%)	17 (2.83%)	17 (2.80%)	16 (2.89%)
On-board seating availability	On-board features	3 (7.92%)	3 (7.96%)	3 (8.15%)	2 (8.88%)	3 (8.12%)	1 (11.90%)	2 (8.36%)	5 (7.43%)	9 (5.31%)	2 (7.79%)	5 (6.91%)	1 (8.49%)	1 (10.28%)	2 (7.50%)	2 (8.02%)	1 (8.35%)	3 (8.19%)	2 (8.55%)	2 (8.36%)	1 (10.36%)	2 (8.78%)	2 (8.44%)	3 (8.16%)	2 (8.07%)	2 (8.32%)
On-board seating comfort		10 (4.70%)	11 (4.72%)	10 (4.83%)	12 (4.20%)	10 (4.81%)	11 (4.50%)	10 (4.96%)	11 (4.41%)	11 (4.67%)	11 (4.62%)	12 (4.10%)	10 (5.04%)	12 (4.43%)	11 (4.45%)	10 (4.76%)	11 (4.95%)	10 (4.86%)	10 (5.07%)	10 (4.96%)	11 (4.68%)	10 (5.21%)	9 (5.01%)	10 (4.84%)	11 (4.79%)	18 (2.75%)
On-board temperature		8 (5.68%)	8 (5.70%)	8 (5.84%)	10 (5.07%)	8 (5.82%)	8 (5.43%)	8 (5.99%)	9 (5.33%)	8 (5.64%)	9 (5.59%)	11 (4.95%)	8 (6.08%)	10 (5.35%)	9 (5.38%)	8 (5.75%)	9 (5.99%)	8 (5.87%)	8 (6.13%)	8 (5.99%)	8 (5.66%)	8 (6.29%)	7 (6.05%)	8 (5.85%)	9 (5.78%)	8 (5.96%)
Cleanliness of transit vehicle		15 (3.26%)	16 (3.28%)	15 (3.36%)	18 (2.91%)	14 (3.35%)	16 (3.12%)	15 (3.45%)	16 (3.06%)	16 (3.24%)	16 (3.21%)	9 (5.23%)	15 (3.50%)	16 (3.08%)	16 (3.09%)	16 (3.31%)	16 (3.44%)	15 (3.38%)	15 (3.52%)	15 (3.45%)	16 (3.25%)	15 (3.62%)	16 (3.48%)	15 (3.36%)	16 (3.33%)	14 (3.43%)
Productivity features		14 (3.88%)	15 (3.89%)	14 (3.99%)	16 (3.46%)	19 (1.76%)	15 (3.71%)	14 (4.09%)	15 (3.64%)	15 (3.85%)	15 (3.81%)	16 (3.38%)	14 (4.15%)	15 (3.65%)	4 (7.36%)	15 (3.93%)	15 (4.09%)	14 (4.01%)	14 (4.19%)	14 (4.09%)	9 (5.40%)	14 (4.30%)	15 (4.13%)	14 (3.99%)	15 (3.95%)	13 (4.07%)
Route name/num. identification	Not part of a bundle	16 (2.77%)	17 (2.78%)	16 (2.85%)	9 (5.50%)	16 (2.84%)	17 (2.65%)	16 (2.93%)	10 (4.97%)	17 (2.76%)	17 (2.73%)	17 (2.42%)	16 (2.97%)	17 (2.61%)	18 (2.63%)	17 (2.81%)	17 (2.92%)	16 (2.87%)	16 (2.99%)	16 (2.93%)	14 (4.34%)	16 (3.07%)	12 (4.63%)	16 (2.86%)	7 (6.34%)	15 (2.91%)
Reliability		13 (4.04%)	14 (4.06%)	13 (4.16%)	15 (3.61%)	13 (4.14%)	14 (3.87%)	13 (4.26%)	14 (3.79%)	14 (4.01%)	14 (3.97%)	15 (3.52%)	13 (4.33%)	14 (3.80%)	15 (3.83%)	13 (4.09%)	14 (4.26%)	13 (4.18%)	13 (4.36%)	13 (4.26%)	15 (4.03%)	13 (4.47%)	13 (4.30%)	13 (4.16%)	14 (4.11%)	12 (4.24%)
Schedule span		4 (7.86%)	4 (7.90%)	4 (8.09%)	4 (7.02%)	4 (8.06%)	3 (7.52%)	3 (8.30%)	1 (9.39%)	3 (7.81%)	3 (7.74%)	6 (6.86%)	2 (8.43%)	3 (7.40%)	3 (7.45%)	3 (7.96%)	2 (8.29%)	4 (8.13%)	3 (8.49%)	3 (8.30%)	3 (7.84%)	4 (7.13%)	3 (8.38%)	4 (8.10%)	3 (8.01%)	3 (8.26%)
Transit frequency		2 (9.96%)	1 (10.00%)	1 (10.25%)	1 (8.89%)	1 (10.21%)	2 (9.53%)	1 (10.52%)	2 (9.35%)	1 (9.90%)	1 (9.80%)	2 (8.69%)	5 (6.82%)	2 (9.38%)	1 (9.44%)	1 (10.09%)	3 (7.34%)	1 (10.30%)	1 (9.66%)	1 (10.52%)	2 (9.93%)	1 (8.87%)	1 (10.62%)	1 (10.26%)	1 (10.15%)	1 (10.47%)
Transfer distance		18 (2.74%)	9 (5.30%)	18 (2.82%)	11 (4.63%)	18 (2.80%)	19 (2.62%)	18 (2.89%)	18 (2.57%)	19 (2.72%)	19 (2.69%)	19 (2.39%)	18 (2.93%)	19 (2.58%)	20 (2.59%)	19 (2.77%)	7 (6.18%)	18 (2.83%)	18 (1.79%)	18 (2.89%)	18 (2.73%)	18 (3.03%)	18 (2.92%)	18 (2.82%)	18 (2.79%)	17 (2.87%)
Station/stop distance		1 (11.76%)	2 (8.82%)	6 (6.67%)	7 (5.79%)	2 (8.67%)	5 (6.20%)	5 (6.84%)	7 (6.08%)	5 (6.44%)	6 (6.38%)	8 (5.65%)	4 (6.95%)	6 (6.10%)	6 (6.14%)	5 (6.56%)	5 (6.83%)	6 (6.70%)	5 (7.00%)	5 (6.84%)	5 (6.46%)	3 (7.18%)	14 (4.27%)	2 (9.12%)	5 (6.60%)	5 (6.81%)
Parking distance		-	-	-	-	-	-	-	-	2 (8.41%)	5 (6.79%)	3 (8.27%)	-	-	17 (2.63%)	-	-	-	-	-	-	-	-	-	-	-
Ease of boarding		-	-	-	-	15 (3.12%)	9 (5.03%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fare machines		-	-	-	17 (3.16%)	-	-	-	-	-	-	-	9 (5.09%)	9 (5.43%)	14 (3.95%)	14 (4.08%)	-	-	-	-	-	-	-	-	-	19 (2.67%)

TABLE D-11. MaxDiff model estimation results for commute trips (t-stat)—Charlotte.

LOS/Attribute	Attribute Bundle	Coefficient (t-stat)	Individual Demographics Variables								Household Demographics Variables								Trip Characteristics		Attitude					Willingness to Walk	
			Full-time student (base: part-time student/ not student)	Employment status (base: self-employed/part-time employed/not employed)		Female (base: male)	Long-time resident (> 5 years, base: short-time resident)	Has mobility problem (base: no mobility problem)	Age (base: age < 35)		Number of vehicles in the HH (base: no vehicles)			Family income (base: income < 35k)				Presence of kid(s) in the HH (base: no kids in the HH)	Group travel	(Actual distance /mean distance)	Pro-Transit Attitude	Environment, Productivity, and Time Savings	Pro-Car Attitude	Transit Averse	Low Transit Comfort Level		
				Full-time employed	Retired				35 ≤ Age < 55	Age ≥ 55	Number of vehs in the HH = 1	Number of vehs in the HH = 2	Number of vehs in the HH = 3+	35k ≤ Income < 50k	50k ≤ Income < 75k	75k ≤ Income < 100k	Income ≥ 100k									Willing to walk ≤ 2 min.	Willing to walk ≥ 10 min.
IVTT	-	-0.082 (-17.44)																									
Fare	-	-0.991 (-9.15)																		0.154 (1.74)							
Real-time info		0.959 (14.71)																									
Station/stop security	Station/stop design features	1.34 (17.33)								0.547 (2.88)												0.186 (2.17)			0.206 (2.2)		
Station/stop Lighting/safety		0.891 (6.8)				0.452 (3.09)	0.564 (3.84)			0.394 (2.05)				0.512 (2.35)										0.264 (2.24)	0.204 (2.1)		
Station/stop shelter				0.443 (2.64)		0.33 (2.28)			0.27 (1.9)		0.873 (3.93)	0.859 (4.19)	0.739 (3.24)														
Proximity to services		0.858 (8.02)				0.291 (2.13)								-0.582 (-3.04)									0.203 (2.45)				
Cleanliness of station/stop		0.934 (4.95)								0.539 (2.77)				0.64 (2.33)	1.16 (4.7)	0.781 (3.14)	0.644 (2.91)							0.321 (2.8)			
Station/stop benches		0.982 (8.28)																		-0.314 (-3.19)							
On-board seating availability	On-board features	1.44 (17.08)								0.537 (2.8)					0.465 (2.66)												
On-board seating comfort		2.36 (3.07)	-0.587 (-2.01)				0.39 (2.89)				-1.82 (-2.36)	-1.81 (-2.34)	-2.02 (-2.59)						-0.467 (-2.22)			0.193 (2.36)			0.278 (3.11)		
On-board temperature		0.937 (7.05)							0.415 (2.73)	0.476 (2.33)																	0.27 (1.95)
Cleanliness of transit vehicle		0.66 (10.14)																							0.206 (2.37)		
Productivity features		0.752 (5.77)				-0.257 (-1.92)			0.302 (2.25)									0.354 (2.45)									
Route name/num. identification	Not part of a bundle	0.671 (4.52)				0.276 (2.04)			0.306 (2.11)	0.579 (3)				0.44 (2.16)	0.397 (2.43)							0.196 (2.45)					
Reliability		0.798 (7.45)				0.28 (2.06)																	-0.238 (-2.86)				
Schedule span		0.856 (7.76)				0.307 (2.22)				0.432 (2.32)													-0.172 (-2.05)	-0.217 (-1.97)			
Transit frequency						0.313 (2.39)	0.284 (2.06)				0.508 (3.33)			0.838 (3.67)	1.07 (5.8)	0.708 (4)	1.02 (6.64)										
Transfer distance		1.32 (12.6)																-0.292 (-2.06)	-0.576 (-2.62)						0.172 (1.92)		-0.384 (-2.87)
Station/stop distance		1.24 (8.98)				0.381 (2.62)									0.532 (2.86)		0.414 (2.6)					0.216 (2.43)	-0.265 (-3.01)	-0.247 (-2.17)			
Parking distance		1.06 (5.77)												0.638 (2.33)	0.686 (2.87)	0.568 (2.32)	0.492 (2.26)					0.233 (2.71)					
Ease of boarding								1.13 (3.11)																	0.166 (1.89)	0.682 (4.06)	
Fare machines		0.366 (2.16)				0.292 (2.06)				0.415 (2.28)		0.652 (4.07)	0.671 (3.44)	0.458 (2.04)	0.372 (2.09)	0.413 (2.12)											

TABLE D-12. MaxDiff model estimation results for non-commute trips (t-stat)—Charlotte.

Coefficient (t-stat)

LOS/Attribute	Attribute Bundle	Constant	Individual Demographics variables: Full-time student (base: part-time student/not student)	Individual Demographics variables: Employment status (base: self-employed/part-time employed/not employed): Full-time employed	Individual Demographics variables: Employment status: Retired	Individual Demographics variables: Female (base: male)	Individual Demographics variables: Long-time resident (> 5 years, base: short-time resident)	Individual Demographics variables: Has mobility problem (base: no mobility problem)	Individual Demographics variables: Age (base: age < 35): 35 ≤ Age < 55	Individual Demographics variables: Age (base: age < 35): Age ≥ 55	Household Demographics variables: Number of vehicles in the HH (base: no vehicles): Number of vehs in the HH = 1	Household Demographics variables: Number of vehicles in the HH: Number of vehs in the HH = 2	Household Demographics variables: Number of vehicles in the HH: Number of vehs in the HH = 3+	Household Demographics variables: Family income (base: income < 35k): 35k ≤ Income < 50k	Household Demographics variables: Family income: 50k ≤ Income < 75k	Household Demographics variables: Family income: 75k ≤ Income < 100k	Household Demographics variables: Family income: Income ≥ 100k	Household Demographics variables: Presence of kid(s) in the HH (base: no kids in the HH)	Trip Characteristics: Group travel	Trip Characteristics: (Actual distance /mean distance)	Attitude: Pro-Transit Attitude	Attitude: Environment, Productivity, and Time Savings	Attitude: Pro-Car Attitude	Attitude: Transit Averse	Attitude: Low Transit Comfort Level	Willingness to Walk: Willing to walk ≤ 2 min.	Willingness to Walk: Willing to walk ≥ 10 min.
IVTT	-	-0.038 (-4.97)																									
Fare	-	-1.4 (-9.37)															0.456 (1.97)			0.307 (2.92)							
Real-time info		1.13 (11.31)																					-0.322 (-2.68)				
Station/stop security	**Station/stop design features**	1.24 (6.58)			0.661 (1.97)	0.512 (2.27)																					
Station/stop lighting/safety		1.18 (4.15)		0.475 (1.97)					0.798 (3.03)	1.22 (4.03)				1.05 (3.04)			0.551 (1.91)				-0.394 (-2.69)			0.5 (2.85)		-1.13 (-3.09)	-0.561 (-2.16)
Station/stop shelter		1.47 (9.86)					0.446 (2.05)																				
Proximity to services		0.927 (8.96)																				0.278 (2.43)					
Cleanliness of station/stop		1.84 (15.93)																				0.269 (2.04)					
Station/stop benches		0.462 (3.45)							0.467 (2.28)																		
On-board seating availability	**On-board features**	1.52 (8.42)								0.824 (3.18)					-0.523 (-2.08)				0.486 (2.21)								
On-board seating comfort		0.84 (5.36)																									-0.455 (-2.26)
On-board temperature		1.36 (12.58)																									
Cleanliness of transit vehicle		0.709 (6.98)																									
Productivity features		1.34 (7.24)	1.19 (2.46)			-0.627 (-2.97)				-0.677 (-2.95)																	
Route name/num. identification	**Not part of a bundle**	1.09 (9.82)														0.665 (2.16)											
Reliability		0 (0)		0.586 (3.02)					0.665 (3.66)	0.828 (3.8)																	
Schedule span		1.3 (10.15)								0.627 (2.5)													-0.497 (-3.72)	-0.581 (-3.42)	0.393 (2.54)		
Transit frequency		1.11 (5.94)						-0.606 (-1.94)	0.456 (1.86)	0.834 (2.8)																	
Transfer distance		1.47 (8.73)														0.625 (2.08)											-0.55 (-2.62)
Station/stop distance		1.74 (9.38)										0.539 (2.45)															-0.433 (-1.99)
Parking distance		0.839 (4.56)							0.826 (3.39)	1.1 (3.85)											-0.265 (-1.91)		-0.297 (-2.18)		0.295 (1.91)		
Ease of boarding		0 (0)				0.63 (4.74)		0.595 (2.08)																			
Fare machines		0 (0)		0.727 (3.59)	0.995 (2.96)	0.745 (4.43)	0.445 (2.34)												0.389 (2.09)								

TABLE D-13. Relative rank of attributes by individual demographics, household demographics, trip characteristics, and attitudinal variables (relative importance in %)—Charlotte (commute trips).

Attribute	Attribute Bundle	Variables																								
		Individual Demographics								Household Demographics								Trip Characteristics		Attitude					Willingness to Walk	
		Full-time student (base: part time student/not student)	Employment status (base: self-employed/part-time employed/ not employed)		Female (base: male)	Long-time resident (> 5 years, base: short-time resident)	Has mobility problem (base: no mobility problem)	Age (base: age < 35)		Number of vehicles in the HH (base: no vehicles)			Family income (base: income < 35k)				Presence of kid(s) in the HH (base: no kids in the HH)	Group travel	(Actual distance-mean distance)	Pro-Transit Attitude	Environment, Productivity, and Time Savings	Pro-Car Attitude	Transit Averse	Low Transit Comfort Level	Willing to walk ≤ 2 min.	Willing to walk ≥ 10 min.
			Full-time employed	Retired				35 ≤ Age < 55	Age ≥ 55	Number of vehs in the HH = 1	Number of vehs in the HH = 2	Number of vehs in the HH = 3+	35k ≤ Income < 50k	50k ≤ Income < 75k	75k ≤ Income < 100k	Income≥ 100k										
Real-time info	Station/stop design features	8 (5.38%)	8 (5.08%)	8 (5.21%)	12 (4.55%)	9 (4.88%)	9 (4.90%)	11 (4.86%)	13 (4.29%)	7 (5.33%)	8 (5.29%)	8 (5.38%)	11 (4.49%)	11 (4.15%)	9 (4.59%)	10 (4.57%)	9 (5.19%)	7 (5.52%)	7 (5.30%)	8 (5.21%)	8 (4.93%)	9 (5.34%)	10 (5.17%)	9 (4.88%)	8 (5.02%)	8 (5.24%)
Station/stop security		3 (7.51%)	3 (7.10%)	3 (7.27%)	5 (6.35%)	4 (6.82%)	3 (6.85%)	4 (6.80%)	3 (8.45%)	2 (7.45%)	2 (7.39%)	2 (7.52%)	6 (6.27%)	6 (5.80%)	5 (6.41%)	6 (6.38%)	3 (7.25%)	3 (7.71%)	3 (7.40%)	3 (7.27%)	2 (7.85%)	3 (7.46%)	3 (7.23%)	2 (7.87%)	3 (7.01%)	3 (7.32%)
Station/stop lighting/safety		11 (5.00%)	11 (4.72%)	11 (4.84%)	4 (6.37%)	2 (7.40%)	12 (4.56%)	13 (4.52%)	8 (5.75%)	10 (4.95%)	11 (4.92%)	11 (5.00%)	5 (6.57%)	13 (3.86%)	11 (4.26%)	12 (4.24%)	12 (4.82%)	10 (5.13%)	10 (4.92%)	11 (4.84%)	11 (4.58%)	12 (4.96%)	6 (6.23%)	6 (5.57%)	11 (4.66%)	11 (4.87%)
Station/stop shelter		-	18 (2.35%)	-	19 (1.56%)	-	-	19 (1.37%)	-	11 (4.85%)	12 (4.74%)	16 (4.15%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Proximity to services		12 (4.81%)	12 (4.55%)	12 (4.66%)	8 (5.45%)	12 (4.36%)	13 (4.39%)	14 (4.35%)	14 (3.84%)	12 (4.77%)	13 (4.73%)	12 (4.82%)	19 (1.29%)	14 (3.71%)	12 (4.11%)	13 (4.09%)	13 (4.64%)	11 (4.94%)	11 (4.74%)	12 (4.66%)	13 (4.41%)	5 (5.91%)	12 (4.63%)	13 (4.37%)	12 (4.49%)	12 (4.69%)
Cleanliness of station/stop		10 (5.24%)	10 (4.95%)	10 (5.07%)	15 (4.43%)	11 (4.75%)	11 (4.78%)	12 (4.74%)	4 (6.59%)	9 (5.19%)	10 (5.15%)	10 (5.24%)	3 (7.37%)	2 (9.06%)	2 (8.21%)	3 (7.52%)	11 (5.05%)	9 (5.37%)	9 (5.16%)	10 (5.07%)	10 (4.80%)	11 (5.20%)	5 (6.77%)	11 (4.75%)	10 (4.89%)	10 (5.10%)
Station/stop benches		7 (5.51%)	7 (5.20%)	7 (5.33%)	11 (4.66%)	8 (4.99%)	8 (5.02%)	9 (4.98%)	12 (4.40%)	6 (5.46%)	7 (5.42%)	7 (5.51%)	10 (4.60%)	10 (4.25%)	8 (4.70%)	9 (4.68%)	8 (5.31%)	6 (5.65%)	16 (3.69%)	7 (5.33%)	7 (5.05%)	7 (5.47%)	9 (5.30%)	8 (5.00%)	7 (5.14%)	7 (5.36%)
On-board aeating availability	On-board features	2 (8.07%)	2 (7.63%)	2 (7.82%)	3 (6.83%)	3 (7.32%)	2 (7.36%)	2 (7.30%)	2 (8.85%)	1 (8.01%)	1 (7.94%)	1 (8.08%)	4 (6.74%)	3 (8.24%)	4 (6.89%)	5 (6.86%)	2 (7.79%)	2 (8.28%)	2 (7.95%)	2 (7.82%)	4 (7.40%)	2 (8.02%)	2 (7.76%)	4 (7.33%)	2 (7.54%)	2 (7.86%)
On-board seating comfort		1 (9.94%)	1 (12.51%)	1 (12.81%)	1 (11.19%)	1 (13.99%)	1 (12.07%)	1 (11.97%)	1 (10.56%)	18 (3.00%)	19 (3.03%)	19 (1.91%)	1 (11.04%)	1 (10.21%)	1 (11.30%)	1 (11.24%)	1 (12.77%)	1 (10.89%)	1 (13.03%)	1 (12.81%)	1 (13.13%)	1 (13.15%)	1 (12.73%)	1 (13.42%)	1 (12.35%)	1 (12.89%)
On-board temperature		9 (5.25%)	9 (4.97%)	9 (5.09%)	14 (4.44%)	10 (4.77%)	10 (4.79%)	3 (6.86%)	5 (6.32%)	8 (5.21%)	9 (5.17%)	9 (5.26%)	12 (4.39%)	12 (4.06%)	10 (4.48%)	11 (4.46%)	10 (5.07%)	8 (5.39%)	8 (5.17%)	9 (5.09%)	9 (4.82%)	10 (5.22%)	11 (5.05%)	10 (4.77%)	9 (4.90%)	5 (6.59%)
Cleanliness of transit vehicle		17 (3.70%)	17 (3.50%)	17 (3.58%)	16 (3.13%)	17 (3.36%)	18 (3.38%)	17 (3.35%)	18 (2.95%)	17 (3.67%)	18 (3.64%)	18 (3.70%)	18 (3.09%)	19 (2.86%)	19 (3.16%)	18 (3.14%)	17 (3.57%)	17 (3.80%)	17 (3.64%)	17 (3.58%)	17 (3.39%)	16 (3.68%)	16 (3.56%)	12 (4.41%)	18 (3.45%)	17 (3.60%)
Productivity features		15 (4.22%)	15 (3.99%)	15 (4.08%)	18 (2.35%)	15 (3.82%)	16 (3.85%)	8 (5.35%)	17 (3.37%)	15 (4.18%)	16 (4.15%)	15 (4.22%)	17 (3.52%)	17 (3.25%)	16 (3.60%)	16 (3.58%)	5 (5.98%)	14 (4.33%)	14 (4.15%)	15 (4.08%)	16 (3.87%)	13 (4.19%)	14 (4.06%)	16 (3.83%)	15 (3.94%)	15 (4.11%)
Route name/num. identification		16 (3.76%)	16 (3.56%)	16 (3.64%)	13 (4.49%)	16 (3.41%)	17 (3.43%)	10 (4.96%)	9 (5.59%)	16 (3.73%)	17 (3.70%)	17 (3.77%)	9 (5.20%)	9 (4.62%)	18 (3.21%)	17 (3.20%)	16 (3.63%)	16 (3.86%)	15 (3.71%)	16 (3.64%)	12 (4.46%)	15 (3.74%)	15 (3.62%)	17 (3.41%)	17 (3.51%)	16 (3.66%)
Reliability		14 (4.47%)	14 (4.23%)	14 (4.33%)	9 (5.11%)	14 (4.06%)	15 (4.08%)	16 (4.05%)	15 (3.57%)	14 (4.44%)	15 (4.40%)	14 (4.48%)	16 (3.73%)	16 (3.45%)	14 (3.82%)	15 (3.80%)	15 (4.32%)	13 (4.59%)	13 (4.41%)	14 (4.33%)	15 (4.10%)	17 (3.12%)	13 (4.30%)	15 (4.06%)	14 (4.18%)	14 (4.36%)
Schedule span	Not part of a bundle	13 (4.80%)	13 (4.54%)	13 (4.65%)	7 (5.51%)	13 (4.35%)	14 (4.38%)	15 (4.34%)	7 (5.76%)	13 (4.76%)	14 (4.72%)	13 (4.81%)	13 (4.01%)	15 (3.70%)	13 (4.10%)	14 (4.08%)	14 (4.63%)	12 (4.92%)	12 (4.73%)	13 (4.65%)	14 (4.40%)	14 (3.81%)	17 (3.45%)	14 (4.35%)	13 (4.48%)	13 (4.68%)
Transit frequency		-	-	-	20 (1.48%)	19 (1.44%)	-	-	-	19 (2.82%)	-	-	14 (3.92%)	8 (4.63%)	17 (3.39%)	8 (4.86%)	-	-	-	-	-	-	-	-	-	-
Transfer distance		4 (7.40%)	4 (7.00%)	4 (7.16%)	6 (6.26%)	5 (6.71%)	4 (6.75%)	5 (6.69%)	6 (5.91%)	3 (7.34%)	3 (7.28%)	3 (7.41%)	7 (6.18%)	7 (5.71%)	6 (6.32%)	7 (6.29%)	7 (5.56%)	15 (4.28%)	4 (7.29%)	4 (7.16%)	5 (6.79%)	4 (7.35%)	4 (7.12%)	3 (7.59%)	4 (6.91%)	9 (5.11%)
Station/stop distance		5 (6.95%)	5 (6.57%)	5 (6.73%)	2 (7.69%)	6 (6.31%)	5 (6.34%)	6 (6.29%)	10 (5.55%)	4 (6.89%)	4 (6.84%)	4 (6.96%)	8 (5.80%)	4 (7.67%)	7 (5.93%)	2 (7.88%)	4 (6.71%)	4 (7.13%)	5 (6.85%)	5 (6.73%)	3 (7.49%)	8 (5.43%)	8 (5.35%)	5 (6.31%)	5 (6.49%)	4 (6.77%)
Parking distance		6 (5.94%)	6 (5.62%)	6 (5.75%)	10 (5.03%)	7 (5.39%)	7 (5.42%)	7 (5.38%)	11 (4.74%)	5 (5.89%)	5 (5.85%)	5 (5.95%)	2 (7.95%)	5 (7.56%)	3 (7.79%)	4 (7.39%)	6 (5.73%)	5 (6.10%)	6 (5.85%)	6 (5.75%)	6 (6.65%)	6 (5.90%)	7 (5.72%)	7 (5.39%)	6 (5.55%)	6 (5.79%)
Ease of boarding		-	-	-	-	-	6 (5.78%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19 (0.84%)	16 (3.57%)	-
Fare machines		18 (2.05%)	19 (1.94%)	18 (1.99%)	17 (3.12%)	18 (1.86%)	19 (1.87%)	18 (1.86%)	16 (3.50%)	20 (2.04%)	6 (5.62%)	6 (5.82%)	15 (3.86%)	18 (3.19%)	15 (3.73%)	19 (1.74%)	18 (1.98%)	18 (2.11%)	18 (2.02%)	18 (1.99%)	18 (1.88%)	18 (2.04%)	18 (1.97%)	18 (1.86%)	19 (1.92%)	18 (2.00%)

TABLE D-14. Relative rank of attributes by individual demographics, household demographics, trip characteristics, and attitudinal variables (relative importance in %)—Charlotte (non-commute trips).

Attribute	Attribute Bundle	Variables: Individual Demographics								Household Demographics								Trip Characteristics		Attitude					Willingness to Walk	
		Full-time student (base: part-time student/not student)	Employment status (base: self-employed/part-time employed/not employed)		Female (base: male)	Long-time resident (> 5 years, base: short-time resident)	Has mobility problem (base: no mobility problem)	Age (base: age < 35)		Number of vehicles in the HH (base: no vehicles)			Family income (base: income < 35k)				Presence of kid(s) in the HH (base: no kids in the HH)	Group travel	(Actual distance/ mean distance)	Pro-Transit Attitude	Environment, Productivity, and Time Savings	Pro-Car Attitude	Transit Averse	Low Transit Comfort Level	Willing to walk ≤ 2 min.	Willing to walk ≥ 10 min.
			Full-time employed	Retired				35 ≤ Age < 55	Age ≥ 55	Number of vehs in the HH = 1	Number of vehs in the HH = 2	Number of vehs in the HH = 3+	35k ≤ Income < 50k	50k ≤ Income < 75k	75k ≤ Income < 100k	Income ≥ 100k										
Real-time info	**Station/stop design features**	11 (4.97%)	11 (4.84%)	11 (4.87%)	10 (4.95%)	11 (5.03%)	11 (5.24%)	13 (4.56%)	12 (4.29%)	11 (5.24%)	11 (5.11%)	11 (5.24%)	11 (5.00%)	10 (5.37%)	12 (4.94%)	11 (5.11%)	11 (5.24%)	11 (5.04%)	11 (5.24%)	10 (5.40%)	12 (5.11%)	14 (3.95%)	10 (5.26%)	12 (5.08%)	10 (5.53%)	9 (5.77%)
Station/stop security		9 (5.45%)	10 (5.31%)	1 (8.19%)	2 (7.68%)	9 (5.52%)	9 (5.75%)	12 (5.00%)	11 (4.71%)	9 (5.75%)	9 (5.61%)	9 (5.75%)	10 (5.48%)	8 (5.89%)	10 (5.43%)	10 (5.61%)	9 (5.75%)	9 (5.53%)	9 (5.75%)	9 (5.93%)	9 (5.61%)	8 (6.06%)	9 (5.77%)	9 (5.57%)	9 (6.07%)	8 (6.34%)
Station/stop lighting/safety		10 (5.19%)	3 (7.09%)	10 (5.08%)	9 (5.17%)	10 (5.25%)	10 (5.47%)	1 (7.98%)	1 (9.12%)	10 (5.47%)	10 (5.34%)	10 (5.47%)	1 (9.86%)	9 (5.61%)	11 (5.16%)	3 (7.83%)	10 (5.47%)	10 (5.26%)	10 (5.47%)	15 (3.76%)	11 (5.34%)	9 (5.77%)	3 (7.82%)	10 (5.30%)	18 (0.24%)	16 (3.16%)
Station/stop shelter		5 (6.46%)	5 (6.29%)	5 (6.33%)	5 (6.44%)	1 (8.53%)	4 (6.82%)	7 (5.93%)	8 (5.58%)	4 (6.82%)	4 (6.65%)	4 (6.82%)	5 (6.50%)	3 (6.99%)	6 (6.43%)	5 (6.65%)	4 (6.82%)	4 (6.55%)	4 (6.82%)	4 (7.03%)	4 (6.65%)	4 (7.19%)	5 (6.84%)	5 (6.61%)	4 (7.19%)	3 (7.51%)
Proximity to services		14 (4.07%)	14 (3.97%)	15 (3.99%)	13 (4.06%)	14 (4.13%)	13 (4.30%)	16 (3.74%)	14 (3.52%)	14 (4.30%)	14 (4.19%)	14 (4.30%)	14 (4.10%)	14 (4.41%)	14 (4.06%)	14 (4.19%)	14 (4.30%)	14 (4.13%)	14 (4.30%)	13 (4.43%)	10 (5.45%)	12 (4.53%)	13 (4.31%)	15 (4.17%)	13 (4.54%)	12 (4.74%)
Cleanliness of station/stop		2 (8.09%)	1 (7.88%)	2 (7.92%)	1 (8.06%)	2 (8.19%)	1 (8.54%)	2 (7.43%)	6 (6.99%)	1 (8.53%)	2 (8.32%)	1 (8.53%)	2 (8.14%)	1 (8.74%)	2 (8.05%)	1 (8.32%)	1 (8.53%)	2 (8.20%)	1 (8.53%)	1 (8.80%)	1 (9.54%)	1 (9.00%)	1 (8.56%)	1 (8.27%)	1 (9.00%)	1 (9.40%)
Station/stop benches		18 (2.03%)	20 (1.98%)	19 (1.99%)	20 (2.02%)	18 (2.06%)	19 (2.14%)	15 (3.75%)	19 (1.76%)	18 (2.14%)	18 (2.09%)	18 (2.14%)	18 (2.04%)	18 (2.20%)	18 (2.02%)	18 (2.09%)	18 (2.14%)	18 (2.06%)	18 (2.14%)	18 (2.21%)	18 (2.09%)	18 (2.26%)	18 (2.15%)	18 (2.08%)	17 (2.26%)	17 (2.36%)
On-board seating availability	**On-board features**	4 (6.68%)	4 (6.51%)	4 (6.55%)	4 (6.66%)	4 (6.77%)	3 (7.05%)	6 (6.13%)	2 (8.90%)	3 (7.05%)	3 (6.88%)	3 (7.05%)	4 (6.72%)	13 (4.74%)	5 (6.65%)	4 (6.87%)	3 (7.05%)	1 (8.94%)	3 (7.05%)	3 (7.27%)	3 (6.87%)	3 (7.43%)	4 (7.07%)	4 (6.83%)	3 (7.44%)	2 (7.77%)
On-board seating comfort		15 (3.69%)	15 (3.60%)	16 (3.62%)	14 (3.68%)	15 (3.74%)	14 (3.90%)	17 (3.39%)	15 (3.19%)	15 (3.89%)	15 (3.80%)	15 (3.89%)	15 (3.71%)	15 (3.99%)	15 (3.68%)	15 (3.80%)	15 (3.89%)	15 (3.74%)	15 (3.89%)	14 (4.02%)	15 (3.80%)	13 (4.11%)	14 (3.91%)	16 (3.77%)	14 (4.11%)	18 (1.97%)
On-board temperature		7 (5.98%)	7 (5.82%)	7 (5.86%)	7 (5.96%)	6 (6.06%)	6 (6.31%)	9 (5.49%)	10 (5.17%)	6 (6.31%)	6 (6.15%)	6 (6.31%)	7 (6.01%)	5 (6.46%)	7 (5.95%)	7 (6.15%)	6 (6.31%)	6 (6.06%)	6 (6.31%)	6 (6.50%)	6 (6.15%)	6 (6.65%)	7 (6.33%)	7 (6.11%)	6 (6.65%)	4 (6.95%)
Cleanliness of transit vehicle		17 (3.12%)	18 (3.04%)	18 (3.05%)	18 (3.11%)	17 (3.16%)	16 (3.29%)	18 (2.86%)	17 (2.69%)	17 (3.29%)	17 (3.21%)	17 (3.29%)	17 (3.13%)	17 (3.37%)	17 (3.10%)	17 (3.21%)	17 (3.29%)	17 (3.16%)	17 (3.29%)	16 (3.39%)	17 (3.21%)	16 (3.47%)	17 (3.30%)	17 (3.19%)	16 (3.47%)	15 (3.62%)
Productivity features		1 (11.12%)	8 (5.74%)	8 (5.77%)	17 (3.12%)	7 (5.97%)	7 (6.22%)	10 (5.41%)	18 (2.52%)	7 (6.21%)	7 (6.06%)	7 (6.21%)	8 (5.92%)	6 (6.37%)	8 (5.86%)	8 (6.06%)	7 (6.21%)	7 (5.97%)	7 (6.21%)	7 (6.41%)	7 (6.06%)	7 (6.55%)	8 (6.24%)	8 (6.02%)	7 (6.56%)	5 (6.85%)
Route name/num. identification		13 (4.79%)	13 (4.67%)	13 (4.69%)	12 (4.78%)	13 (4.85%)	12 (5.06%)	14 (4.40%)	13 (4.14%)	13 (5.05%)	13 (4.93%)	13 (5.05%)	13 (4.82%)	12 (5.18%)	3 (7.68%)	13 (4.93%)	13 (5.05%)	13 (4.86%)	13 (5.05%)	12 (5.21%)	14 (4.93%)	11 (5.33%)	12 (5.07%)	14 (4.90%)	12 (5.33%)	11 (5.57%)
Reliability		-	19 (2.51%)	-	-	-	-	19 (2.68%)	16 (3.15%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Schedule span	**Not part of a bundle**	8 (5.71%)	9 (5.57%)	9 (5.60%)	8 (5.70%)	8 (5.79%)	8 (6.03%)	11 (5.25%)	5 (7.32%)	8 (6.03%)	8 (5.88%)	8 (6.03%)	9 (5.75%)	7 (6.18%)	9 (5.69%)	9 (5.88%)	8 (6.03%)	8 (5.79%)	8 (6.03%)	8 (6.22%)	8 (5.88%)	15 (3.93%)	16 (3.35%)	3 (7.61%)	8 (6.36%)	7 (6.64%)
Transit frequency		12 (4.88%)	12 (4.75%)	12 (4.78%)	11 (4.86%)	12 (4.94%)	18 (2.34%)	5 (6.32%)	3 (7.39%)	12 (5.15%)	12 (5.02%)	12 (5.15%)	12 (4.91%)	11 (5.27%)	13 (4.86%)	12 (5.02%)	12 (5.15%)	12 (4.95%)	12 (5.15%)	11 (5.31%)	13 (5.02%)	10 (5.43%)	11 (5.17%)	13 (4.99%)	11 (5.43%)	10 (5.67%)
Transfer distance		5 (6.46%)	5 (6.29%)	5 (6.33%)	5 (6.44%)	5 (6.55%)	4 (6.82%)	7 (5.93%)	8 (5.58%)	4 (6.82%)	4 (6.65%)	4 (6.82%)	5 (6.50%)	3 (6.99%)	1 (9.17%)	5 (6.65%)	4 (6.82%)	4 (6.55%)	4 (6.82%)	4 (7.03%)	4 (6.65%)	4 (7.19%)	5 (6.84%)	5 (6.61%)	4 (7.19%)	13 (4.70%)
Station/stop distance		3 (7.65%)	2 (7.45%)	3 (7.49%)	3 (7.62%)	3 (7.75%)	2 (8.07%)	3 (7.02%)	7 (6.61%)	2 (8.07%)	1 (10.31%)	2 (8.07%)	3 (7.69%)	2 (8.27%)	4 (7.61%)	2 (7.87%)	2 (8.07%)	3 (7.75%)	2 (8.07%)	2 (8.32%)	2 (7.87%)	2 (8.51%)	2 (8.10%)	2 (7.82%)	2 (8.51%)	6 (6.68%)
Parking distance		16 (3.69%)	16 (3.59%)	17 (3.61%)	15 (3.68%)	16 (3.74%)	15 (3.89%)	4 (6.72%)	4 (7.37%)	16 (3.89%)	16 (3.80%)	16 (3.89%)	16 (3.71%)	16 (3.99%)	16 (3.67%)	16 (3.79%)	16 (3.89%)	16 (3.74%)	16 (3.89%)	17 (2.75%)	16 (3.79%)	17 (2.65%)	15 (3.90%)	11 (5.10%)	15 (4.11%)	14 (4.29%)
Ease of boarding		-	-	-	19 (2.76%)	-	17 (2.76%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fare machines		-	17 (3.11%)	14 (4.28%)	16 (3.26%)	19 (1.98%)	-	-	-	-	-	-	-	-	-	-	-	19 (1.73%)	-	-	-	-	-	-	-	-

Summary of Key Findings on Transit Attributes

TABLE D-15 shows a comparison of scaled values of premium transit attributes across all three cities where surveys were conducted. The values are in equivalent minutes of in-vehicle travel time and have been presented separately for both commute and non-commute trips. In the case of Salt Lake City, the coefficients from which these values have been derived were estimated for bus and train modes combined. For Chicago and Charlotte, the values shown are averages of bus and train values.

TABLE D-15. Scaled equivalent minutes of in-vehicle travel time for premium service attributes.

Attribute	CommuteTrips			Non-CommuteTrips		
	Charlotte	Salt Lake City	Chicago	Charlotte	Salt Lake City	Chicago
Station/stop design features bundle	**3.71**	**4.61**	**4.97**	**-9.05**	**1.57**	**4.42**
Real-time info	0.40	*	0.62	-1.06	*	0.44
Station/stop security	0.60	0.88	0.85	-1.56	0.22	0.84
Station/stop lighting/safety	0.66	0.88	0.86	-1.62	0.20	0.82
Station/stop shelter	0.64	1.10	0.86	-1.57	0.37	0.69
Proximity to services	0.40	0.84	0.40	-0.89	0.47	0.50
Cleanliness of station/stop	0.73	0.42	0.90	-1.74	0.15	0.86
Station/stop benches	0.28	0.49	0.48	-0.62	0.16	0.27
On-board features bundle	**4.58**	**3.53**	**5.84**	**-9.47**	**3.8**	**10.79**
On-board seating availability	1.46	1.23	2.15	-3.32	1.41	4.09
On-board seating comfort	0.56	0.51	0.77	-1.02	0.41	1.39
On-board temperature	1.20	0.81	1.41	-2.42	0.85	2.41
Cleanliness of transit vehicle	0.60	0.44	0.64	-1.26	0.39	1.56
Productivity features	0.76	0.54**	0.87	-1.45	0.74**	1.34
Unbundled features	**8.94**	***	**11.17**	**-10.61**	***	**9.77**
Route name/number Identification	0.57		0.63	-1.23		0.61
Reliability	4.59		5.64	-		4.63
Schedule span*	0.52		0.77	-1.47		0.82
Transit frequency	0.60		0.82	-1.49		0.71
Transfer distance	0.46		0.56	-1.29		0.48
Station/stop distance	0.80		0.92	-1.76		0.84
Parking distance	0.72		0.84	-1.44		0.71
Ease of boarding	0.08		0.21	-0.52		0.25
Fare machines	0.60		0.78	-1.40		0.72
All premium service features	**17.23**	**8.14**	**21.98**	**29.13**	**5.37**	**24.98**

*The attribute was not part of station/stop design features bundle in the survey for Salt Lake City.

** The attribute was referred simply as “Wi-Fi” in the survey for Salt Lake City.

***The scaling process was not applied for unbundled features in Salt Lake City during Phase 1.

There are key findings derived from this comparison that are useful for planning purposes:

- Reliability and on-board seating availability have relatively high values irrespective of trip purpose or geographic location.
- In terms of size, Chicago and Charlotte can be considered as ends of the spectrum. Salt Lake City may fall somewhere in the middle. The size of a city does not necessarily influence the importance of premium service characteristics consistently.
- There appears to be not much variation in the values of premium transit attributes for commute trips. At an aggregate level, both station/stop design features and on-board features bundles have similar values for commuters across all three cities which fall in a relatively narrow range between 4 and 6 minutes.
- On the other hand, for non-commute trips, there seems to be some differences in the values of transit attributes based on city size. The values for station amenities range from 2 to 9 minutes and the values for on-board amenities range from 4 to 11 minutes. The unbundled attributes for Chicago and Charlotte are more closely aligned (10 to 11 minutes combined); Salt Lake City did not have these attributes scaled in the analysis.
- Overall, the premium service characteristics account for 17 to 29 minutes of in-vehicle travel time in Chicago and Charlotte. Of this amount, 8 to 18 minutes are accounted for with station and on-board amenities. In Salt Lake City, 5 to 8 minutes (depending on trip purpose) of in-vehicle time are associated with station and on-board amenities.

The set of attributes having relatively high scaled values was compared to the corresponding set with unscaled values (see TABLE D-1). It was observed that the relative importance of transit attributes could change after the scaling process. Specifically, reliability and on-board temperature which were not relatively important according to unscaled values were found to be quite important in the scaled version. This shows the importance of scaling of the attribute values in which they are appropriately traded-off against travel times and costs. The scaling process makes the attribute values more realistic in the broader perspective so that they can be used in mode choice modeling and planning.

APPENDIX E

Multinomial Logit Models for Mode Choice

Contents

Model Formulation

The mode choice model is the second step in the decision process and models the choice of the mode given the alternatives that are present in the choice set. We use both the RP and SP data and estimate a joint model. However, in order to use both data records together we have to use different variances (scales) for the RP and SP observations. Consider the following utility equations for the RP and SP models:

$$U_{qi}^{SP} = \beta x_{qi} + \beta_{SP}\,\tilde{x}_{qi} + \tilde{\varepsilon}_{qi} \qquad (1)$$

$$U_{qi}^{RP} = \beta x_{qi} + \beta_{RP}\,\breve{x}_{qi} + \breve{\varepsilon}_{qi} \qquad (2)$$

where x_{qi} is the set of variables that are available in both the SP and RP observations, while $\tilde{x}_{qi}$ and $\breve{x}_{qi}$ can have variables that are available only in SP and RP, respectively. The parameters to be estimated are β, β_{SP}, and β_{RP}. In addition, it is also necessary to estimate the scale difference between the SP and RP utility given by

$$\lambda^2 = \frac{Var(\breve{\varepsilon}_{qi})}{Var(\tilde{\varepsilon}_{qi})} \qquad (3)$$

Model Specification

The survey effort in this project resulted in the collection of two major elements of data on the choice behavior of individuals. One element of the data is the revealed preference (RP) component providing information about actual choices made by individuals under real-world scenarios. Data was collected about a specific trip that was undertaken by each of the sample of respondents. The second element of the data is the stated preference (SP) component providing information about travel choices that people would make under a series of hypothetical scenarios. Each respondent was presented a series of eight modal scenarios where automobile, bus, and train modes were altered with respect to their level-of-service attributes. Respondents were asked to identify the mode that they would choose under each of the scenarios to obtain key insights into how travelers exercise trade-offs across attributes in exercising choices. Thus, the entire survey data collection effort in this project resulted in the compilation of both RP and SP survey components that together provide a realistic depiction of travel choices made by individuals as well as key insights into the types of trade-offs that drive traveler mode choice behavior.

In order to maximize the utilization of data collected in this project, the project team developed joint RP-SP model systems for Chicago and Charlotte in which the RP choice and SP choice were estimated in a joint simultaneous equations model system that included a RP-SP scaling coefficient that accounted for the differing variance of the error term in the respective equations of the simultaneous equations model system. In the Salt Lake City models, estimated in the first phase of the study, mode choice models were based on SP choices only.

After extensive testing of alternative model specifications, it was found that some of the values of time implied by an unconstrained model estimation effort were extremely small and inconsistent with expectations. This is not uncommon in mode choice model estimation. Considerable work on the potential causes of the artificially low values of time obtained from the model system suggested that the quality of the skim data used in the estimation of the RP choice equation may be contributing to estimates of value of time that are not intuitive. The use of network skim data in RP choice models is often fraught with issues as there is no direct information or observation of the level-of-service attributes for non-chosen modes of transport (further details about the network skim data are presented under "Model Results" in this appendix). Instead, analysts must rely on skims extracted from model networks to serve as surrogates of the non-chosen modal level-of-service attributes. These attributes are often limited in that they are subject to aggregation errors, as network level of service is virtually always available only at the zone-to-zone level as opposed to point-to-point level.

In order to better control the implied values of time obtained from the joint RP-SP choice model system, the project team developed and estimated a SP-only choice model system where all modal attribute information is given by the experimental design of the SP survey component. The values of time obtained from a SP-only choice model then served as constraints in the joint RP-SP model estimation effort. More specifically, the value of in-vehicle travel time (IVTT) is used as the constraint in the joint RP-SP model estimation exercise with the value of (in-vehicle) travel time essentially representing the ratio of the coefficients associated with the fare (or auto travel cost) and IVTT variables. This constrained estimation process was found to provide more appropriate values of IVTT without compromising model goodness-of-fit in any appreciable way. Essentially, the coefficient on the fare or auto travel cost variable in the joint RP-SP model is obtained as the ratio of the coefficient on the IVTT variable and the value of IVTT implied by the SP-only model. The standard errors for the value of time (VOT) and the fare (cost) coefficient were computed using the well-established delta method (see http://www.stata.com/support/faqs/stat/deltam.html). The joint RP-SP mode choice modeling efforts were applied to data sets of both Chicago and Charlotte to obtain comparative insights into similarities and differences in mode choice determinants between the two geographical contexts. The remainder of Appendix E offers an overview of the model estimation results. In both cases, the choice set for each individual is constrained based on the outcome of the awareness and consideration models where a specific transit alternative is included in the feasible choice set only if the individual is both aware of the mode and considers it for the trip in question. The composition of the choice set therefore varies across individuals in the RP portion of the model.

Summary of Variables

All of the models estimated in this effort are multinomial logit choice models. Nested logit choice models were tested in the first phase of the study in Salt Lake City but did not provide significant additional goodness-of-fit, and so the additional complexity associated with the nested modeling structure was avoided in the Chicago and Charlotte model estimation process.

Five sets of attributes were considered for inclusion in the model specification. They include:

- **Modal level-of-service attributes:** Mode choice is inevitably affected by various attributes of the choice alternatives. For the SP choice model component, these attributes are drawn from the choice experiment. For the RP choice model component, information is obtained from the respondent only for the chosen mode. For the non-chosen modes, attribute information is drawn from the skim data because that is the best information available. In the models estimated for this study, non-traditional attributes that depict whether a mode is premium in nature are also included with a view to understanding the value that these non-traditional attributes provide travelers.
- **Individual sociodemographic attributes:** Individual socioeconomic and demographic characteristics are key predictors of traveler behavior. Heterogeneity in behavior due to observed characteristics is best captured through the inclusion of individual socioeconomic attributes such as age, gender, and employment status.
- **Household sociodemographic attributes:** Although mode choice is an individual traveler decision, it is likely to be impacted by household level socioeconomic and demographic variables. Such variables capture the household-level decisions and interactions that affect individual-level traveler choices. Household variables such as household size, number of workers, number of drivers, income, and car ownership are typical variables included in traveler behavior models.
- **Trip attributes:** Mode choice is affected by the nature of the trip that is being pursued. The purpose of the trip, the number of people traveling together, the timing of the trip, the length of the trip, and the presence of trip chaining can all have an impact on mode choice. The mode choice model specifications in this study include trip attributes to capture these effects.
- **Attitudinal factors:** As mentioned earlier, individual attitudes, perceptions, and values toward different modes of transport are likely to impact mode choice. The survey conducted in this study provided a rich set of attitudinal variables describing how respondents viewed each mode of transport. The factor analysis presented earlier reduced the attitudinal variables into a manageable number of factors that were found, for the most part, to be highly correlated to mode choice. The inclusion of these factors in the model specification allows for the explicit accounting for the effects of such individual traits without having to relegate them to the random error term of the utility equations.

Mode choice models were estimated with and without awareness and consideration information to determine the impact of including these constraints on the choice set. In each case, the best-fit model specification was adopted with a view to examining whether the inclusion of an awareness and consideration component added significant value in terms of goodness-of-fit and predictive power. It was found that mode choice models with awareness and consideration choice sets produced significantly better log-likelihoods than those without constraints on the choice sets. This confirms prior research on the usefulness of including choice sets constraints in mode choice models.

Model Results

Overall, the mode choice models for Chicago and Charlotte are found to offer plausible behavioral indications. For the most part, both Charlotte and Chicago respondents show similar sensitivity to various factors in their mode choice behaviors; however, there are some key differences between the two contexts that are reflective of the differences in the built environment, the modal level of service, and the preferences of travelers.

In the Salt Lake City models, the logit choice modeling included two transit attitudinal factors and a series of non-traditional variables that were significant in the mode choice models. The inclusion of these variables improved the models' goodness-of-fit. The non-traditional variables included: reliability, real-time transit information, station amenities, and on-board amenities. In addition to these non-traditional variables included in the model directly, a series of variables that interacted level of service with these non-traditional variables were tested. Ultimately, two of these interaction variables were found to be significant in the mode choice models for work trips:

- **IVTT interacted with modern on-board amenities—**This variable indicates that as in-vehicle travel time for train modes increases, the modern on-board amenities become more important in choosing a train.
- **Wait time interacted with real-time transit information—**This variable indicates that as wait time for train modes increases, real-time information becomes more important in choosing a train.

Both of these interaction variables confirm our intuition that some amenities become more important if the travel times or wait times are longer.

In the Charlotte and Chicago models, the logit choice modeling included five transit attitudinal factors, two other latent variables, and non-traditional transit service variables that were significant in mode choice. In addition, the choice sets were constrained to those alternatives that travelers were aware of and willing to consider. The models were estimated to provide equivalent model specifications, to allow more comparative analysis. These models were exploratory, given the added focus on awareness and consideration as well as incorporating latent variables, so all logical variables were retained in the models, even if they were not significant.

Values of time were reviewed for all three cities to understand whether these values were reasonable. Most of the values of time ranged from $2 per hour to $13 per hour, but the non-commute transit trips in Charlotte were less than $1 per hour and the non-commute auto trips in Salt Lake City were $20 per hour, due to unreasonable in-vehicle travel time coefficients (in Charlotte) and low cost coefficients (in Salt Lake City). Also, the lower values of time in

Chicago compared to Charlotte and Salt Lake City are counterintuitive, but the inconsistency in travel time estimates among the three cities may make these types of comparisons more difficult.

Salt Lake City Models

Separate multinomial logit (MNL) models were estimated for the work and non-work segments, the results of which are presented in the following sections. Models were initially non-nested, then nested models were estimated toward the end of the effort. There are two overarching objectives to evaluate the logit choice models: The first objective is to achieve the best fit statistically, including avoiding violations of the independence of irrelevant alternatives (IIA) property. The second objective is to reduce the size and significance of the modal constants. These two objectives may not always be consistent when choosing the final model.

Tests for model specifications of work trips and non-work trips were conducted systematically. The selection of a final model was dependent on the best fit statistics, the desire to avoid violations of the IIA property, and the goal of reducing the value and significance of modal constants. The model estimation results of final work-trip mode choice model are presented in TABLE E-1. All of the numbers in the "Value" column were calculated relative to the auto IVTT coefficient.

Separate IVTT coefficients were estimated for auto and transit modes. An attempt to estimate separate IVTT coefficients for bus and train resulted in convergence issues. Transit IVTT was found to be more onerous than that of auto. This is reasonable considering the fact that transit modes are generally less comfortable than an automobile. The disutility associated with transit IVTT is 16.5% more than that associated with auto IVTT. Both access and wait times are 50% more onerous than auto IVTT. This again is an intuitive result. All of the costs associated with various modes had negative coefficients as expected. The value of time (VOT) calculated from these coefficients ranged from \$5 to \$11 per hour. The VOT for people using transit was less than that for those using the auto mode. From the trip gas cost, VOT was found to be around \$11/hr which is roughly one-half of the wage rate of \$20/hr. Reliability contributed negatively to the utility of a mode. This is because of the way in which reliability was represented as a variable. It was defined as the number of minutes of delay occurring on 10% of the trips. A higher number represented lower reliability, hence the negative coefficient. The number of transfers adds to the burden of travel on transit modes. Each transfer was found to be worth about 10 minutes of auto IVTT.

All of the three premium transit attributes considered—real time transit info, modern stop design, and modern on-board facilities—were found to be highly significant. Each of these was contributing the equivalent of a reduction of 4 minutes to 5 minutes of IVTT. In addition, a couple of interaction variables between the premium attribute and travel time variables were of considerable influence. Presence of modern on-board amenities reduced the IVTT burden by about 15%. Similarly, provision of real-time transit information reduced the disutility of waiting by around 40%. Both of these outcomes are intuitive and logical. It should be noted that these were found to be significant only for the train mode and not for the bus mode. So, for bus, even though the premium transit attributes contribute positively to the overall utility, they do not have a significant impact through interaction with travel time variables. Introduction of the access mode variable led to a model convergence error.

TABLE E-1. Final model estimation results for work trips.

Attribute	Mode Utility Eqn.	Coefficient	Std. Err	t-stat	Value	Notes
IVTT (min)	All modes	-0.034	0.005	-7.109		
Access time (min)	Bus,train	-0.051	0.008	-6.379	1.491	times IVTT
Wait time (min)	Bus,train	-0.048	0.004	-12.178	1.413	times IVTT
Trip Gas Cost ($)	Auto	-0.240	0.024	-9.946	8.518	$ per hour
Fare ($ one-way)	Bus,train	-0.346	0.015	-22.607	5.906	$ per hour
Parking Cost ($/day)	Auto	-0.231	0.007	-32.744	8.823	$ per hour
Reliability	All modes	-0.024	0.005	-5.009	0.707	
Transfers (0 = no, 1 = yes)	Bus,train	-0.340	0.040	-8.590	10.002	minutes
Transit Info (0 = no real-time, 1 = real-time)	Bus,train	0.168	0.051	3.306	4.926	minutes
Stop design (0 = standard, 1 = modern)	Bus,train	0.148	0.040	3.702	4.353	minutes
On-board amenities (0 = standard, 1 = modern)	Bus,train	0.106	0.048	2.222	3.126	minutes
IVTT (min) with modern on-board amenities	Train	0.005	0.002	2.536	0.156	times IVTT
Wait time (min) with real-time information	Train	0.013	0.005	2.637	0.394	times IVTT
Option to work from home (0 = no, 1 = yes)	Train	0.829	0.206	4.018	24.377	minutes
Male (0 = no, 1 = yes)	Auto	-0.129	0.068	-1.902		
HH income less than 125K (0 = no, 1 = yes)	Auto	-0.250	0.101	-2.478		
HH income 125K or more (0 = no, 1 = yes)	Train	0.151	0.061	2.485		
Origin TAZ is rural (0 = no, 1 = yes)	Train	1.164	0.335	3.470	34.211	minutes
Transit users inclination factor	Auto	-0.102	0.040	-2.539	3.009	minutes
Transit users service availability factor	Auto	-0.532	0.049	-10.915	15.625	minutes
Auto constant		0.262	0.153	1.710	7.697	minutes
Train constant		0.009	0.058	0.157	0.266	minutes
Bus constant		0.000	fixed			
Number of observations		6608				
Log likelihood		-5860.896				
Log likelihood (no coefficients)		-10635.166				
R-sqrd		0.449				
RsqAdj		0.448				

Moving on to some of the other explanatory variables in the model, the option to work from home was found to be significant and positive in the train utility equation. There seems to be a correlation between the types of individuals (occupations) that have the flexibility to work from home and the tendency to use rail. This represents a modal preference applied to a limited population and should be explored further. Females were found to be more inclined to use auto than males. A probable reason for this may be that female commuters' trips chain more due to household obligations that, in turn, induces them to use auto. It appears that the lower income groups prefer train and bus modes over the auto mode for commuting, whereas the higher income groups prefer the train mode over the bus and auto modes. These income effects need to be explored further. Geographic variables representative of the origin and destination of the work trip were significant as well. Trips originating in rural TAZs (suburbs located far away from the urban core) had a higher probability of being undertaken on train and lower probability of being undertaken on auto. Riding the rail from a rural area was perceived to be equivalent to a 25-minute reduction in auto travel time. It is possible that the accessibility of train and the distance to commute for those residing in rural TAZs are influencing factors. This also represents a modal preference and should be explored further.

Two attitudinal factors from the factor analysis were found to be significant. Both of the factors were calculated using attitudinal responses from transit users (persons who have used some form of transit in the past year). They were "transit inclination" and "service availability" factors. A higher score on each of them lowered the probability of choosing the auto. This is again an intuitive result considering the attitudes represented by the factor explanatory variables.

The auto constant estimated had a positive value of 0.7, whereas that of train was insignificant and close to zero. The constant for bus was fixed as zero, denoting it as the base alternative. This model seems to have largely taken care of many unobserved components influencing the choice between bus and train modes, considering that both the mode-specific constants are zero.

The final model estimation results for non-work trips are presented in Table E-2. All of the numbers in the "Value" column were calculated relative to the auto IVTT coefficient. Again, separate IVTT coefficients were estimated for auto and transit modes. Transit IVTT was more onerous than auto IVTT, just as in the work-trip model. Transit IVTT resulted in a 60% higher burden than auto IVTT. This is considerably higher than that found in the work-trip model where the gap between the effects of auto and transit IVTTs was relatively less. Access time was found to be associated with a 60% higher disutility when compared to that due to auto IVTT. Unlike what was found in the work-trip model, wait time disutility was almost equivalent to that due to IVTT. It is possible that waiting time in the context of pursuing a non-work/non-mandatory activity is less inconvenient than in the context of a commuting trip when one is more time pressured. The values of time (VOT) calculated from the various costs associated with modes ranged from $5 to $20 per hour. From the trip gas cost, VOT was found to be around $20/hr, significantly higher than that calculated in the work-trip model. This may be attributed to the fact that a work trip may inherently involve a sense of earning or income on the part of the individual. This, in turn, may lower the value associated with time spent traveling to work. On the other hand, time spent traveling to non-mandatory activities might be considered of greater value due to the absence of distinct monetary gains associated with them. Reliability was significant and contributed negatively to the utility of all modes just as in the case of the work-trip model. Similarly, the number of transfers required to make the trip increased the inconvenience associated with transit modes. The magnitude of the impact was less than that in the work-trip model. A transfer was equivalent to only about 4 auto IVTT minutes.

TABLE E-2. Final model estimation results for non-work trips.

Attribute	Mode Utility Eqn.	Coefficient	Std. Err	t-stat	Value	Notes
IVTT_A (min)	Auto	-0.031	0.010	-3.146		
IVTT_Transit (min)	Bus,train	-0.049	0.011	-4.440	1.601	times IVTT_A
Access time (min)	Bus,train	-0.049	0.016	-3.111	1.600	times IVTT_A
Wait time (min)	Bus,train	-0.031	0.007	-4.144	0.998	times IVTT_A
Trip Gas Cost ($)	Auto	-0.093	0.044	-2.124	19.855	$ per hour
Fare ($ one-way)	Bus,train	-0.393	0.046	-8.540	4.683	$ per hour
Parking Cost ($/day)	Auto	-0.186	0.013	-13.749	9.905	$ per hour
Reliability	All modes	-0.025	0.011	-2.270	0.804	
Transfers (0 = no, 1 = yes)	Bus,train	-0.131	0.079	-1.662	4.260	minutes
Transit Info (0 = no real-time, 1 = real-time)	Bus,train	0.196	0.079	2.472	6.391	minutes
Stop design (0 = standard, 1 = modern)	Bus,train	0.070	0.079	0.893	2.301	minutes
On-board amenities (0 = standard, 1 = modern)	Bus,train	0.153	0.079	1.935	4.985	minutes
Age between 35 and 64 years (0 = no, 1 = yes)	Auto	0.418	0.121	3.466	13.645	
HH income between 75K and 200K (0 = no, 1 = yes)	Train	0.708	0.155	4.560	23.107	
Origin TAZ is urban (0 = no, 1 = yes)	Auto	-0.286	0.126	-2.270	9.337	minutes
Bus users inclination factor	Train	-0.199	0.080	-2.484	6.503	minutes
Transit users service availability factor	Auto	-0.137	0.083	-1.642	4.457	minutes
Auto constant		0.938	0.190	4.949	30.620	minutes
Train constant		0.135	0.073	1.838	4.403	minutes
Bus constant		0.000	fixed			
Walk access (vs. drive)	Bus,train	0.433	0.087	5.002	10.173	minutes
	IV Parameters					
Auto Nest (Auto)		1.000	fixed			
Transit Nest (Bus, Train)		0.559	0.102	5.469		
Number of observations		10680				
Log likelihood		-1786.737				
Log likelihood (no coefficients)		-3084.505				
R-sqrd		0.421				
RsqAdj		0.418				

Two out of the three premium transit attributes were significant. Modern stop design was not statistically significant in influencing the mode choice probabilities. Interaction variables, when introduced into the model, made the original premium transit attribute variables insignificant and hence were not included in the specification. The coefficient for access mode variable was estimated in this model. Walk access was found to have a positive impact on the utility of both bus and train, indicating that having transit in walk access range makes a significant difference to the utility associated with transit. The difference between walk access and drive access was quantified as 10 minutes of auto IVTT.

A couple of sociodemographic variables were entered into the model specification. Individuals aged over 35 years and less than 64 years had a higher tendency to use the auto than the transit modes, presumably due to lifecycle-stage effects that demand more trip chaining and serve-passenger/serve-child type trips. Similar to the work-trip model, a higher income group with annual household income between 75K and 200K was more likely to choose the train. If the origin TAZ of the trip was urban, the probability of the mode being auto decreased. This may be due to higher accessibility and availability of transit options in an urban area when compared to other areas.

The same attitudinal factors from the work model were found to be significant here too; however, the difference was in the utility equations they influenced. The inclination factor was termed as the bus user's inclination factor because it negatively influenced the utility of train. As in the work-trip model, a higher service availability factor decreased the auto utility.

The auto constant estimated was 0.9 and the train constant was barely significant at the 95% level, indicating that all of the explanatory variables in the model, taken together, helped account for mode choice behavior with very little in the way of unobserved or unmeasured attributes whose effects were reflected by the mode-specific constant.

Chicago Models

Joint RP-SP mode choice model estimation results are presented for Chicago in TABLE E-3. Separate mode choice models are estimated for commute and non-commute trips to reflect the differing nature of the determinants of mode choice for these two major trip types. The table provides a side-by-side comparison of estimation results for the two trip types. The alternative specific constant for auto is set to zero; relative to the auto mode, both bus and rail show positive alternative specific constants. This finding is rather counterintuitive. It appears that the distribution of responses to the SP scenarios is contributing to the positive alternative-specific constants for transit modes. A review of TABLE C-10 (see Appendix C) shows that about 70 percent of the respondents chose a transit mode in at least one of the eight scenarios of the SP experiment and 14 percent of the respondents chose transit in every single scenario. These statistics may have contributed to the finding that, all else being equal, individuals actually exhibited an intrinsic preference to choose a transit mode over the auto mode. This intrinsic preference is captured by the alternative-specific constants.

The first category of variables is level-of-service attributes. For the RP portion of the data, this corresponds to network skim data, and for the SP portion of the data, this corresponds to values of attributes provided in the experimental scenario. In general, all coefficients provide indications and have signs consistent with expectations. Access time negatively impacts the utility of bus and train modes. The interaction variable between access time and access mode (= walk) has a positive coefficient indicating that the ability to access a transit mode by walk enhances its utility to the traveler (this variable is unique to the SP choice equation). This finding is consistent with the statistics presented in Appendix C, Figures C-33 through C-35 where it is reported that about 90 percent of respondents are not willing to walk more than 20 minutes to access transit. The IVTT variable has a negative coefficient across all modes of transport and is a generic variable taking the same value across all utility functions. The magnitude of the coefficient is somewhat larger for commute trips suggesting that people are more time conscious in the context of commute travel, a finding that is consistent with

TABLE E-3. Chicago multinomial mode choice model.

	Commute			Non-Commute		
Explanatory Variables	**Auto**	**Bus**	**Train**	**Auto**	**Bus**	**Train**
Alternative-Specific constant		2.644 (4.4)	1.062 (5.0)		1.515 (3.6)	1.071 (2.7)
Level of Service						
Access time (min.)†		-0.057 (-3.4)	-0.102 (-5.9)		-0.062 (-5.6)	-0.062 (-5.6)
Access time (min.) x Access mode (= walk)†		0.024 (2.2)	0.039 (3.7)		0.032 (3.7)	0.011 (1.5)
IVTT (min.)	-0.025 (-8.5)	-0.025 (-8.4)	-0.025 (-8.4)	-0.019 (-8.1)	-0.019 (-8.1)	-0.019 (-8.1)
Wait time (min.)		-0.057 (-6.7)	-0.041 (-6.5)		-0.027 (-6.4)	-0.027 (-6.4)
Fare ($)†		-0.493 (-4.4)	-0.493 (-4.4)		-0.508 (-4.9)	-0.321 (-4.7)
Auto cost($)	-0.207 (-4.3)			-0.211 (-4.9)		
Parking cost ($)†	-0.070 (-5.3)	-0.143 (-6.5)	-0.022 (-2.0)	-0.073 (-5.3)		-0.041 (-3.6)
Access mode (walk over drive)†						
Span of service (all day v. only peak)†		0.688 (7.6)	0.688 (7.6)		0.495 (6.0)	0.571 (6.8)
Reliability (% on time)†		0.147 (2.1)	0.135 (2.1)	0.091 (1.4)	0.088 (1.6)	
No transfer		0.365 (6.1)	0.365 (6.1)		0.180 (4.4)	0.180 (4.4)
Premium on-board (prem. over standard)†		0.146 (2.5)	0.146 (2.5)		0.205 (3.5)	
IVTT (min.) x amenities†			0.005 (2.8)			
Premium stop design (prem. over standard)†		0.124 (2.5)	0.124 (2.5)		0.084 (2.3)	0.084 (2.3)
Individual Demographics						
Full-time student					0.431 (3.6)	0.431 (3.6)
Full-time employed		0.170 (2.1)	0.170 (2.1)			
Homemaker						-0.126 (-1.4)
Retired						-0.161 (-2.1)
Female		-0.224 (-2.3)	-0.374 (-4.0)			
Longtime resident (>5 years)			0.225 (3.0)		-0.091 (-1.5)	
Has mobility problem		0.345 (2.4)			0.228 (2.5)	0.228 (2.5)
Age less than 35 years		0.469 (4.2)				
Age between 35 and 55			-0.462 (-4.2)			
Age more than 55 years			-0.423 (-3.4)			

TABLE E-3. (Continued).

	Commute			Non-Commute		
Explanatory Variables	**Auto**	**Bus**	**Train**	**Auto**	**Bus**	**Train**
Household Demographics						
Number of vehicles in HH		-0.162 (-3.9)	-0.162 (-3.9)		-0.142 (-4.1)	
Family income (lnIncome)		-0.220 (-4.3)			-0.071 (-2.1)	-0.071 (-2.1)
More drivers than vehicles					0.597 (3.3)	0.597 (3.3)
Kids present		0.290 (3.5)	0.290 (3.5)			0.186 (2.9)
Trip Characteristics						
Group travel					-0.223 (-3.5)	-0.223 (-3.5)
Weekend trip			-0.159 (-1.3)			0.090 (1.5)
Makes stop for groceries					-0.407 (-4.2)	-0.407 (-4.2)
Makes stop for other reasons		-0.206 (-2.7)	-0.206 (-2.7)			
Attitude						
Very informed about transit		0.221 (2.7)				
Pro-transit attitude		0.955 (8.3)	0.955 (8.3)		0.633 (7.5)	0.633 (7.5)
Consciousness attitude		0.379 (6.3)	0.379 (6.3)		0.226 (4.8)	0.226 (4.8)
Pro-car attitude		-0.619 (-7.2)	-0.619 (-7.2)		-0.466 (-6.9)	-0.466 (-6.9)
Transit averse		-0.136 (-2.4)	-0.136 (-2.4)		-0.179 (-3.6)	-0.179 (-3.6)
Low transit comfort level					0.101 (2.0)	0.101 (2.0)
Willing to walk not more than 2 min.		-0.688 (-4.6)	-0.688 (-4.6)		-0.781 (-5.4)	-0.781 (-5.4)
Willing to walk 10 or more min.			0.177 (2.3)			0.165 (2.5)
RP SP Scaling Coefficient						
rho*	0.889 (1.1)			1.293 (1.8)		
Model Fit Statistics						
Log-likelihood (final)	-5799.515			-4734.170		
Log-likelihood (constants)	-6772.581			-5779.123		
Pseudo rho-squared	0.144			0.181		
Number of observations	7272			6237		

† Variable present only in SP utility equation

* t-stat with respect to 1

expectations. Similarly, wait time also presents significant negative coefficients, and the coefficient on wait time is twice that of IVTT for commute mode choice and about 50 percent higher than that of IVTT for non-commute mode choice. This clearly indicates that people view waiting time as being considerably more onerous than IVTT.

Transit fare is a variable that enters the SP utility equation only; it is treated as a generic variable in the commute mode choice model and as an alternative specific variable in the non-commute mode choice model. The coefficients are uniformly negative as expected. Auto travel cost enters the auto utility equation with a negative coefficient; however, the coefficient on the auto travel cost variable is about one-half of that for the transit fare variable, suggesting that individuals are generally more sensitive to transit fare changes than auto travel cost changes. An increase in parking cost at the transit station negatively impacts the utility of auto; as expected, an increase in parking costs at the transit station (park-and-ride) negatively impacts transit mode utilities as well. This variable is unique to the SP choice equation.

There are several variables that positively impact the utilities of transit alternatives. Improvements in span of service and modal reliability (% on-time performance), attributes that were included in the SP choice utility equation, enhance the utility of transit modes as evidenced by the positive coefficients on these variables. The absence of a transfer also enhances the utility of transit, suggesting that people intrinsically prefer not to have to transfer in the course of a trip.

Of much importance and interest in the context of this study is the set of three variables from the SP choice experiment that represent the effects of the presence of premium service attributes on transit mode choice. Premium on-board amenities are found to significantly impact bus and rail utilities for the commute mode and only the bus mode for non-commute trips. The positive coefficient on the interaction term between IVTT and on-board amenities in the context of the rail mode for commute trips suggests that the presence of premium on-board amenities is valued by travelers in the context of commute travel and mitigates the effect of longer IVTT that may be viewed as more onerous in the absence of such premium service attributes. Premium stop design and amenities at stop locations also significantly positively impact utilities of transit modal alternatives. These findings clearly suggest that travelers do value premium service attributes and the presence of such attributes can have significant impacts on mode choice behavior of individuals. Additional insights on the value of premium service attributes are provided in Appendix D.

The next category of variables is that of individual demographics. Full-time students are more likely to choose bus and rail modes for non-commute travel, while full-time employed individuals are more likely to choose bus and rail modes for their commute travel. In the Chicago data set, a little over 53 percent of the respondents are full-time employed individuals and about 14 percent are students (see Appendix C, Figure C-11 and Figure C-12). The substantial presence of these demographic groups in the respondent sample allows the accounting of these person attributes on mode choice behavior. Homemakers are less likely to choose rail for non-commute travel, perhaps due to the constraints that rail imposes in the ability to undertake serve-passenger and serve-child trips and accomplish multi-stop trip chains. Likewise, retired individuals show a lower preference for rail transit mode for non-commute travel, possibly due to the difficulty for older individuals to access rail stations which may be farther away from the point of origin or destination of travel. In general, bus service (bus stops) tends to be more ubiquitous and easily accessed.

Females are less inclined to select transit modes for their commute travel, perhaps because of the need to link non-commute stops to the commute journey making the use of transit modes rather difficult. A review of National Household Travel Survey (NHTS) data has consistently shown that females continue to shoulder a greater amount of household maintenance activities and undertake more trip chaining (than do males) in the context of their commute journey. Previous work has also shown that multi-stop trip chaining is a detriment to transit mode use. The NHTS data has also shown that females generally have shorter commute distances than men, further contributing to the lower use of transit by female workers. Longtime residents who have been in place more than 5 years are found to prefer the rail mode for commute travel, perhaps due to their familiarity with the system over time. On the other hand, they are less likely to use bus for non-commute travel, a finding that is consistent with that reported in the previous section (on awareness and consideration of choice alternatives). Younger individuals are more likely to choose bus for commute travel, while older individuals are less likely to choose rail for commute travel. A variety of factors, including residential location and the need to undertake other activities in conjunction with the commute, may be contributing to this age effect. It is difficult to isolate these contributing factors in the absence of additional data on residential location; further exploration of this phenomenon is therefore left for future research and study. Finally, among person attributes, individuals with mobility problems show a proclivity toward transit modes.

Household demographics comprise the next set of explanatory variables. As the number of vehicles in the household increases, the inclination to choose transit modes decreases as evidenced by the negative coefficients on these variables. Similarly, individuals in higher income households are less likely to choose transit modes, a finding that is consistent with expectations. In households where there is a vehicle deficiency (i.e., the number of drivers exceeds the number of vehicles), it is found that the likelihood of using transit modes increases for non-commute travel. This is consistent with expectations, although it is not entirely clear why a similar trend is not seen in the case of commute travel modal utility equations. The presence of children in the household (not necessarily on the trip) increases the likelihood of using transit modes, a finding that is worthy of further exploration.

Among trip characteristics, group travel negatively contributes to the utility of transit alternatives. In general, one would expect that group travel is more easily accomplished using personal means of transportation as opposed to public transportation due to cost considerations and the potential need to stop at multiple locations along a tour to serve the needs of different individuals on the tour. It is found that weekend *commute* trips are less likely to be undertaken by rail, while weekend *non-commute* trips are more likely to be undertaken by rail. Having to make stops (trip chaining) is generally a deterrent to transit usage as evidenced by the negative coefficients on the stop variables, and is consistent with findings reported in previous studies. Making stops for groceries negatively impacts utility of transit for non-commute travel, whereas making stops for other reasons negatively impacts utility of transit alternatives for commute travel.

Attitudinal factors are found to play a significant role in shaping modal utility equations. Individuals very informed about transit are found to be positively inclined toward choosing bus mode for commute travel, the only utility equation that is significantly impacted by this variable. It is possible that information campaigns aimed at enhancing the extent to which individuals are informed about transit service options play a particularly useful role in the context of bus use for commute travel. In combining the findings from the awareness and consideration model with the choice model, it appears that a person needs to be very informed about transit to be aware of, consider, and choose the bus mode. For the rail mode, being informed about transit brings the mode into the choice set; once it is in the choice set, then being informed about transit has no further impact on the choice of rail. This is an important finding that points to the greater need for information (detail) for individuals to use the bus mode of travel; due to the greater visibility of rail and perceived premium attributes associated with rail, travelers do not feel the need to have the same level of information to use the premium mode.

Other attitudinal factors provide very plausible indications. Factors representing a pro-transit stand and a heightened level of consciousness positively impact the choice of transit alternatives, consistent with the exploratory descriptive statistics presented in the factor analysis section of this report.. Those with a pro-car attitude are less likely to choose transit, as are those who are transit averse. The factor representing low transit comfort level appears to be providing counterintuitive indications, with a positive coefficient for this factor in the non-commute transit choice utility equations. The issue with this factor in the Chicago case study is that the factor includes two variables that are pro-transit in nature but take negative loading values in the factor. These two variables that enter the "low transit comfort level" factor are "It's easy to plan a trip using transit" and "If I wanted to, I could use public transit more frequently." The presence of these two variables in this particular factor in the Chicago case study appears to be contributing to this counterintuitive indication. Those willing to walk no more than 2 minutes are less likely to choose transit while those willing to walk more than 10 minutes are more likely to choose rail transit (consistent with the notion that using rail entails longer access distance).

The RP-SP scaling coefficient is found to be significant for the non-commute travel context and insignificant for the commute travel context. It appears that the variance of the error terms of the RP and SP utility equations are quite consistent with one another in the case of commute travel; this is reflective of the ability of respondents to provide more realistic choice information for SP experiments that deal with commute travel—a journey with which they are very familiar and can easily relate. On the other hand, in the case of non-commute travel, respondents are not able to accurately depict choice behaviors under alternative scenarios and there may be greater levels of randomness in the actual choice behaviors relative to the choice behaviors reported in the rather controlled SP survey. Hence it is expected to have a significant RP-SP scaling coefficient in the context of non-commute travel.

Overall, the Chicago model is found to provide plausible behavioral indications with a rich set of demographic, trip, level-of-service, and attitudinal factors affecting choice of mode for both commute and non-commute travel.

Charlotte Models

Results of the Charlotte mode choice model estimation effort are shown in TABLE E-4. Many of the indications are consistent with and similar to those obtained in the context of the Chicago case study; hence, in the interest of brevity, the discussion in this section will not be as detailed as that provided for the Chicago mode choice model. In terms of the alternative specific constants, it is found—similar to the Chicago case study—that respondents are more inclined to choose transit modes, *all else being equal*. Only the train alternative in the commute travel context has an insignificant alternative specific constant.

TABLE E-4. Charlotte multinomial mode choice model.

	Commute			Non-Commute		
Explanatory Variables	**Auto**	**Bus**	**Train**	**Auto**	**Bus**	**Train**
Alternative-specific constant		1.939 (4.6)	0.024 (0.2)		2.825 (5.0)	0.934 (4.5)
Level of Service						
Access time (min.)†		-0.017 (-2.1)	-0.025 (-2.4)		-0.040 (-2.6)	-0.084 (-4.6)
Access time (min.) x Access mode (= walk)†			-0.015 (-1.1)			0.02 (1.7)
IVTT (min.)	-0.022 (-6.5)	-0.022 (-6.5)	-0.022 (-6.5)	-0.021 (-6.7)	-0.008 (-6.9)	-0.008 (-6.9)
Wait time (min.)		-0.031 (-6.1)	-0.031 (-6.1)		-0.026 (-4.0)	-0.039 (-4.7)
Fare ($)†		-0.242 (-4.2)	-0.242 (-4.2)		-0.694 (-1.0)	-0.829 (-1.0)
Auto cost($)	-0.102 (-4.6)			-0.160 (-2.5)		
Parking cost ($)†	-0.072 (-5.7)	-0.220 (-5.2)	-0.126 (-4.2)	-0.169 (-4.8)	-0.123 (-4.4)	-0.142 (-2.6)
Access mode (walk over drive)†			0.221 (1.9)			
Span of service (all day v. only peak)†		0.344 (5.8)	0.344 (5.8)		0.567 (5.8)	0.567 (5.8)
Reliability (% on time)†		0.101 (2.3)				
No transfer		0.235 (5.4)	0.235 (5.4)		0.146 (2.6)	0.146 (2.6)
Premium on-board (prem. over standard)†		0.101 (2.1)	0.101 (2.1)		0.180 (3.1)	0.180 (3.1)
IVTT (min.) x amenities†		0.004 (2.6)	0.005 (3.0)			
Premium stop design (prem. over standard)†		0.103 (2.4)	0.060 (1.6)		0.172 (2.1)	
Individual Demographics						
Full-time student		0.254 (2.8)	0.254 (2.8)			
Full-time employed		0.176 (2.8)				-0.336 (-3.5)
Homemaker						-0.457 (-3.3)
Retired						
Female		-0.141 (-2.7)	-0.241 (-4.4)			
Longtime resident (>5 years)			-0.107 (-2.6)			-0.156 (-2.1)
Has mobility problem					0.600 (4.3)	
Age less than 35 years		-0.236 (-4.5)	-0.236 (-4.5)			
Age between 35 and 55 years						
Age more than 55 years		0.228 (3.6)			-0.273 (-2.8)	-0.273 (-2.8)

TABLE E-4. (Continued).

	Commute			Non-Commute		
Explanatory Variables	**Auto**	**Bus**	**Train**	**Auto**	**Bus**	**Train**
Household Demographics						
Number of vehicles in HH						
Family income (lnIncome)		-0.234 (-5.3)			-0.300 (-5.4)	
More drivers than vehicles						
Kids present						
Trip Characteristics						
Group travel		0.251 (3.4)				0.241 (2.9)
Weekend trip		0.234 (2.3)	-0.167 (-1.6)		-0.620 (-4.8)	-0.465 (-4.3)
Makes stop for groceries						-0.240 (-2.7)
Makes stop for other reasons					-0.288 (-2.9)	-0.240 (-2.7)
Latent Variables						
Very informed about transit		0.482 (5.2)	0.284 (3.9)		0.554 (4.3)	0.554 (4.3)
Pro-transit attitude		0.319 (6.0)	0.319 (6.0)		0.425 (5.2)	0.439 (5.2)
Consciousness attitude		0.342 (6.1)	0.342 (6.1)		0.621 (6.4)	0.648 (6.5)
Pro-car attitude		-0.480 (-6.4)	-0.480 (-6.4)		-0.427 (-5.7)	-0.443 (-5.7)
Transit averse		-0.044 (-1.4)	-0.044 (-1.4)		-0.144 (-2.2)	-0.151 (-2.2)
Low transit comfort level		-0.327 (-6.0)	-0.327 (-6.0)		-0.475 (-5.6)	-0.496 (-5.6)
Willing to walk not more than 2 min.		-0.101 (-1.4)	-0.254 (-3.4)			
Willing to walk 10 or more min.		0.169 (3.8)	0.169 (3.8)		0.468 (4.7)	0.468 (4.7)
RP-SP Scaling coefficient						
rho*	1.462 (2.1)			1.080 (0.51)		
Model Fit Statistics						
Log-likelihood (final)	-7125.940			-3377.919		
Log-likelihood (constants)	-8605.211			-4024.945		
Pseudo rho-squared	0.172			0.161		
Number of observations	9369			4185		

† Variable present only in SP utility equation

* t-stat with respect to 1

With respect to level-of-service attributes, access time is found to negatively impact transit mode choice as evidenced by the negative coefficients on this variable for all transit mode alternatives. This variable only appears in the SP choice utility equation, but the negative sign is consistent with descriptive statistics presented earlier in this appendix for Chicago and Salt Lake City, where it was found that 90 percent of respondents would not walk more than 20 minutes to access transit. The interaction variable between access time and mode provides slightly different indications in the Charlotte context than in the Chicago context. In the Charlotte case study, this interaction variable negatively impacts rail utility for commute travel, suggesting that travelers appear to be more prone to accessing rail by driving rather than by walking (although this effect is statistically insignificant), a finding that is supported by the higher percent of park-and-ride access depicted in Appendix C, Figure C-40. For non-commute travel, on the other hand, this variable has a positive coefficient on the rail alternative similar to Chicago—it appears that individuals are more inclined to access rail by walking in the context of non-commute travel. This interaction variable has no impact on bus utility (in contrast to the Chicago mode choice model). In-vehicle travel time (IVTT), a generic variable in the model specification has a negative coefficient across all modal alternatives. The IVTT coefficient is more negative for commute travel, suggesting that travelers are more sensitive to travel time when commuting.

Wait time is considered more onerous than IVTT as evidenced by the substantially higher negative values on the coefficients for the wait time variable across all transit modes. Transit fare has a negative coefficient, as expected, for all transit modes (this variable is only in the SP choice utility equation). It is found that transit fare is not a significant predictor of transit choice for non-commute travel in the Charlotte case study. Charlotte respondents are not exhibiting sensitivity to fare fluctuations (at least in the range of values used in the SP choice experiment) leading to the statistically insignificant coefficient estimates in the non-commute transit utility equations. Auto cost negatively impacts auto utility while parking cost at the transit station negatively impacts utilities across all modal alternatives, similar to the Chicago case study.

A host of other service attributes positively impact transit choice, very similar to the Chicago context. Being able to access rail by walk appears to enhance its utility, particularly for commute travel. Improving span of service and service reliability increased the utility of transit alternatives, similar to the Chicago mode choice model findings. The absence of the need to transfer also increases transit utility as does the presence of a host of premium service amenities—both on-board and at stations. The presence of on-board premium amenities significantly impacts transit utility across all transit alternatives. Similarly, the presence of premium stop design attributes enhances transit utility for all transit alternatives except rail for non-commute travel, consistent with the limited availability of rail service in Charlotte. The interaction between IVTT and the presence of amenities is found to positively impact utilities of transit alternatives for the commute trip. This suggests that the presence of amenities is particularly valuable in mitigating the effects of longer travel times on the commute trip, potentially because people can be productive during the journey when such amenities are provided. The need to be productive is of less importance and significance in the context of non-commute travel—a finding that is similar between the two contexts.

As expected, individual demographics play an important role in shaping travel mode choice behavior. In Charlotte, students are more likely to choose transit alternatives for the commute trip. Full-time employed individuals are more likely to choose the bus in Charlotte (presumably because of limited rail service in Charlotte). Homemakers are less inclined to use rail for non-commute travel similar to the Chicago case study, for the same reason that rail does not serve multi-stop trip chaining needs well. Females are less likely to choose transit for their commute travel, a finding that is consistent with that of the Chicago context—once again demonstrating that shorter commutes and the need to link non-work stops with the commute journey contribute to lowering the utility of choosing transit alternatives for females. Longtime residents are found to be less likely to choose rail for both commute and non-commute travel in the Charlotte context, a finding that is in stark contrast to that of the Chicago case study. Longtime residents are likely to be aware of the rail mode and consider it for their travel needs. Hence, rail is present in the choice set, but the utility of choosing rail as a mode of transportation is lower for these residents. Persons with a mobility challenge are more likely to choose bus for non-commute travel, a finding similar to that of the Chicago sample—but the effect of this variable on transit utilities is considerably subdued in the Charlotte context. Younger individuals are less likely to choose transit for commute travel in the Charlotte context, a finding that is again in stark contrast to that of Chicago, where younger individuals were more prone to choosing transit for their commute. Older individuals do show a propensity to use the bus for commute travel; on the other hand, they are less likely to use transit alternatives for non-commute travel where a greater level of flexibility may be desired. These findings are rather different from those of the Chicago case study as well.

Among household demographics, only family income is found to have a statistically significant impact on mode choice, with individuals from higher income households less likely to choose the bus mode for their commute and non-commute travel. Interestingly, such a negative coefficient is not seen in the rail utility equation, implying that higher income households view auto and rail in equivalent terms. In other words, respondents in higher income households view rail as a premium mode on par with auto (all else being equal). Among trip characteristics, group travel contributes positively to bus utility for the commute and to rail utility for non-commute travel. The findings on group travel are in contrast to those in the Chicago case study, where group travel was a clear deterrent to transit mode use. On weekends, individuals are generally less likely to choose transit modes, consistent with the greater need for flexibility for weekend trips. The only exception is that weekend commuters are more inclined to use the bus. Stop-making negatively impacts the choice of transit alternatives, particularly for non-commute travel in the case of the Charlotte case study. This finding is consistent with expectations in that stop-making is generally a deterrent to transit mode use. However, in the Chicago case study, it was found that stop-making was a deterrent to transit mode use in the case of commute travel as well as non-commute travel; in the Charlotte case study, it was found that this is true only for non-commute travel.

Virtually all of the attitudinal factors are statistically significant in explaining mode choice behavior in the Charlotte context, suggesting that the factors extracted in the factor analysis procedures are appropriate for modeling mode choice phenomena. Those who are very informed about transit are more inclined to use transit alternatives across the board, a finding that is in contrast to the Chicago case study where information appears to only impact bus utility for commute travel. Those with a pro-transit attitude and those with a consciousness attitude (see Appendix G) are more likely to use transit alternatives for both trip types. On the other hand, a pro-car attitude and a transit-averse attitude contribute negatively to transit utility across all transit modes and trip types. In the case of Charlotte, low transit comfort is more easily interpreted as a factor because only two pure anti-transit variables are loaded into the factor (as opposed to the Chicago case, where two additional pro-transit variables entered the factor with negative loadings). The variable has negative coefficients in all transit utility equations, suggesting that individuals with higher levels of transit discomfort are less likely to use transit.

Those willing to walk no more than 2 minutes are less likely to use transit for the commute trip, a finding that is consistent with that found in Chicago. In the Chicago case study, this variable also had a negative impact on transit utility for non-commute travel, but such a finding is not obtained in the Charlotte case study. On the other hand, when people are willing to walk more than 10 minutes to access transit, then all four transit mode utility equations are positively affected—a finding that is in agreement with that obtained in the Chicago mode choice model.

In the case of the Charlotte sample, the RP-SP scaling coefficient is statistically significant for commute travel and statistically insignificant for non-commute travel. This is exactly opposite of what was found in the Chicago case study. In the Charlotte context, transit mode splits are substantially lower than in Chicago (particularly for non-commute travel) as depicted in Appendix C, Figure C-29 and Figure C-30. People are so disinclined to use transit for non-commute travel that there is hardly any difference in the variance of the random error term between the RP and SP utility equations for non-commute travel. A difference in random error variance arises in the Charlotte case study in the context of commute travel where people may be willing to consider using transit (at least in the SP scenarios). Thus, for the commute trip, there may be fundamental differences between revealed and stated preferences that contribute to the significant RP-SP scaling coefficient. In the case of non-commute travel, people are just so consistently disinclined to using transit (in both the RP and SP scenarios) that there is no significant scaling coefficient between the RP and SP choice behaviors.

Overall, the models are found to offer plausible behavioral indications. For the most part, both Charlotte and Chicago respondents show similar sensitivity to various factors in their mode choice behaviors; however, there are some key differences between the two contexts that are reflective of the differences in the built environment, the modal level of service, and the preferences of travelers.

Equivalent Value of Travel Time for Mode Choice Attributes

The project team used the parameter values in the mode choice models to compute the equivalent value of different attributes in terms of IVTT (in minutes). This may be done for all non-cost variables by simply dividing the coefficient of each attribute by the coefficient of IVTT. For all cost variables, an equivalent VOT ($/hour) is computed by dividing the IVTT coefficient by the cost coefficient and then multiplying by 60. The results of the exercise are shown in Table E-5 and E-6. The values may be interpreted in a straightforward way as representing the equivalent increase or decrease in IVTT (in minutes) corresponding to a unit change in the attribute of interest. Thus, a positive entry in the tables implies that the attribute is equivalent to an increase in IVTT corresponding to the value in the cell. Conversely, a negative entry in the table implies that the attribute is equivalent to decreasing the IVTT by an amount equal to the value in the cell.

The equivalent minutes of IVTT for traveler attitudes in Salt Lake City were derived from the mode choice models. The traveler attitudinal factors for Salt Lake City were developed for transit users only. The negative sign on these attributes indicates that for auto commute trips, travelers who are positively inclined toward transit will consider this worth 3 minutes of in-vehicle time to use auto. Travelers who have transit service availability will consider this worth 16 minutes of in-vehicle time to use auto. For non-commute travel, travelers who think positively about bus will be negatively inclined to take train, and travelers who think positively about transit will be negatively inclined to take auto.

TABLE E-5 presents the results of computing equivalent minutes of IVTT for the Chicago sample. It is found that access time is generally considered two to four times more onerous than IVTT, while waiting time is considered about 1.5 to two times more onerous. In the case of access time attributes, access time to rail for commute travel appears to be two times more onerous than access time to bus, a finding that may reflect greater levels of sensitivity to access time in the context of commute travel and the greater distances that one may have to

TABLE E-5. Equivalent IVTT (in minutes) for various attributes of MNL model in Chicago.

	Commute			Non-Commute		
Explanatory Variables	Auto	Bus	Train	Auto	Bus	Train
Level of Service						
Access time (min.)		-2.28			-3.26	-3.26
Access time (min.) x Access mode (= walk)		-0.96			1.68	0.58
IVTT (min.)	1.00	1.00	1.00	1.00	1.00	1.00
Wait time (min.)		-2.28	-1.64		-1.42	-1.42
Fare ($) *		-3.04	-3.04		-2.24	-3.55
Auto cost($) *	-7.25			-5.40		
Parking cost ($) *	-21.43	-10.49	-68.18	-15.62		-27.80
Span of service (all day v. only peak)		27.52	27.52		26.05	30.05
Reliability (% on time)†		5.88	5.40	4.79	4.63	
No transfer		14.60	14.60		9.47	9.47
Premium on-board (prem. over standard)†		5.84	5.84		10.79	
IVTT (min.) x amenities			0.20			
Premium stop design (prem. over standard)		4.96	4.96		4.42	4.42
Individual Demographics						
Full-time student					22.68	22.68
Full-time employed		6.80	6.80			
Homemaker						-6.63
Retired						-8.47
Female		-8.96	-14.96			
Longtime resident (>5 years)			9.00		-4.79	
Has mobility problem		-13.80			12.00	12.00
Age less than 35 years		-18.76				
Age between 35 and 55 years			-18.48			
Age more than 55 years			-16.92			

TABLE E-5. (Continued).

	Commute			Non-Commute		
Explanatory Variables	**Auto**	**Bus**	**Train**	**Auto**	**Bus**	**Train**
Household Demographics						
Number of vehicles in HH		-6.48	-6.48		-7.47	
Family income (lnIncome)		-8.80			-3.74	-3.74
More drivers than vehicles					31.42	31.42
Kids present		11.60	11.60			9.79
Trip Characteristics						
Group travel					-11.74	-11.74
Weekend trip			-6.36			4.74
Makes stop for groceries					-21.42	-21.42
Makes stop for other reasons		-8.24	-8.24			
Attitude						
Very informed about transit		8.84				
Pro-transit attitude		38.20	38.20		33.32	33.32
Consciousness attitude		15.16	15.16		11.89	11.89
Pro-car attitude		-24.76	-24.76		-24.53	-24.53
Transit averse		-5.44	-5.44		-9.42	-9.42
Low transit comfort level					5.32	5.32
Willing to walk not more than 2 min.		-27.52	-27.52		-41.11	-41.11
Willing to walk 10 or more min.			7.08			8.68

* In the case of Fare, Auto Cost, and Parking Cost, the values are in units of $/hour of IVTT

† Variable present only in SP utility equation.

travel to access a rail station relative to a bus stop. With respect to values of time corresponding to cost variables, it appears that every hour of increase in IVTT would translate to an equivalent additional fare of $3.04 on transit, or an auto operating cost increase of $7.25, or a parking cost increase of $10 to $70, depending on the mode of transport. These values correspond to commute travel. Values are somewhat similar, albeit consistently lower, for non-commute travel—a finding consistent with expectations in that values of time are likely to be lower for non-commute travel. The values obtained for fare and auto operating cost are found to be rather similar to values obtained from the Salt Lake City data set, but the value for parking cost greatly exceeds that for Salt Lake City.

Increasing span of service (from peak period only to entire day) has dramatic impacts in that it is equivalent to reducing IVTT by 25 to 30 minutes. Every one percent increase in reliability is equivalent to reducing IVTT by 4 to 6 minutes. The elimination of a transfer is equivalent to shaving off 15 minutes in a commute trip and nearly 10 minutes in a non-commute trip. The presence of premium on-board amenities is found to have a larger impact in the context of non-commute travel, potentially because of the greater variability associated with non-commute trips. The presence of on-board amenities is equivalent to reducing travel time by about 6 minutes for commute travel and 10 minutes for non-commute travel.

Equivalent values of travel time are provided for all other variables as well, including individual and household demographic variables and individual attitudinal factors. Essentially, the value for each variable represents the amount by which IVTT would have to be increased or decreased to keep the utility value of the mode unchanged when the demographic or attitudinal factor of interest were to shift by unity. For example, when a person transitions to becoming a full-time employed person, then the IVTT by transit modes may be increased by 6.8 minutes for this individual to perceive no change in modal utility values. Household vehicle ownership, on the other hand, has a negative impact on transit utilization. Then, according to TABLE E-6, an additional vehicle in the household would be equivalent to an increase in travel time by bus and rail by 6.48 minutes.

Results of the IVTT equivalence computations are depicted in TABLE E-6. Access time for commute travel is not a whole lot more onerous than IVTT in Charlotte; however, access time is more onerous in the context of non-commute travel with each minute of access time equivalent to five minutes of IVTT on bus and 10 minutes of IVTT on train. Wait time is more onerous than IVTT, particularly for non-commute travel where each minute of waiting is equivalent to nearly 3 to 5 minutes of IVTT.

In terms of the cost variables, it is found that the transit fare coefficient implies an equivalent value of travel time of $5.45 per hour for commute travel and a small amount less than $1 per hour for non-commute travel. As those using transit for non-commute travel are likely to be captive riders who are in the lower income groups, their values of travel time are likely to be lower and their willingness to pay additional fare for travel time savings is likely to be modest. The transit fare value of $5.45 per hour is quite similar to the value of $4.93 per hour that was obtained in the Salt Lake City case study (for commute trips). In the Salt Lake City case study, the value of travel time implied by the auto operating cost explanatory variable was $11.40 per hour. The Charlotte modeling results provide a value that is rather similar at close to $13.00 per hour. The value of travel time for non-commute trips is, as expected, lower than that for commute trips. Unlike the Chicago case study, the value of travel time implied by the parking cost variable coefficients is more in line with the $8.50 per hour obtained in the Salt Lake City case study. Once again, values of travel time derived from the parking cost variable coefficients are higher for commute trips than for non-commute trips.

Being able to walk (rather than drive) to access rail service is equivalent to a saving of 10 minutes of IVTT on rail, suggesting that people would like the convenience of accessing rail by walk mode. This is indicative of a desire to access premium modes; the ability to access premium transit service by walk is equivalent to saving 10 minutes of IVTT on premium transit. An improvement in span of service (from a peak period-only service to an entire-day service) is valued quite highly, particularly in the context of non-commute travel, which is likely to exhibit considerable variability. As a consequence, having the assurance of all-day service provides a

TABLE E-6. Equivalent IVTT (in minutes) for various attributes of MNL model in Charlotte.

	Commute			Non-Commute		
Explanatory Variables	**Auto**	**Bus**	**Train**	**Auto**	**Bus**	**Train**
Level of Service						
Access time (min.)		0.77	1.14		5.00	10.50
Access time (min.) x Access mode (= walk)			0.68			2.50
IVTT (min.)	1.00	1.00	1.00	1.00	1.00	1.00
Wait time (min.)		1.41	1.41		3.25	4.88
Fare ($) *		5.45	5.45		0.69	0.58
Auto cost($) *	12.94			7.88		
Parking cost ($) *	18.33	6.00	10.48	7.46	3.90	3.38
Access mode (walk over drive)			10.05			
Span of service (all day v. only peak)		15.64	15.64		70.88	70.88
Reliability (% on time)†		4.59				
No transfer		10.68	10.68		18.25	18.25
Premium on-board (prem. over standard)†		4.59	4.59		22.50	22.50
IVTT (min.) x amenities		0.18	0.23			
Premium stop design (prem. over standard)		4.68	2.73		21.50	
Individual Demographics						
Full-time student		11.55	11.55			
Full-time employed		8.00				42.00
Homemaker						57.13
Retired						
Female		6.41	10.95			
Longtime resident (>5 years)			4.86			19.50
Has mobility problem					75.00	
Age less than 35 years		10.73	10.73			
Age between 35 and 55 years						
Age more than 55 years		10.36			34.13	34.13

TABLE E-6. (Continued).

	Commute			Non Commute		
Explanatory Variables	**Auto**	**Bus**	**Train**	**Auto**	**Bus**	**Train**
Household Demographics						
Number of Vehicles in HH						
Family Income (lnIncome)		10.64			37.50	
More drivers than vehicles						
Kids present						
Trip Characteristics						
Group Travel		11.41				30.13
Weekend Trip		10.64	7.59		77.50	58.13
Makes stop for groceries						30.00
Makes stop for other reasons					36.00	30.00
Latent Variables						
Very informed about Transit		21.91	12.91		69.25	69.25
Pro-Transit Attitude		14.50	14.50		53.13	54.88
Consciousness Attitude		15.55	15.55		77.63	81.00
Pro-Car Attitude		21.82	21.82		53.38	55.38
Transit Averse		2.00	2.00		18.00	18.88
Low Transit Comfort Level		14.86	14.86		59.38	62.00
Willing to walk not more than 2 min.		4.59	11.55			
Willing to walk 10 or more min.		7.68	7.68		58.50	58.50

* In the case of Fare, Auto Cost, and Parking Cost, the values are in units of $/hour of IVTT

† Variable present only in SP utility equation.

great value in the context of non-commute travel, much of which takes place in off-peak periods. Extending service beyond the peak periods to the all-day period has a more modest value for commute travel, corresponding to an IVTT savings of 15 minutes. Every additional 1% increase in on-time performance (reliability) is equivalent to savings of about 5 IVTT minutes, a value that is considerably higher than that obtained in the Salt Lake City case study but about the same as that obtained in the Chicago data set. The elimination of a transfer has an equivalent IVTT worth of about 10 minutes for commute travel and 18 minutes for non-commute travel suggesting that people are more resistant to transferring in the context of discretionary travel.

Premium service attributes including on-board amenities, stop amenities, and information systems are valued more highly in the context of discretionary non-commute travel. This is in contrast to the findings of the Chicago data set, where premium service attributes had similar equivalent IVTT value for both commute and non-commute trips. It appears that premium service attributes would make a bigger impact (and be valued more highly) in the context of non-commute trips because travelers in Charlotte are less likely to use public transit than travelers in Chicago for such trips. In Chicago, there is already a greater level of transit patronage so it appears that premium service attributes are not likely to have as much an impact in that context; people are already riding transit regardless of the presence of those premium service attributes. For commute trips, the value of the premium amenities is about 5 IVTT minutes, which is quite similar to the values obtained in the Salt Lake City case study as well.

With respect to demographic and socioeconomic characteristics, findings are generally consistent with what was found in the Chicago case study. Being a full-time student is equivalent to a drop in IVTT of about 12 minutes while that for full-time employed persons is about 8 minutes (similar to the Chicago case study). According to the MNL model estimation results, full-time employed individuals and homemakers are less likely to use rail for non-commute travel, presumably because of the inconvenience associated with using rail for such trips. It is not surprising, then, that these two demographic categories are equivalent to high values of IVTT in the context of using rail for non-commute trips. Belonging to one of these two categories is equivalent to adding in the neighborhood of 45 minutes of equivalent IVTT for non-commute trips. In Charlotte, individuals with a mobility challenge have a high IVTT equivalence for bus mode for non-commute travel. It is presumably very difficult for individuals with mobility challenges to use bus for such trips and hence the very high value of IVTT associated with this demographic (75 minutes). Younger individuals are less likely to commute by public transit in Charlotte, resulting in an IVTT equivalence of about 11 minutes. Those greater than 55 years of age are generally not inclined to use public transit modes for non-commute travel and this is reflected in a high value of IVTT equivalence (34 minutes). Individuals residing in households with higher incomes are less inclined to use the bus mode for both commute and non-commute trips; the IVTT equivalence is, however, greater for non-commute trips, largely because higher income individuals are even less inclined to use transit for such trips than for commute trips.

Overall, it appears that the analysis has yielded plausible behavioral interpretations of the equivalent IVTT corresponding to various attributes in the model, although some key differences between Chicago and Charlotte emerge particularly in the non-commute travel segment.

An Examination of Value of Time

The research team performed extensive tests to draw inferences regarding values of IVTT. After much investigation, it was found that the values of travel time obtained from a pure SP choice model were most appropriate for use in this study, in part because of the uncertainty associated with the attribute values of the non-chosen modes in the RP component of the survey. As the SP choice experiment provides exact values of service attributes for all modal alternatives, it was felt that the values of travel time inferred from a SP-only model would better reflect the distribution of this attribute across the sample. As mentioned earlier, the values of time inferred from the SP-only model were used to constrain the estimation of the joint RP-SP model systems presented earlier in this section. Essentially, these values of time constrain the ratio of the cost and time coefficients in the joint RP-SP models.

The values of time obtained from the SP-only choice models used to constrain the estimation of the joint RP-SP models presented in the prior section are shown in TABLE E-7. In Chicago and Charlotte, it is found that the VOT is higher for commute travel than for non-commute travel in both the Chicago and Charlotte case studies, a finding that is consistent with expectations and the large body of literature devoted to evaluating value of travel time. This is not the case in Salt Lake City, where the auto cost coefficient is quite low, or for the rail mode in Chicago, where both commute and non-commute travel appear to have similar values of travel time. In Charlotte, the low values of time are due to unreasonably low IVTT coefficients. In Salt Lake City, the high values of time for auto non-commute travel are due to unreasonably low cost coefficients. Otherwise, these values of time are reasonable.

TABLE E-7. VOT comparison for MNL models.

		Value of IVTT ($/hr) (std. error in parenthesis)		
		Car	Bus	Rail
Salt Lake City	**Commute**	8.50	5.90	5.90
	Non-commute	20.00	7.48	7.48
Chicago	**Commute**	7.09	2.98	2.98
	Non-commute	5.52	2.29	3.64
Charlotte	**Commute**	13.04	5.50	5.50
	Non-commute	7.67	0.68	0.57

APPENDIX F

Awareness and Consideration Models

Contents

Awareness and consideration of different modes of transportation are key determinants of the choice set generation process. In general, it may be assumed that an alternative is included in the feasible mode choice set only if an individual is aware of the travel mode and actually considers it as a possible option for undertaking a trip. Even if a person is aware of a mode, he or she may choose to not consider it, thus eliminating it from the choice set. If a person is not aware of a travel mode to begin with, then it is automatically not considered and not part of the feasible choice set. As described earlier, the project team formulated a two-step model system where the choice set is formed first by combining a modal awareness model with a modal consideration model.

One novel aspect of the work in this project is the development of a choice set generation model for awareness and consideration combined with a discrete choice model for mode choice (as opposed to a pure discrete choice model that does not account for choice set generation). There is a rich body of literature devoted to this topic, virtually all of which has shown and stated that the combination of a choice set generation model and discrete choice model is superior to a pure discrete choice model that assumes constant choice set for all observations (Castro et al. 2011). In much of the research to date, a latent choice set generation approach was necessary because data on awareness and consideration of alternatives were not available. However, in this project, explicit data about awareness and consideration were collected, thus eliminating the need to adopt a latent choice set generation model and allowing for the development of an observed choice set generation model. Findings in the literature, and in this project, show that a model system that combines a choice set generation model with a mode choice model provides greater insights and forecasting accuracy than a model that ignores choice set formation. A model that accounts for mode choice awareness and consideration provides key information to the analyst about the context, person attributes, household attributes, trip attributes, and modal attributes that contribute to a person being aware of a certain mode and then actually considering it for the trip in question. The choice awareness and consideration model provides information on potential policies, strategies, and modal service attributes that can enhance the probability that an individual would become aware of the mode and consider it. By accounting for heterogeneity in choice set composition that is prevalent in the population, the model system is better able to replicate mode awareness, consideration, and choice processes and provides greater levels of accuracy in prediction. The approach adopted in this study is motivated by the evidence in the literature that clearly points to the superior performance of choice model systems that account for awareness and consideration of choice alternatives (choice set generation and composition processes).

Awareness and consideration models rely on variables that are also used in mode choice models, so a joint model of awareness, consideration and mode would be ideal. This would provide an opportunity to test on variables in the models. There are, however, practical constraints to jointly estimating models of awareness, consideration and mode that are addressed in Appendix H.

Joint Bivariate Binary Probit Model Formulations

Awareness and consideration are handled using choice set models as part of a two-step decision process. An individual who has a car available to make the trip is assumed to be aware of the option and always considers it in the choice set. Consequently, the car option enters the choice set in a deterministic way. The complete choice set for each individual q is formed as a result of awareness and consideration of the transit options (bus and rail). The following utility expression for an individual's awareness is considered:

$$Y_{qi} = \gamma_i w_{qi} + \zeta_{qi}, i \in \{Bus, Rail\} \quad (1)$$

In this equation, w_{qi} represents all the factors that affect the individual's awareness of the transit alternative i. Without loss of generality, it can be assumed that the person is aware of the transit alternative if the utility is greater than zero. The parameter to be estimated, γ_i, includes a constant. Due to common unobserved factors that could affect the awareness of different transit options, the error term ε_{qi} is allowed to be correlated across transit alternatives.

$$Corr(\zeta_{q,bus}, \zeta_{q,rail}) = \rho_a, \ \zeta_{qi} \sim N(0,1) \quad (2)$$

If it is assumed that the error term ζ_{qi} is standard normally distributed, a joint bivariate binary probit model is obtained. The only additional issue to be incorporated is that the choice set for an individual must not be a null set, so individuals without a car must be aware of at least one of the two transit alternatives. The following terms are introduced to aid in the writing of the likelihood expression:

$$\text{Let } a_{qi} = \begin{cases} 1 \text{ if } Y_{qi} > 0 \\ 0 \text{ if } Y_{qi} \le 0 \end{cases} \text{ and } d_q = \begin{cases} 1 \text{ if Car available} \\ 0 \text{ if Car not available} \end{cases}$$

With these notations, the following expression serves as the likelihood of the observed awareness of all alternatives:

$$L_{aq} = \frac{\Phi_2\left((2a_{bus}-1)\gamma_{bus} w_{q,bus}, (2a_{rail}-1)\gamma_{rail} w_{q,rail}, (2a_{bus}-1)(2a_{rail}-1)\rho_a\right)}{1-\left(1-d_q\right)\Phi_2\left(-\gamma_{bus} w_{q,bus}, -\gamma_{rail} w_{q,rail}, \rho_a\right)} \quad (3)$$

In the above equation, $\Phi_2(\cdot)$ is the bivariate normal cumulative density function and the expression in the denominator is to ensure that the probabilities of all valid non-null awareness sets add up to 1 for individuals not having a car.

Consideration comes in the second stage of the choice set formation step. Even if a person is aware of a transit alternative, it may or may not be considered an option for a specific trip. Consideration is modeled using a utility expression similar to that used for awareness:

$$Z_{qi} = \delta_i u_{qi} + \xi_{qi}, i \in \{Bus, Rail\} \tag{4}$$

Here u_{qi} represents variables that affect the consideration decision of the individual q about transit alternative i. Again it is assumed that the person considers the transit alternative if the utility Z_{qi} is greater than zero. The parameter to be estimated δ_i includes a constant. It is assumed that the error terms are independent and identically distributed (i.i.d.) standard normally distributed and the formulation allows the error terms to be correlated across alternatives:

$$Corr(\xi_{q,bus}, \xi_{q,rail}) = \rho_c, \xi_{qi} \sim N(0,1) \tag{5}$$

The consideration indicator is defined based on the utility equation (4) as follows:

$$c_{qi} = \begin{cases} 1 \text{ if } Z_{qi} > 0 \\ 0 \text{ if } Z_{qi} \leq 0 \end{cases}$$

With these notations, the following serves as the likelihood of the observed consideration set of all the alternatives:

$$L_{cq} = \frac{\Phi_2\left((2c_{bus}-1)\delta_{bus}u_{q,bus}, (2c_{rail}-1)\delta_{rail}u_{q,rail}, (2c_{bus}-1)(2c_{rail}-1)\rho_c\right)}{1-\left(1-d_q\right)\Phi_2\left(-\delta_{bus}u_{q,bus}, -\gamma_{rail}u_{q,rail}, \rho_c\right)} \tag{6}$$

The above likelihood expressions for awareness and consideration are quite straight forward and the parameters can be estimated by the maximum likelihood method. It must be noted that not all observations can be used in the estimation because some observations provide no information on awareness and consideration. An individual can be aware of a transit option only if that particular option is available (or feasible). Similarly, an alternative can be considered only if the individual is aware of that particular alternative. This implies that the following two categories of observations will not provide any information in the estimation of the awareness model: (1) both bus and train are not available (2) car is not available and only one of the transit options is available. It should be noted that there may be instances where the car is not considered by a trip maker even when it is available. Although this is a distinct possibility, there is insufficient information in the survey data set to help establish criteria or develop a model of auto mode consideration. As such, within this study, a deterministic approach was taken with respect to auto consideration. If the auto mode is available, then it is assumed that the trip maker is aware of it and considers it (thus it is included in the awareness set and the consideration set). As the focus of this study is on understanding awareness and consideration of bus and rail modes, this simplification for the determination of auto mode consideration was done.

Transit Awareness and Consideration Analysis

The awareness and consideration analysis conducted in Salt Lake City was designed primarily to support development of awareness and consideration models for Chicago and Charlotte. This provided key information to support the need for these models and the design of surveys to collect awareness and consideration of transit models. There were key findings from the analysis of the revealed preference survey for awareness as follows:

- Travelers appear to be aware of the existence of some form of transit within walking distance of their homes. This understanding is highest among travelers from 0-car households who presumably need to know more about the transit system than travelers from households with cars.
- Trip-makers are less aware of the full range of all transit sub-mode options within walking distance that are available in their neighborhood. This phenomenon is most pronounced for low income travelers who are less aware of the range of travel options than the population as a whole.
- Opportunities to drive to transit are less-well understood by survey respondents than their walk access options. This may be a result of the fact that drive access distances are much greater than walk access distances and therefore park-and-ride facilities are located outside of traveler's normal sphere of activity.

There were also key findings for availability of modal alternatives from this analysis:

- Survey respondents report many fewer modal options as being available for a commonly-made trip than does the travel forecasting model. Transit customers, are particularly likely to report no option or only one option suggesting that they are more likely to be either transit captives or that alternative transit sub-modes are not considered to be viable options.
- The high proportion of travelers stating that no option exists to their current mode describes a situation in which many travelers perceive themselves to be dependent on their current mode. This is most true for transit users but also exists for automobile users.
- A typical approach for representing transit dependency is membership in a 0-car household. Survey responses suggest that transit dependency may be more nuanced. For instance a large number of transit travelers from households with 2 or more automobiles stated that they had no transit options while other travelers from 0-car households made trips by automobile.

These results provided insights to design questions for the awareness and consideration portion of the survey to support model estimation.

Transit Awareness and Consideration Models

There is very limited work, in the literature on understanding factors that affect awareness and consideration of alternative modes of transportation. In this study, an attempt was made to test the significance of a number of different attributes with respect to their influence on the awareness and consideration of alternative transit modes. Besides the usual socio-economic and demographic attributes that are known to influence mode usage patterns (age, income, employment status), the study considered a few additional categories of attributes as possibly explanatory entities.

The survey asked respondents to provide information on awareness and consideration of transit modes for a reference trip. The characteristics of the trip itself may influence how people view alternative transit modes. A variety of hypotheses may be constructed in this context. An individual may be more aware of transit options on weekdays than on weekends. An individual may be more likely to consider transit options for commute travel than for non-commute travel. The regularity of the commute trip, the likelihood that transit service is competitive during the peak commute hours, and auto costs (e.g., parking costs) may motivate an individual to consider transit for commute travel more than for non-commute travel. Party size (number of people traveling together on the trip) is another trip attribute that may influence modal consideration. The survey results reported in Appendix C showed that party size tends to be smaller for transit trips, particularly in Charlotte. The difference in party size distribution is less pronounced in the Chicago data set. In Charlotte, it may be the case that travelers are less likely to consider transit alternatives when undertaking joint travel.

This study attempts to explicitly account for attitudes, perceptions, and values in modeling transit awareness and consideration. The results of the factor analysis described in the previous section demonstrate the strong correlation between attitudinal factors and mode choice. If attitudinal factors are strongly correlated with mode choice, then one would expect the factors to be also strongly correlated with modal awareness and consideration (because choice is inextricably linked to awareness and consideration). The models in this study consider attitudinal factors as possible explanatory variables to account for these attitudes, perceptions, and values that are traditionally unmeasured, unobserved, and relegated to being absorbed in the random error term.

A key question that merits consideration is the extent to which modal level of service variables should enter the awareness and consideration model specifications. It may be hypothesized that people are more aware of and would give greater consideration to transit modes when transit level of service is greater, more competitive with the auto, and of high quality. In the current study, transit awareness and consideration is modeled whenever transit is available (as determined by the presence of a valid skim value). While it is certainly possible to include transit level of service attributes and measures of competitiveness in the model specification for transit awareness and consideration, such variables are not included in the model specifications presented in this report. The inclusion of such variables in models of awareness and consideration may be fruitful directions for future research, with due consideration given to the ramifications of including such level of service attributes in *both* models of awareness and consideration *and* mode choice. As noted in the survey results (Appendix C), it is found that a large percent of individuals who did not consider transit options in the revealed preference portion of the survey actually chose a transit option in the stated preference portion of the survey. This is not unexpected in any way as one would expect individuals to choose transit options when information about their service attributes is presented in a clear way vis-à-vis service attributes of the auto mode. In a stated preference survey design, transit service attributes are designed such that the transit alternatives are competitive against the auto mode thus facilitating the determination of trade-offs in attributes during choice processes. While this suggests that transit competitiveness is important in the "choice" process, it does not necessarily imply that transit service competitiveness is important in the "awareness and consideration" process. Again, the research team believes that this notion needs to be tested in future research by explicitly including transit competitiveness measures and service attributes in models of awareness and consideration.

In this study, the team has taken a more simplified approach where the awareness and consideration models include the extent to which a person is "informed" about transit as an explanatory variable. In the stated preference survey, respondents are being "informed" about the presence of transit service alternatives and the levels of attributes associated with service variables. In essence, the formulation in this study assumes that individuals may become aware and consider a mode of transport when they have information about the modal alternative. As a first attempt at developing a modal awareness and consideration model, the study includes the extent to which a person is informed about transit as an explanatory variable. In FIGURE C-9 of Appendix C, it is readily apparent that this is an important explanatory variable influencing transit usage. If an individual is very well informed about a modal option, then he or she is likely to be aware of it and consider it.

Given the objective of this TCRP project, it is possible to make the case that primary interest lays in traveler awareness and consideration of, and therefore choice between, premium and non-premium modes of transport – as opposed to the traditional modal designations of "bus" and "rail". The study team recognizes that there is considerable interest in understanding the value that travelers place on premium mode attributes and how this translates into awareness, consideration, and choice. Although it is theoretically possible to replace the term "bus" with "non-premium mode" and "rail" with "premium mode" in this study, it is not practically feasible to do so. The entire survey instrument that was presented to survey respondents labeled the modal options as bus and rail, and it is therefore important to label the choice set elements in the same way that the options were presented to respondents. It is likely that there is a strong correlation between modal labels and the premium label, but travelers are generally more familiar with thinking of modes using the traditional labels of bus and rail. As such, the choice modeling effort of this study treats modal options as bus and rail, with the idea that the value placed on premium attributes can be inferred – to a strong degree – from the awareness, consideration, and choice models.

Awareness Models for Chicago and Charlotte

TABLE F-1 presents estimation results for the joint bivariate probit awareness models for both Chicago and Charlotte. Utility functions are estimated for both transit modes – bus and rail – in the two geographical contexts, and the error terms of the modal utility equations are allowed to be correlated with another. Thus, if there are unobserved factors that affect the awareness of both bus and rail in a particular city, then the model is able to account for the presence of such common unobserved factors. As noted previously, the inclusion of auto mode choice in the choice set is based on a deterministic rule and hence the awareness models apply only to transit modes. Some interpretations of the results is provided below but should not be interpreted as conclusions.

TABLE F-1. Awareness models.

Explanatory Variable	Chicago		Charlotte	
	Bus	Rail	Bus	Rail
Alternative specific constant	0.124 (1.1)	0.415 (2.1)	3.745 (5.6)	0.202 (1.4)
Individual Demographics				
Full-time student	-0.501 (-2.2)			
Full-time employed		0.298 (2.3)	0.379 (2.8)	
Retired			-0.535 (-2.0)	
Female		-0.365 (-2.8)		
Longtime resident (> 5 years)	-0.339 (-2.7)	-0.241 (-1.7)	0.226 (2.0)	
Has mobility problem		0.448 (2.1)		
Household Demographics				
Family income (Income in $ per year).			-0.351 (-5.7)	
More drivers than vehicles	0.757 (1.5)			
Kids present in household			0.197 (1.3)	
Trip characteristics				
Weekend trip		0.332 (1.6)	-0.534 (-3.3)	1.045 (4.2)
Traveler Attitudes and Latent Variables				
Pro-transit attitude	0.456 (5.3)	0.785 (8.1)	0.180 (2.3)	
Consciousness	0.189 (2.4)		0.220 (3.1)	
Pro-car attitude		-0.221 (-2.5)	-0.226 (-3.1)	

TABLE F-1. (Continued).

Explanatory Variable	Chicago		Charlotte	
	Bus	Rail	Bus	Rail
Low transit comfort level			-0.276 (-3.1)	-0.486 (-3.9)
Willing to walk not more than 2 minutes		-0.317 (-1.3)		-0.739 (-2.6)
Willing to walk 10 or more minutes		0.674 (4.6)		0.319 (1.8)
Very informed about transit	0.367 (2.3)		0.665 (3.9)	0.374 (1.7)
Error Correlation				
rho	0.288 (2.7)		0.178 (1.3)	
Model Fit Statistics				
Log-likelihood (final)	-543.6		-518.3	
Log-likelihood (constants)	-683.9		-630.1	
Pseudo rho-squared	0.205		0.177	
Number of observations	801		748	

There are interesting differences in the awareness model estimation results between Chicago and Charlotte. The alternative specific constant for bus mode is statistically insignificant in the awareness model of Chicago, but statistically significant in the corresponding model of Charlotte. On the other hand, for the rail mode, it is found that the alternative specific constant in Chicago's model is statistically significant but that in the Charlotte model is statistically insignificant. This suggests that there is an overall propensity for respondents in Chicago to be aware of the rail mode (relative to bus) while there is an overall propensity for respondents in Charlotte to be aware of the bus mode (relative to rail). This is presumably due to the more extensive rail network in the Chicago area, and hence respondents are likely to be more aware of the rail mode. On the other hand, Charlotte has very limited rail service, and as a consequence, travelers are more likely to be aware of bus service that has greater coverage and presence in the area. This broad finding is consistent with the finding that 70 percent of Charlotte survey respondents had no rail service available, while the corresponding percentage for Chicago is just over 50 percent. In Charlotte, less than 50 percent of respondents had no bus service available (as evidenced by the absence of a skim value) – which is considerably less than the percent that had no rail service available. In Chicago, about 50 percent of respondents have no bus service available – which is almost identical to the percent of respondents who have no rail service available.

With respect to individual demographics, it is found that several variables influence the awareness of bus and rail modes. Full-time students, perhaps due to their transient nature, are less likely to be aware of bus services in Chicago (relative to rail service, which tends to be more visible). This finding is not seen in Charlotte, presumably because rail service is quite limited. On the other hand, full-time employed individuals are more likely to be aware of rail service in Chicago; in Charlotte, full-time employed individuals are more likely to be aware of bus services. In other words, regular commuters are likely to be aware of the more prevalent transit services in their respective geographic areas – that would be rail in Chicago and bus in Charlotte.

In Chicago, females are less likely to be aware of rail service possibly because there is a lower prevalence of full-time commuters among them and because females continue to be more auto-dependent as they carry a greater share of household obligations and serve-passenger/child trips. A longtime resident (more than 5 years) is less likely to be aware of both bus and rail services in the Chicago sample; however, between the two transit modes, it is found that longtime residents are less aware of bus relative to rail (as evidenced by the larger negative coefficient in bus awareness model), suggesting that rail is more visible in a rail rich market such as Chicago. In Charlotte, on the other hand, longtime residents are more likely to be familiar with the bus service as evidenced by the positive coefficient on that variable in the bus awareness model. Essentially, longtime residents are more aware of rail in Chicago (relative to bus) and more aware of bus (relative to rail) in Charlotte, once again pointing to greater awareness of the more visible transit mode in the respective contexts. Individuals with a mobility problem are more likely to be aware of rail service in Chicago, presumably because the rail service in Chicago accommodates the needs of mobility-challenged persons and provides greater geographical coverage.

With respect to household demographics, persons in households with higher income are less likely to be aware of bus services in Charlotte. Such income-based differences are not observed in Chicago; this is not unexpected given the transit-rich market that is Chicago. In a transit market such as Charlotte, higher income individuals are not likely to use – and therefore familiarize themselves with – bus service (which likely caters to more transit-captive lower income riders). Respondents in vehicle-deficit households (where the number of drivers exceeds the number of vehicles) show a greater level of bus awareness in the Chicago sample. This is presumably because these individuals are more transit-captive and more dependent on bus services. This variable does not differentially affect awareness of bus and rail in Charlotte. This is not to say that the variable has no impact on awareness of bus and rail; the absence of the variable in the utility equations simply indicates that the variable has no differential effect on awareness of bus versus rail in Charlotte. It appears that respondents in vehicle-deficient households in Charlotte are likely to be equally aware of bus and rail services.

The only trip characteristic that is found to significantly impact modal awareness is the indicator corresponding to a weekend trip. For weekend trips, it appears that Chicago respondents are more aware of rail service. In the Charlotte area too, respondents exhibit a greater level of awareness of rail for weekend trips and a lower level of awareness for bus service. Attitudinal variables and factors are found to be quite important in shaping the awareness of transit modes among individuals. Those with a higher pro-transit attitude are more likely to be aware of bus and rail services in Chicago and more likely to be aware of bus service in Charlotte; this finding is consistent with the exploratory analysis of the relationship between factor scores and mode choice presented in the previous section of the report. It is likely that the rail mode awareness is not significantly affected by this attitudinal factor in the Charlotte model because of the limited rail service in the region. Those with a higher level of consciousness demonstrate a greater proclivity to be aware of bus services in both Chicago and Charlotte (over rail services), presumably due to their predisposition towards being aware of transit alternatives that are environmentally friendly and allow them to be productive while traveling. It is true that the same argument applies to rail mode as well, but there appears to be a differential in the awareness of bus versus rail depending on level of consciousness. Pro-transit people are likely to be more aware of both bus and rail services (relative to non pro-transit people); being "conscious" adds an additional awareness level in the context of the bus mode – a mode that traditionally does not necessarily garner the same attention as rail.

Those with a pro-car attitude are expected to be less aware of transit services. The estimation results are consistent with this expectation, although there is a differential impact on the awareness of bus versus rail in each city. Those with a pro-car attitude are less likely to be aware of rail services in Chicago, and less aware of bus services in Charlotte. In other words, it appears that the pro-car factor is more negatively associated with awareness of the more visible or prevalent transit service in each region. It is likely that those with such a pro-car attitude in Chicago live in the outlying suburbs not served well by rail. Such a residential self-selection pattern is not likely to be prevalent in Charlotte where pro-car folks are likely to be more uniformly spread throughout the region. Isolating these residential self-selection effects is a challenge that should be addressed in future research endeavors. As expected, the transit aversion factor is not significant in any of the models and this finding is consistent with the rather weak trends seen in the exploratory descriptive statistics and charts (presented in the previous section) for this particular variable. Those who consider it difficult to access transit and have a generally lower level of comfort with transit usage do not show any specific tendencies in the Chicago model, but show a clear tendency to be less aware of both bus and rail services in the Charlotte sample. It appears that those with this attitude are not necessarily less aware of the transit services in Chicago (transit services in Chicago are quite noticeable and one would have to be aware of them to develop a comfort or discomfort level and make a judgment regarding ease of access), but rather less likely to just use the mode of transport. Charlotte is a less transit-rich market and therefore lower levels of awareness are likely to be associated with an attitudinal factor that represents low transit comfort level.

Those with a low tolerance to walking are less likely to be aware of rail services, while those with a high tolerance for walking time are more likely to be aware of rail services. It is likely that accessing rail stations generally tends to be more demanding than accessing bus stops, and as a result, walking time sensitivity more significantly impacts awareness of rail service as opposed to awareness of bus service. Those who are willing to walk not more than two minutes to access transit are less likely to be aware of rail services that generally demand a greater level of walking. On the other hand, those willing to walk more than 10 minutes are more likely to be aware of rail services as they seek out and are willing to endure more effort in availing of a premium service mode. Finally, those very informed about transit services are more likely to be aware of bus services relative to rail services. This finding is consistent with expectations. In general, as rail services tend to be more visible, it is not necessary for individuals to be "very informed about transit" to be aware of rail services. However, there is a difference when it comes to bus service. In the case of bus services (that are not so visible), if a person is not "very informed about transit", then the likelihood of being aware of bus services is lower than that for rail services. When a person is very informed about transit services, the difference is likely to manifest itself in the bus arena.

The error correlation between the transit utility functions is statistically significant for the Chicago area suggesting that there are correlated unobserved factors affecting awareness of these two modes in Chicago. On the other hand, the measure is statistically insignificant in the Charlotte context, possibly due to the lower level of complexity (and hence unobserved factors) associated with explaining modal awareness in a context where rail service is dwarfed by the bus system.

Consideration Model Results for Chicago and Charlotte

TABLE F-2 presents estimation results for the consideration models for both Chicago and Charlotte. Utility functions are estimated for both transit modes – bus and rail – in the two geographical contexts, and the error terms of the modal utility equations are allowed to be correlated with one another. Thus, if there are unobserved factors that affect the consideration of both bus and rail in a particular city, then the model is able to account for the presence of such common unobserved factors. As noted previously, the inclusion of auto mode choice in the choice set is based on a deterministic rule and hence the consideration models apply only to transit modes. Some interpretations of the results are provided below but should not be interpreted as conclusions.

The set of consideration models for the two city samples also provides plausible behavioral indications. Consideration is generally a step that follows the awareness stage. Once an individual is aware of a certain mode of transport, the question is whether the individual will actually consider using the mode for the particular trip in question. The alternative specific constants show a clear differential between rail and bus; the alternative specific constants (in the consideration utility equations) are higher for rail than for bus. This finding suggests that, all else being equal, individuals are more likely to consider rail over bus. This finding is consistent with the statistics reported in Appendix C where it is found that the ratio of "the number of individuals who consider rail to the number of individuals who do not consider rail" is consistently greater than the ratio of "the number of individuals who consider bus to the number of individuals who do not consider bus".

Among individual demographic attribute effects, homemakers are less likely to consider bus than rail (in Chicago), presumably because bus is not a convenient mode for taking care of household obligations and serve child trips. In Charlotte, there is no differential consideration effect between bus and rail – presumably homemakers give (or do not give) equal levels of consideration to bus and rail. Long-time residents are less likely to consider bus (relative to rail), presumably because the bus mode is not viewed in the same vein as the (more premium) rail mode (this is also seen in Appendix C). This finding is consistent across both data sets. Those with mobility problems are more likely to consider bus mode of travel, presumably because the bus mode is easier to access. Accessing rail service may entail longer access distances and times which may be inconvenient for those with mobility challenges. As such, even though there may be instances where mobility-challenged persons are more likely to be aware of rail service (as in Chicago), the fact is that they are more likely to consider bus services due to the reality of their mobility-challenged situation. Those aged less than 35 years are more likely to consider rail in Chicago (relative to bus); no such differential is seen in Charlotte suggesting that the greater prevalence of rail in Chicago makes a difference in its consideration level for this demographic.

TABLE F-2. Consideration models.

Explanatory Variable	Chicago		Charlotte	
	Bus	Rail	Bus	Rail
Constant	0.018 (0.3)	0.767 (5.9)	0.779 (4.2)	1.021 (5.0)
Individual Demographics				
Homemaker	-0.774 (-2.0)			
Female			0.296 (1.9)	
Longtime resident (> 5 years)	-0.483 (-2.8)		-0.493 (-3.2)	
Has mobility problem	0.405 (1.4)		0.748 (1.8)	
Age less than 35 years		0.428 (2.1)		
Trip Characteristics				
Group travel				0.737 (5.8)
Weekend trip				0.988 (2.2)
Makes stop for groceries		-0.407 (-2.7)		
Makes stop for other reasons	0.349 (2.0)	-0.407 (-2.7)		
Non-commute trip	0.374 (1.8)		-0.668 (-3.7)	
Traveler Attitudes and Latent Variables				
Pro-transit attitude	0.499 (4.1)	0.503 (4.4)	0.567 (5.2)	
Consciousness savings	0.434 (4.0)	0.229 (2.3)	0.154 (1.6)	
Pro-car attitude	-0.312 (-2.5)	-0.242 (-2.2)		-0.155 (-1.0)
Transit averse				

TABLE F-2. (Continued).

Explanatory Variable	Chicago		Charlotte	
	Bus	Rail	Bus	Rail
Low transit comfort level			-0.316 (-2.8)	-0.318 (-1.7)
Willing to walk not more than 2 minutes				-0.679 (-1.7)
Willing to walk 10 or more minutes	0.609 (3.5)	0.706 (5.1)	0.356 (2.1)	0.443 (1.6)
Very informed about transit		0.301 (1.3)		
Error Correlation				
Rho	0.798 (12.1)		0.737 (5.8)	
Model Fit Statistics				
Log-likelihood (final)	-265.6		-236.8	
Log-likelihood (constants)	-341.0		-287.0	
Pseudo rho-squared	0.221		0.175	
Number of observations	584		550	

It is interesting to note that there are no household demographics that significantly impact the consideration of transit alternatives. It appears that individuals are largely indifferent to household influences when it comes to considering different modes of transportation. Rather, it is their own demographic and attitudinal characteristics, and the characteristics of the trip they are undertaking, that influence consideration of transit alternatives. Group travel is positively associated with consideration of rail in Charlotte (relative to bus), while no such differential impacts are seen in Chicago. It appears that individuals in Chicago consider bus and rail as equally conducive (or not conducive) to group travel, while those in Charlotte view rail as being more conducive to accommodating group travel. Charlotte respondents are more likely to consider rail for weekend trips (relative to bus); further research is warranted to fully explore the context of weekend travel that may explain this differential in consideration between the transit modes. Making a stop for groceries or other reasons generally reduces consideration of rail alternatives in the Chicago context, possibly because of the difficulty associated with accomplishing multi-stop trip chains using rail. Making a stop for other reasons positively impacts consideration of bus in the Chicago context. Similarly, if the trip is a non-commute trip, then there is a greater likelihood of consideration of the bus alternative in the Chicago context. It appears that bus is viewed as a fairly flexible and accessible mode of transport in the Chicago context and hence the greater level of consideration of this mode for multi-stop journeys or non-commute trips. On the other hand, Charlotte respondents are less likely to consider the bus mode for non-commute trips, a finding consistent with expectations in light of the lower levels of transit service (both bus and rail) in the Charlotte area when compared with Chicago.

It is found that attitudinal factors play a key role in shaping consideration of transit modes. Those with a pro-transit attitude are more likely to consider transit alternatives and this finding is consistent across both geographical contexts. In Chicago, the magnitudes of coefficients in the consideration model associated with this factor are virtually identical suggesting that there is no differential impact of this factor in consideration of bus or rail. In Charlotte, however, pro-transit attitudes are associated with greater consideration of bus travel mode. This is consistent with expectations; given the limited rail service, it is likely that pro-transit attitudes make a differential impact on bus mode consideration. Those who are conscious of the environment and value productivity are found to give greater consideration to the bus mode relative to the rail mode (in both Chicago and Charlotte). Once again, it appears that this attitudinal factor has a net additional impact on bus consideration (similar to awareness) over and above the pro-transit attitude.

Those with a pro-car attitude are less likely to consider transit alternatives, particularly in Chicago. It is found that the coefficient associated with rail is less negative than that for bus, suggesting that pro-car individuals are less likely to consider bus relative to rail. In Charlotte, there is no appreciable difference in the consideration of bus versus rail modes as a function of this particular factor. As shown in the previous chapter, the respondents in Charlotte are more auto-centric in general (in their mode usage patterns); this implies that Charlotte respondents are less likely to consider transit alternatives in general, and being pro-car does not have a differential impact between the two transit modes. While the transit aversion factor is not found to affect transit mode consideration, the factor representing a low level of comfort with accessing and using transit is found to significantly impact transit mode consideration in the Charlotte case study. In Charlotte, it is found that a low level of comfort with transit negatively impacts consideration of both transit modes (to a similar degree). However, no such statistically significant indications are found in the Chicago case study suggesting that this factor does not have an additional net impact over and above other attitudinal factors (for Chicago).

Consistent with the sparse rail service in Charlotte, those not willing to walk more than two minutes are less likely to consider rail service in that city (relative to bus). On the other hand, those willing to walk more than 10 minutes are more likely to consider bus and rail for their trip in both cities, with the rail consideration consistently higher than the bus consideration. This finding is consistent with expectations as those willing to walk further distances are more likely to consider rail alternatives (due to the desire to access premium mode). Those who are very informed of transit are not necessarily likely to show a different transit mode consideration pattern than those who are not very informed of transit. Perhaps transit information campaigns affect awareness, but do little to affect consideration. Rather it is the individual characteristics, attitudinal factors, and trip characteristics that are more likely to determine consideration of a transit mode alternative. There is a weak positive impact (not statistically significant at the 95 percent confidence level) of being informed about transit on rail consideration in the Chicago context.

The error correlation between the two transit utility functions in the consideration model is statistically significant in both cities. This suggests that there are significant common unobserved factors that affect the consideration of both rail and bus. Further research is needed to explore what these common unobserved factors may be and how best they can be accounted for in model specifications that purport to predict consideration choice sets for individuals. An example of a common unobserved factor may, for example, be fuel price. Spikes in fuel costs may suddenly spur a die-hard single-occupant vehicle mode user to potentially consider transit alternatives. The individual may look into the possibility of using either bus or rail services, thus potentially influencing the presence of both transit alternatives in the consideration set. In other words, a common unobserved factor (fuel price/cost, which is not included as an explanatory variable in the consideration model) may affect the consideration of *both* bus and rail alternatives. A rise in fuel price would presumably lead to greater consideration of *both* bus and rail alternatives. As a result of this common unobserved factor having the same directional influence (positive) on *both* bus and rail mode consideration, the consideration model error correlation is positive. This is but one example of a common unobserved factor and there may be several other common unobserved factors that influence consideration of transit modes. In the future, it should be possible to enhance model specifications to explicitly include transit competitiveness, auto operating costs, transit service attributes, and other supply measures in the model specifications to better account for such attributes on awareness and consideration. The testing of such enhanced specifications remains a future research exercise.

Summary of Awareness and Consideration Models

One primary question for the awareness and consideration models is whether the mode choice with and without these constraints on awareness and consideration are substantially better than with these constraints. During the development of these models, a test was performed to estimate mode choice models with and without the awareness and consideration models. These tests showed that the model estimation statistics were improved when awareness and consideration models constrained the choice sets for mode choice:

- In Chicago, the rho-squared was 0.712 and 0.782 for commute trips and non-commute trips, respectively, with awareness and consideration models to constrain the choice set and was 0.556 and 0.752 without these constraints.
- In Charlotte, the rho-squared was 1.408 and 1.027 for commute trips and non-commute trips, respectively, with awareness and consideration models to constrain the choice set and was 0.686 and 1.241 without these constraints.

For rho-squared, all but the non-commuters in Charlotte were improved with the awareness and consideration models. The log-likelihood statistics improved across all segments for both cities. These statistics support the hypothesis that the awareness and consideration models contribute to improving mode choice models.

APPENDIX G

Factor Analysis for Traveler Attitudes

Contents

Overview

The survey that was administered to respondents in Chicago and Charlotte included numerous attitudinal questions that were aimed at obtaining information about how travelers viewed or valued different modes of transportation and the amenities/services that they provide. In addition to socioeconomic and demographic variables, as well as a host of service attributes, it is possible that attitudinal variables also play an important role in shaping traveler choices and preferences. Including attitudinal variables as explanatory variables can help enhance the goodness-of-fit of choice models and improve the sensitivity of such models to changes in exogenous conditions. The effects of these variables are traditionally captured in the random error components of the utility equations of choice models; in this particular study, the effects of these variables are explicitly represented—thus separating them from other random behavioral effects embedded in the random error term.

The survey included a rather large number of attitudinal questions, some of which addressed similar issues or items of interest in the attitudinal spectrum. As some of the attitudinal responses may be correlated with one another, it may not be prudent to include a multitude of variables as explanatory variables in the model given the potential presence of multicollinearity that may lead to erroneous coefficient estimates. However, omitting some attitudinal variables while including others may contribute to an ineffective utilization of all of the information contained in the attitudinal variables. In order to address these dual concerns, analysts often employ a statistical technique called *factor analysis.* Factor analysis is a method by which many different variables, correlated with one another to different degrees, may be reduced to a set of manageable factors that are orthogonal (not correlated) to one another. Each factor is a linear combination of several highly correlated variables that address a similar dimension or aspect of behavior or attitudes. In factor analysis, variables are combined into factors such that the distance between variables within each factor is minimized and the distance between factors is maximized. The factors, which presumably capture the multitude of dimensions represented by the attitudinal variables, may then be included as explanatory variables in the choice model specification. Because the factors are orthogonal to one another, no multicollinearity problem needs to be addressed, and because the factors capture all of the different attitudinal variables within them, information contained in the attitudinal variables is utilized effectively.

The survey that was administered in Salt Lake City had fewer attitudinal questions, and respondents were identified as either transit or non-transit users. Respondents were put under the category of transit users if they had used public transit at least once in the past year. The analysis was done using SPSS, and principal axis factoring was used to extract the initial set of factors. A frequently used orthogonal rotation procedure—varimax (Abdi 2003) - was applied to better interpret the extracted factors. Factor scores were then computed for each respondent using regression and were used as explanatory variables in the logit model estimation (explained in the next section).

One of the challenges with using factor analysis for traveler attitudes is that factors are difficult to forecast, and a separate model is required to prepare attitudinal factors in the future. The integrated choice and latent variable models provide an opportunity to estimate traveler attitudes as a function of socioeconomic variables within mode choice where the multinomial logit models require that traveler attitudes be developed outside the mode choice models. This allows us to forecast these attitudes within the mode choice model rather than developing a separate model. These models are discussed in Appendix H.

Salt Lake City Analysis

Opinions of Transit Users

For individuals that used transit in the last year, responses to statements listed under Factor 1 were scored to respondents and responses to statements listed under Factor 2 were also scored to respondents. These factors and respondents' scores were analyzed and seemed generally to make sense. These factors were cross-tabulated with choices made in the stated preference experiments to understand how individual attitudes about transit or auto correlate with stated mode preferences in the SP experiments.

FIGURE G-1 shows the variation of the percentages falling in each category with the actual responses to the level of agreement with the statement, "I currently make an effort to take public transit whenever I can." The more the respondents agree with this statement, the more the proportions of higher factors score among them. It appears that a stronger agreement with this statement positively influences the inclination factor score. The inclination factor was also found to increase with the increase in agreement to transit fares being easy to purchase and for respondents who are aware of the transit schedule.

The inclination factor is not highly correlated with mode choices made in the stated preference experiments, which may suggest that the variables considered in the factors don't factor heavily into mode choice decisions. The mode shares for different inclination factors are also summarized in FIGURE G-1.

The relationship of service factor scores to the responses is less uniform in case of willingness to use transit frequently (FIGURE G-2). In this case, there is about an even split

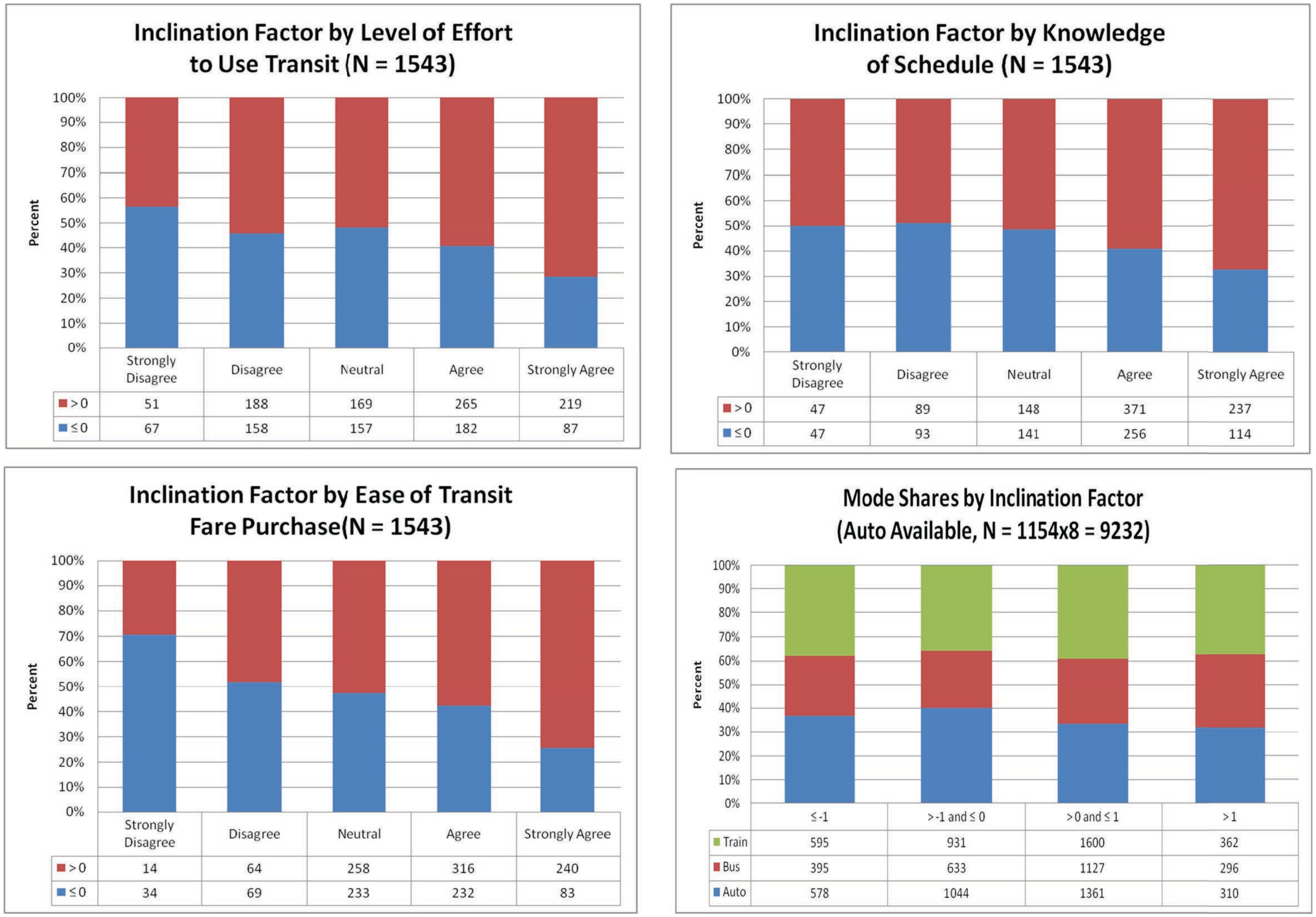


FIGURE G-1. Inclination factors and mode shares for transit users.

between people who disagree with the relationship between service and frequent transit usage, except for those that agree most strongly, where there is a strong indication that improved service is related to frequent transit usage. Higher service factors were also found for people who strongly felt they could use transit to access downtown (FIGURE G-2) and for those respondents who felt that better service would lead to useful destinations being accessible by transit (FIGURE G-2). In both of these cases, there is also a relationship between poor service and respondents disagreeing with using transit to access downtown and using transit to make certain destinations more accessible.

The service availability factor is highly correlated with stated mode choice. An increased service factor was found to decrease the auto shares noticeably in the stated preference survey. In other words, those individuals who felt more positive about the availability of transit were more likely to choose transit modes in the stated preference experiments.

Both the inclination and service factors for transit users were tested and included in the final work-trip mode choice models for the auto mode with negative coefficients. In the final non-work-trip mode choice models, the service factor for transit users was included for auto modes, and the inclination factor for bus users was included for the rail mode—again with negative coefficients, as expected.

Opinions of Non-Transit Users

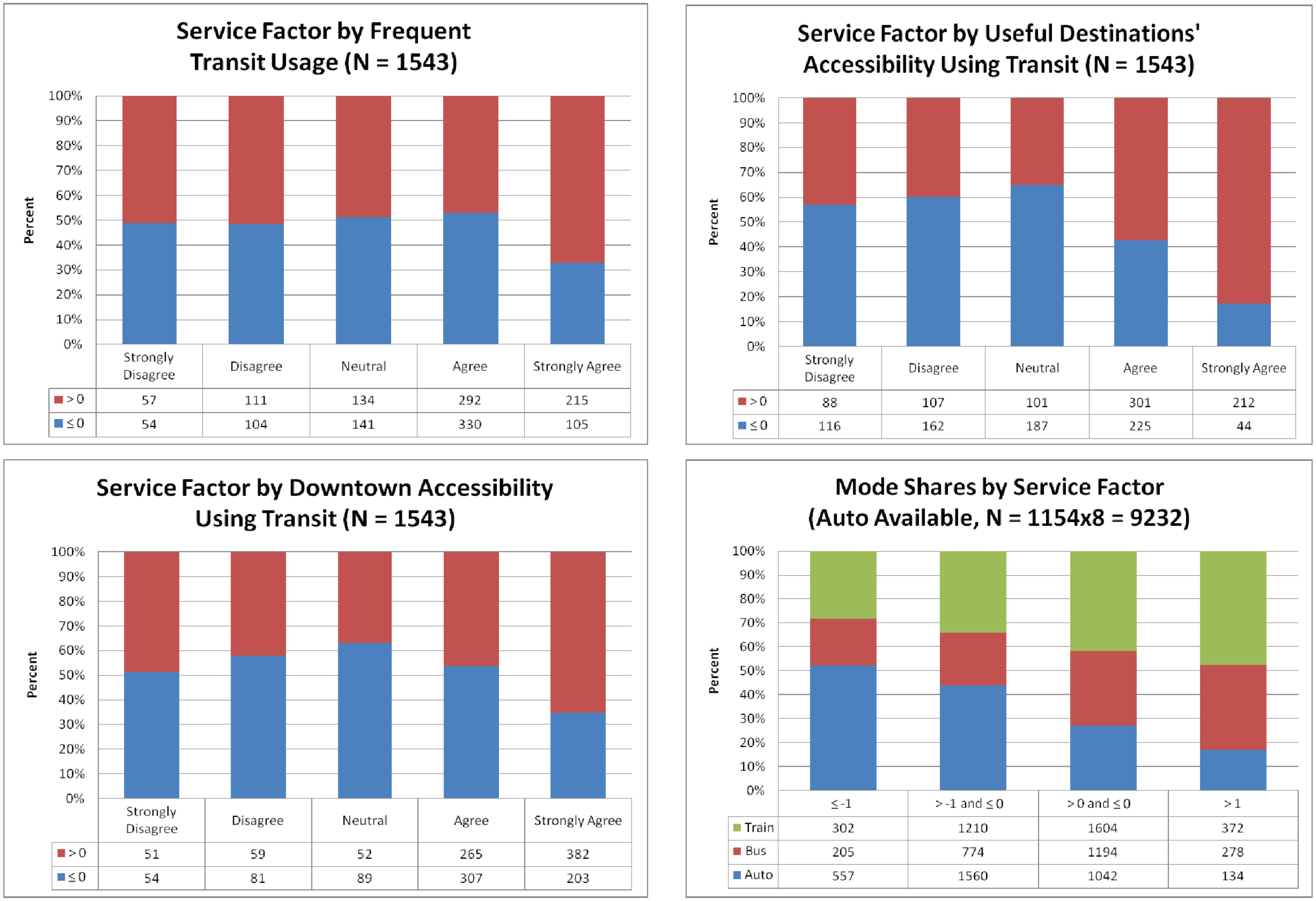
In the case of non-transit users, the inclination factor was highly correlated with people who agreed with being "the kind who ride transit" (not surprising), with people who are "not afraid to ride transit," and with people who agreed that they would use transit if the stop/station environment were convenient, as shown in FIGURE G-3. For people who declared that "car is king" and that "nothing will replace my car as my main mode of transportation," the inclination factor decreased.

Mode shares presented in FIGURE G-3 also increase for transit as the inclination factor increases. The inclination factor for non-transit users is different than it is for transit users, which was correlated with making an effort to ride transit, ease of purchasing fares, and real-time information at transit stops/stations.

The discomfort and access factor is presented in FIGURE G-4 (as discomfort) to demonstrate correlation with respondents' opinions about transit being dirty, transit stops being perceived as unpleasant, and drive access to transit being inconvenient. Mode shares by the discomfort factor are also presented in FIGURE G-4.

The inconvenience factor is also presented to demonstrate the correlation with infrequent transit service, presented in FIGURE G-5. The inconvenience factor decreases as the ease of trip planning increases. Mode shares by the inconvenience factor were also reviewed, but they are not presented here because they do not contribute to the understanding of this factor.

Both the discomfort and access factor and the inconvenience factor were tested in the mode choice model estimation. Neither factor was found to be significant, so both were dropped from the final models.



Service Factor by Frequent Transit Usage (N = 1543)

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
> 0	57	111	134	292	215
≤ 0	54	104	141	330	105

Service Factor by Useful Destinations' Accessibility Using Transit (N = 1543)

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
> 0	88	107	101	301	212
≤ 0	116	162	187	225	44

Service Factor by Downtown Accessibility Using Transit (N = 1543)

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
> 0	51	59	52	265	382
≤ 0	54	81	89	307	203

Mode Shares by Service Factor (Auto Available, N = 1154x8 = 9232)

	≤ -1	> -1 and ≤ 0	> 0 and ≤ 0	> 1
Train	302	1210	1604	372
Bus	205	774	1194	278
Auto	557	1560	1042	134

FIGURE G-2. Service factors and mode shares for transit users.

FIGURE G-3. Inclination factors and mode shares by non-transit user.

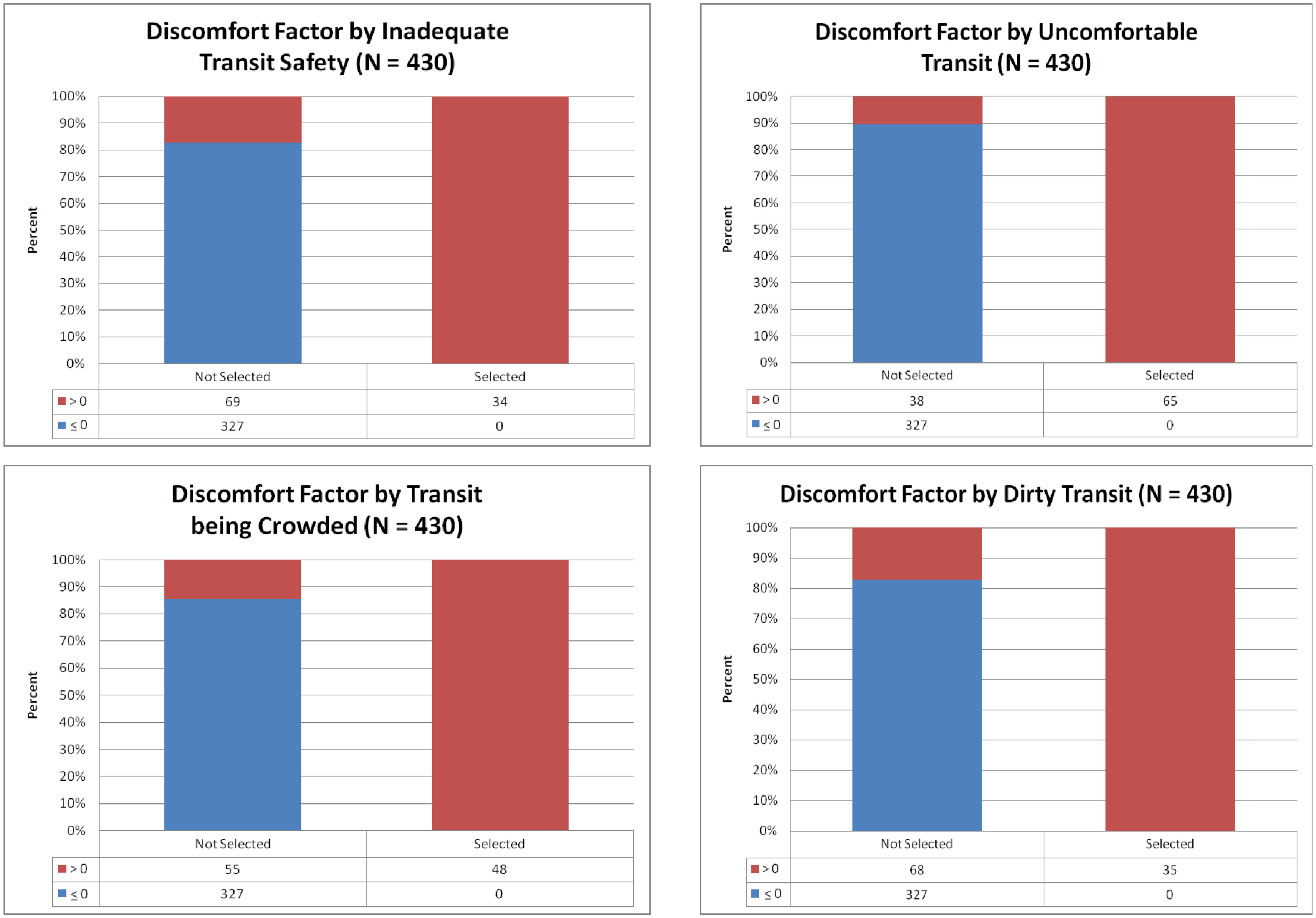


FIGURE G-4. Discomfort factor and mode shares by non-transit users.

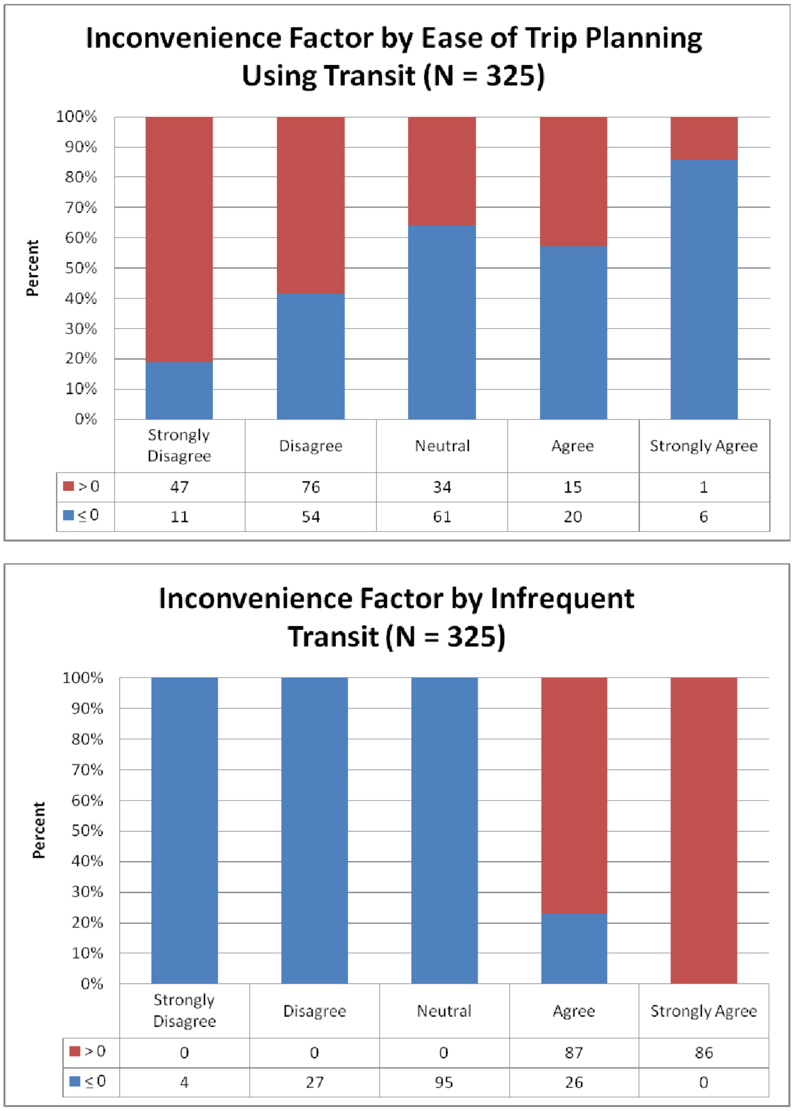


FIGURE G-5. Inconvenience factors for non-transit users.

Opinions of Non-Transit Choosers

The discomfort factor for non-transit choosers (FIGURE G-6) is different than it is for non-transit users. It is highly correlated with respondents who feel that transit is not safe enough, too crowded, uncomfortable, and dirty. This contrasts with the discomfort and inaccessibility factor for non-transit users, who agreed with the statement that transit is often dirty, but did not agree strongly with the safety, crowding, or uncomfortable parts of the discomfort factor. Instead, non-transit users focused more on the inaccessibility aspects of this factor.

The inconvenience factor (FIGURE G-7) correlates strongly with opinions about transit service, including opinions that travel time is too long, that transit doesn't fit a respondent's schedule, that transit service is less reliable than driving, that transit doesn't go where the respondent needs to go, and that transit requires too many transfers. This factor also correlates with aspects of access and egress in the statement that it is "too difficult to get to the transit stop/station." This inconvenience factor contrasts with non-transit users' inconvenience factor, which correlated with less transit frequency and the difficulty in planning a trip.

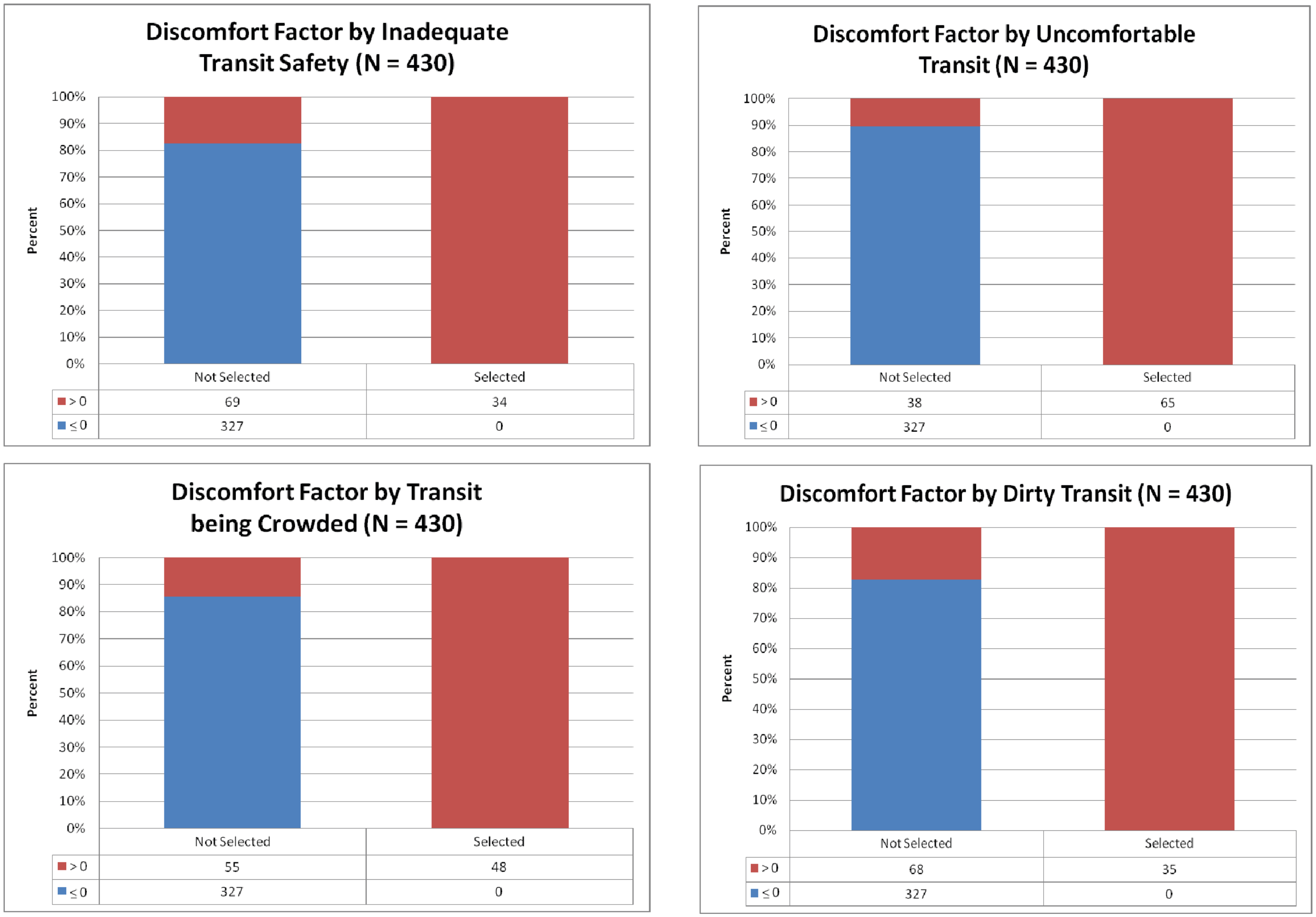
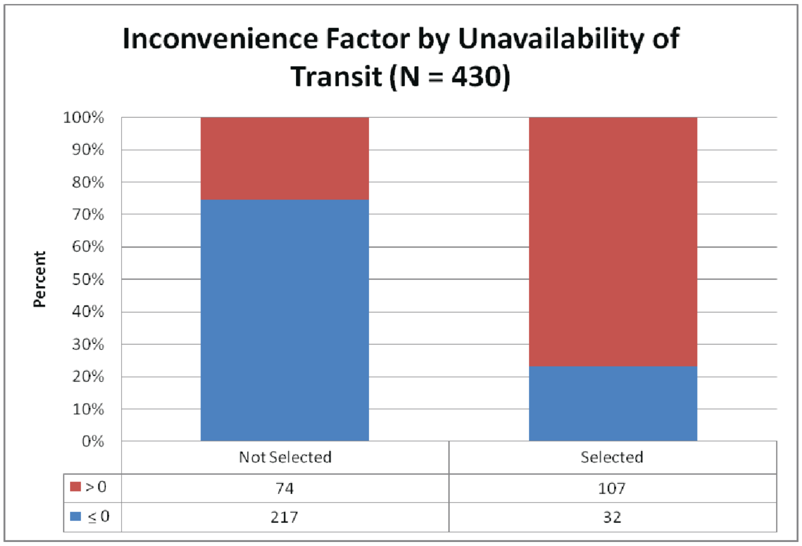


FIGURE G-6. Discomfort factor for non-transit choosers.



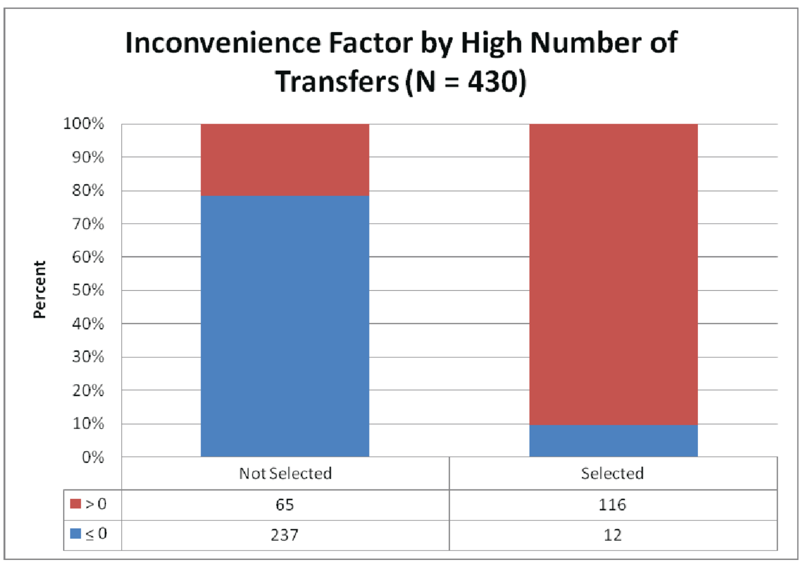


FIGURE G-7. Inconvenience factor for non-transit choosers.

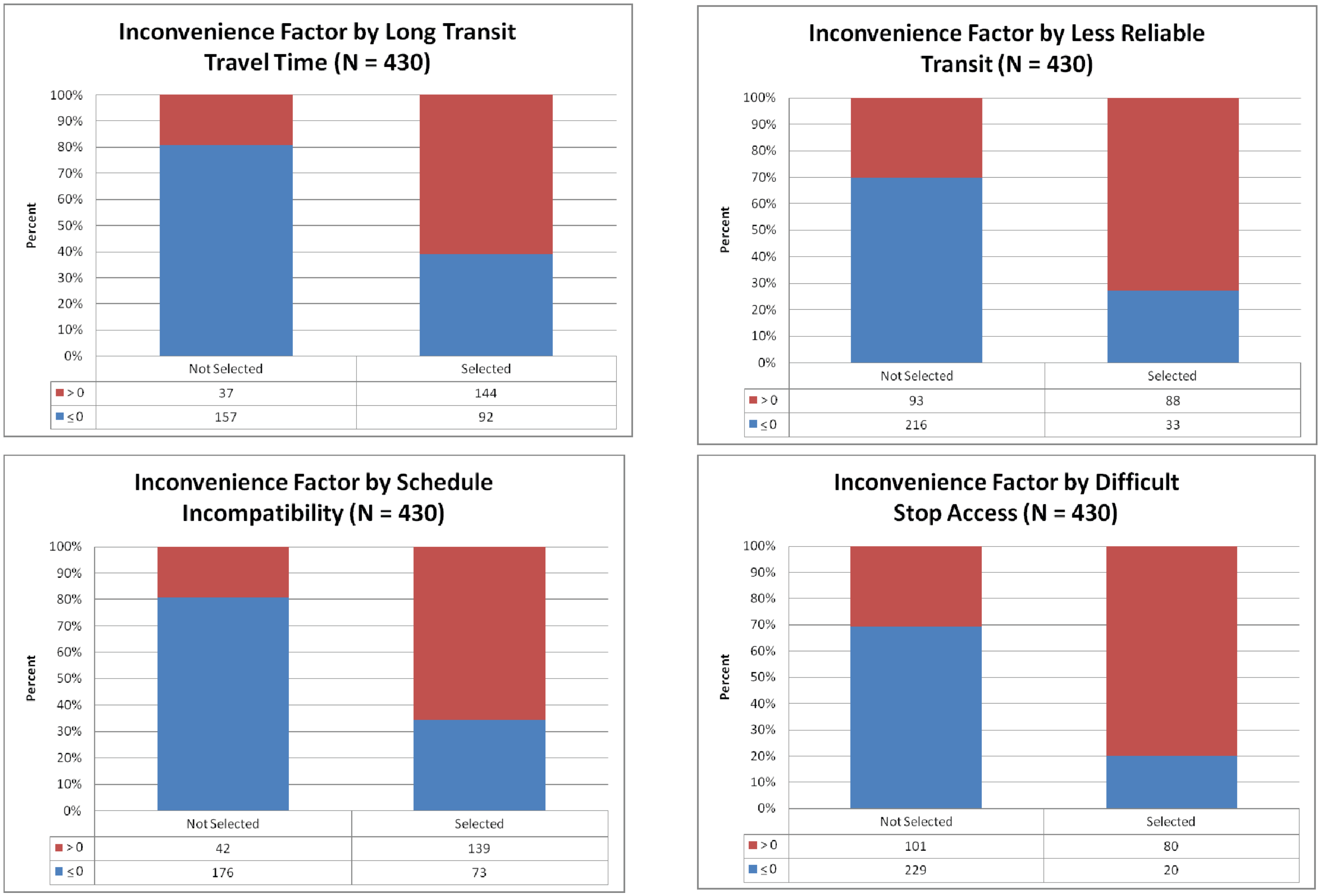


FIGURE G-7. (Continued).

Attitudes of non-transit choosers were tested in the work-trip mode choice models, but one was found to be counter-intuitive (a positive coefficient on the service perception factor for rail modes) and the three that were included (perception factor for auto and rail modes and the convenience factor) caused several other variables to become insignificant (access time, gas cost and premium attributes). As a result, these were not included in the final work-trip mode choice models.

Least Preferred Mode Shares

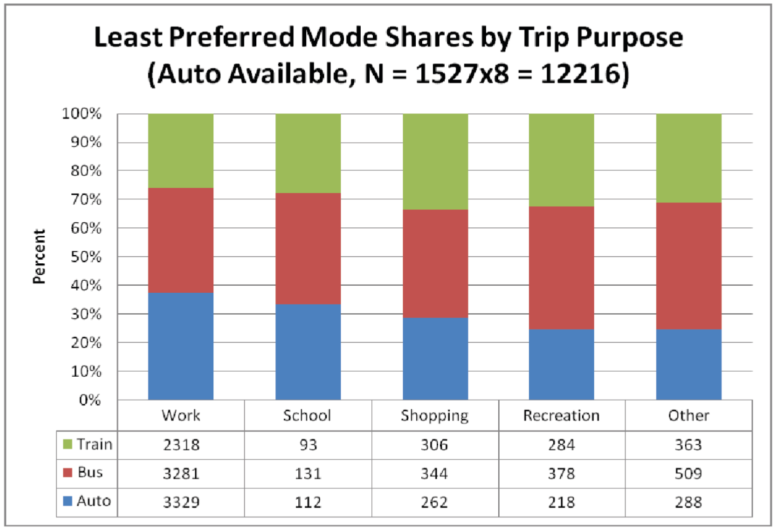
Survey respondents were also asked to select their least preferred mode among the options in the CBC experiment. These results were analyzed to understand the factors that affect the least preferred choices. In each case, these results are presented for respondents who had an auto available for their trip and those respondents who did not have an auto available for their trip.

Trip purpose does not statistically affect least preferred mode shares (FIGURE G-8) for respondents who did not have an auto available; but for respondents who did have an auto available, auto preference was less for work and school trips than for other trips. This may be because of a number of factors, such as the need for the car when carrying packages (for shopping trips), the desire to use the car for multiple passengers (for recreation trips), and/or the convenience of using a car for a series of non-work trips (trip chaining). This result is supported by data from most urban areas, who report that transit ridership is higher for work and school travelers.

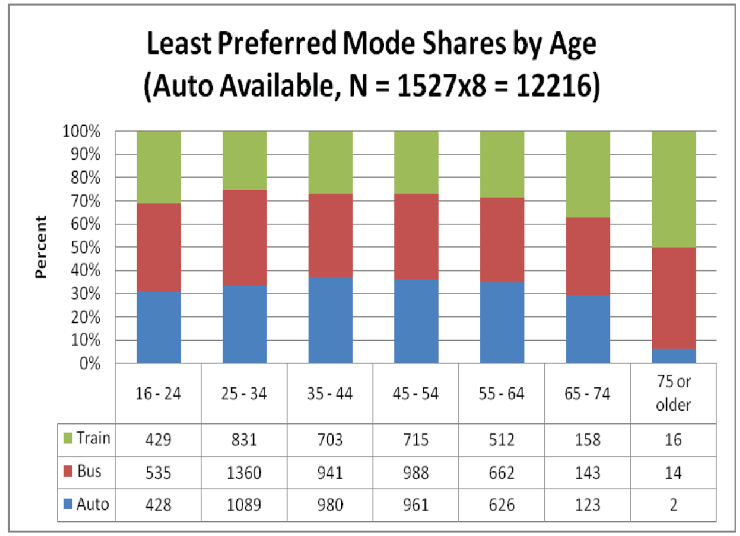
Age also does not statistically affect least preferred mode shares (FIGURE G-8) for respondents who did not have an auto available; but for respondents who did have an auto available, auto preference was less for the middle age group (ages 35 to 64 years) than it was for younger (ages 16 to 34 years) or older (age 65 years and up) travelers. This may be due to mobility issues for older travelers and due to livability issues for younger travelers (e.g., college students who choose to live close to school and walk or bike everywhere).

Household income is also not statistically significant for least preferred mode shares (FIGURE G-9) of travelers who did not have an auto available, but auto preference was less for the middle income group ($75,000 to $150,000) than it was for lower income or higher income households of respondents who did have an auto available. This may be due to middle income families who have responsibilities for children or older parents that are easier to attend to with an auto.

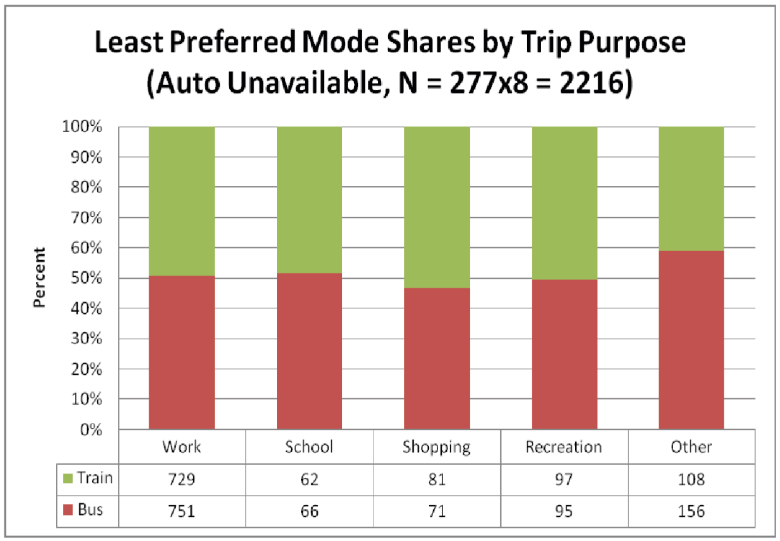
The least preferred mode share analysis also included an evaluation of the origin and destination TAZs, based on characteristics of the surrounding area (FIGURE G-10), such as central business district (CBD), urban, suburban, transition, and rural. If auto was available, respondents' least preferred mode shares were reasonably consistent across origin TAZs, but there was a clear trend toward more auto preference in destination TAZs from less dense areas. If auto was unavailable, respondents' least preferred mode shares trended toward bus for the origin TAZs and destination TAZs in less dense areas.



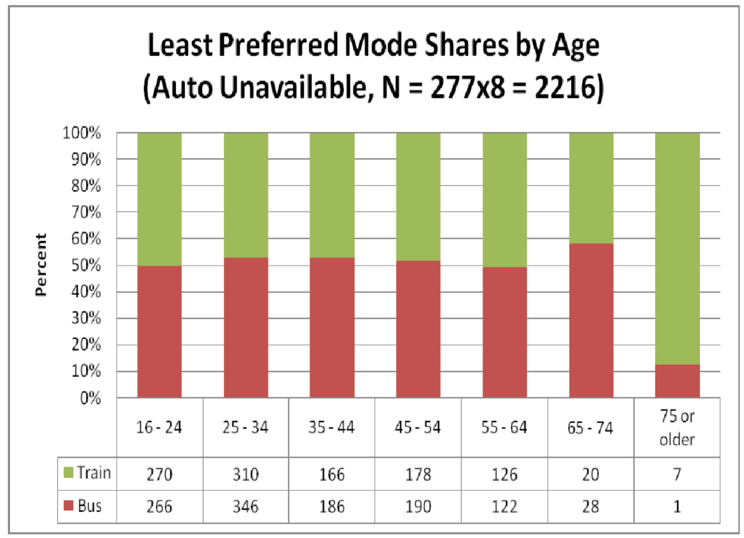
	Work	School	Shopping	Recreation	Other
Train	2318	93	306	284	363
Bus	3281	131	344	378	509
Auto	3329	112	262	218	288



	16 - 24	25 - 34	35 - 44	45 - 54	55 - 64	65 - 74	75 or older
Train	429	831	703	715	512	158	16
Bus	535	1360	941	988	662	143	14
Auto	428	1089	980	961	626	123	2

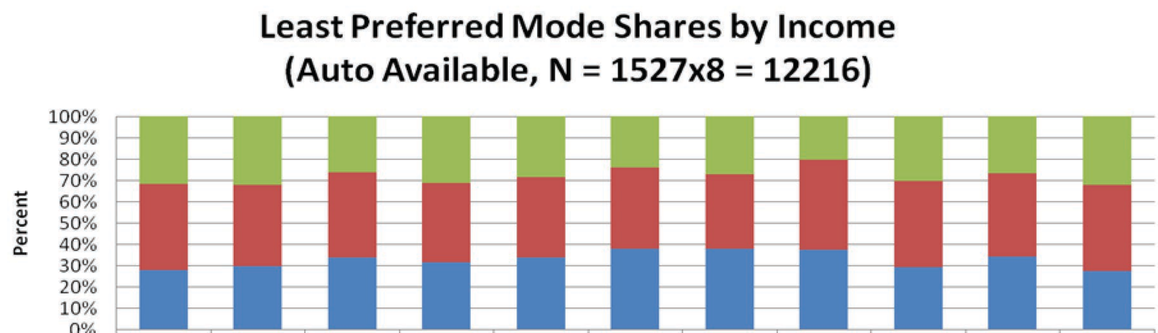


	Work	School	Shopping	Recreation	Other
Train	729	62	81	97	108
Bus	751	66	71	95	156



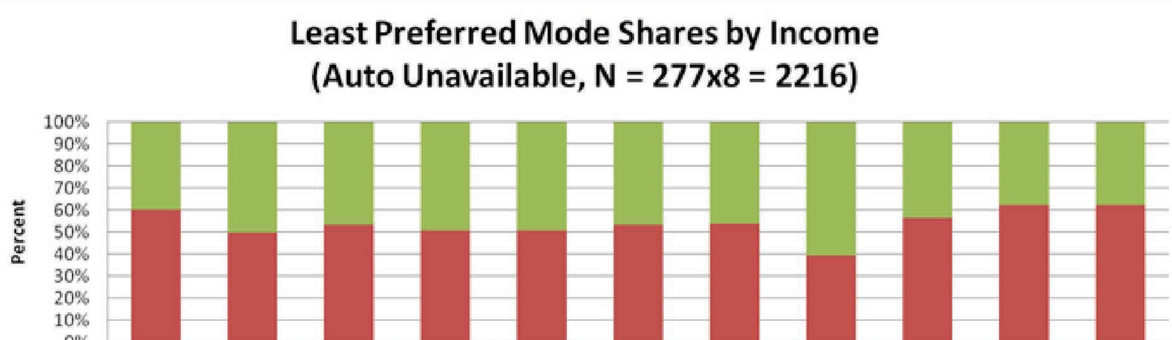
	16 - 24	25 - 34	35 - 44	45 - 54	55 - 64	65 - 74	75 or older
Train	270	310	166	178	126	20	7
Bus	266	346	186	190	122	28	1

FIGURE G-8. Least preferred mode shares by trip purpose and age.



	Missing	Less than $25,000	$25,000 – $34,999	$35,000 – $49,999	$50,000 – $74,999	$75,000 – $99,999	$100,000 – $124,999	$125,000 – $149,999	$150,000 – $174,999	$175,000 – $199,999	$200,000 or more
Train	58	342	307	522	858	557	414	114	77	36	79
Bus	74	406	471	629	1135	888	543	241	103	53	100
Auto	52	316	398	537	1031	883	587	213	76	47	69

FIGURE G-9. Least preferred mode shares by income.



	Missing	Less than $25,000	$25,000–$34,999	$35,000–$49,999	$50,000–$74,999	$75,000–$99,999	$100,000 – $124,999	$125,000 – $149,999	$150,000 – $174,999	$175,000 – $199,999	$200,000 or more
Train	19	309	130	150	253	104	63	29	14	3	3
Bus	29	307	150	154	259	120	73	19	18	5	5

FIGURE G-10. Least preferred mode shares by origin TAZ and destination TAZ.

Chicago and Charlotte Analysis

An Analysis of Modal Shares by Factor Score Quartiles

This section provides a more in-depth examination of the relationship between modal shares and factor scores. The sample is divided into quartiles for each factor, thus ensuring that there is an equal sample size in each factor quartile segment. For each quartile, the modal share is computed. A comparison of modal shares across the factor quartile segments offers insights into how mode choice behavior is related to factor scores and is useful for developing model specifications in the mode choice modeling effort that will follow the factor analysis.

To facilitate an easy comparison between the Chicago and Charlotte factor analysis results, each figure provides a pair of charts, one for the Charlotte data set and another for the Chicago data set. Each figure corresponds to a comparison of the modal shares across factor score quartiles for Charlotte and Chicago, thus offering a perspective on how strongly factor scores and modal shares are related in both of the data sets.

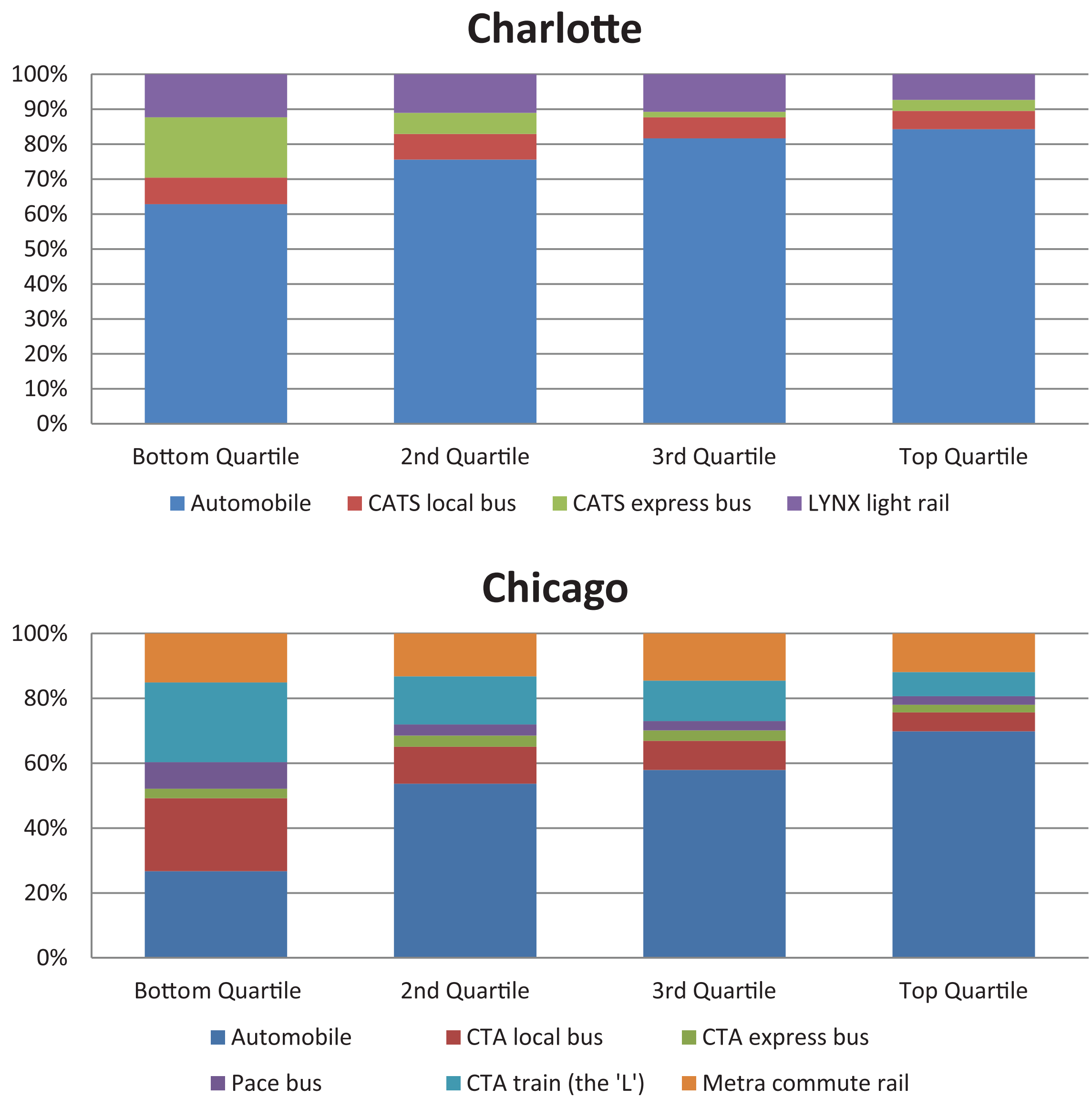


FIGURE G-11. Modal shares by factor score quartiles—pro-car attitudinal factor.

FIGURE G-11 provides a comparison for the pro-car attitudinal factor. It is found that there is a strong correlation between pro-car attitudinal factor and modal shares in both the Charlotte and Chicago data sets. As one proceeds from the bottom quartile to the highest quartile, the auto mode share is found to systematically and noticeably increase while transit mode shares decrease. In other words, as the pro-car attitude gets stronger (which would be the case in the higher quartiles), the auto mode share increases in an intuitive way. It appears that the pro-car attitudinal factor would be a strong predictor of mode shares, as evidenced by this trend in modal shares across factor quartiles for this factor.

FIGURE G-12 shows the modal share trend for the Consciousness attitudinal factor. This attitudinal factor is such that, as the value of the factor increases, one would expect the auto mode share to decrease. Those respondents more conscious of the environment and interested in being productive while traveling are more likely to be transit users than auto users. This is largely played out in the charts depicted in FIGURE G-12. In both Charlotte and Chicago, there is a systematic drop in auto mode split as one proceeds from left to right (i.e., from the bottom quartile to the highest quartile in the Consciousness factor spectrum). The transit mode shares

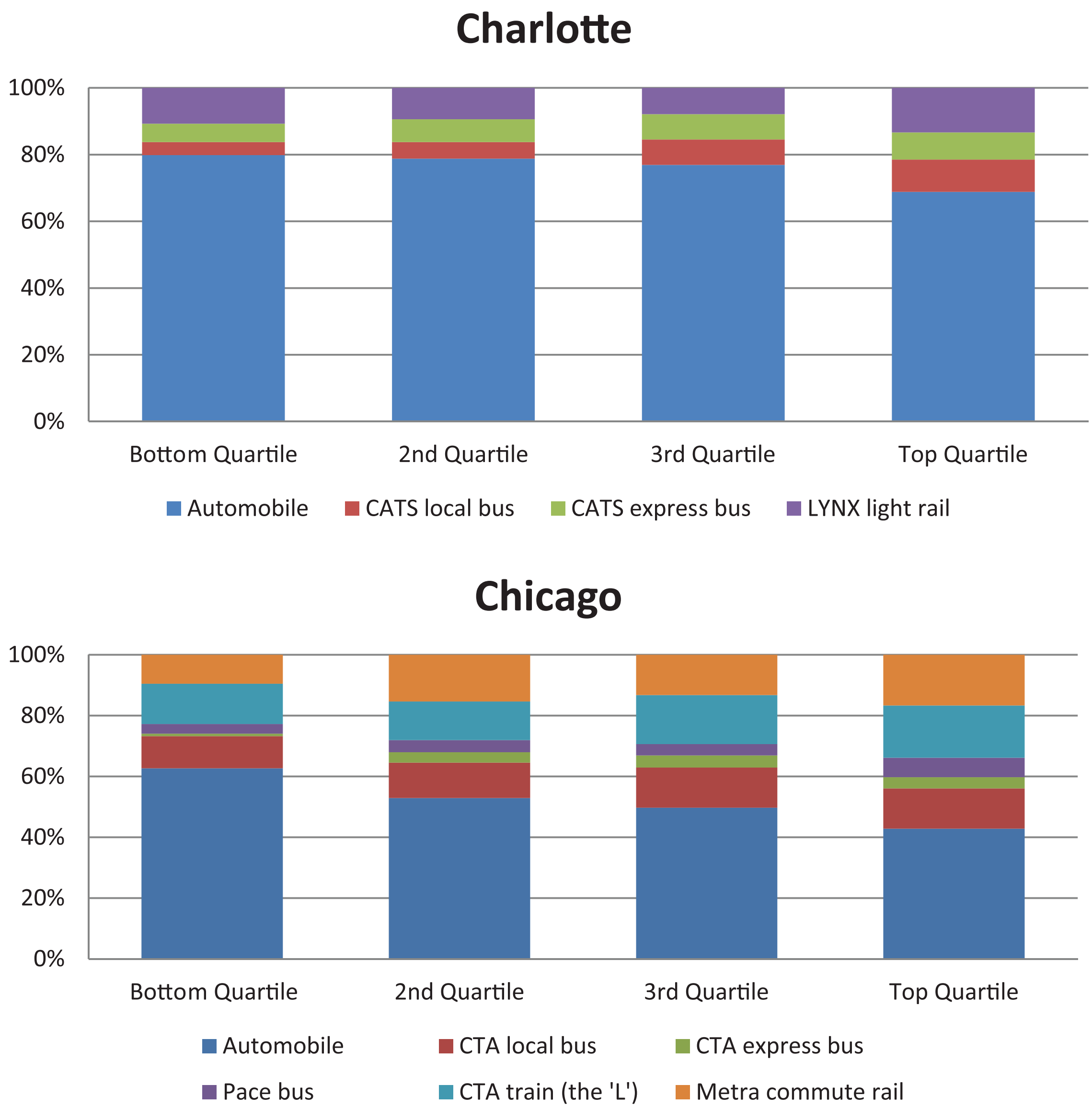


FIGURE G-12. Modal shares by factor score quartiles—consciousness attitudinal factor.

show concomitant increases across the factor quartiles. Once again, it appears that this factor is likely to be a significant predictor of mode choice behavior.

In the case of the low transit comfort level factor (FIGURE G-13), the Charlotte data set exhibits a strong correlation. As one proceeds from the bottom quartile to the highest quartile, one would expect to see auto mode share to increase. There is a very strong tendency of this nature in the Charlotte chart. An examination of the chart shows that those with the highest values for Low transit comfort (i.e., respondents who are least comfortable with transit) exhibit the highest mode share for auto mode of transport. The trend is not as strong in the Chicago data set. For the second, third, and highest quartiles, there is a modest trend that may be discerned. Across these three quartiles, the auto mode split is found to increase slightly from one quartile to the next, suggesting that there is at least some correlation between low transit comfort level and mode share. The bottom quartile, however, shows an auto mode share that is greater than that of the second quartile and is virtually identical to that of the third quartile. The weak relationship

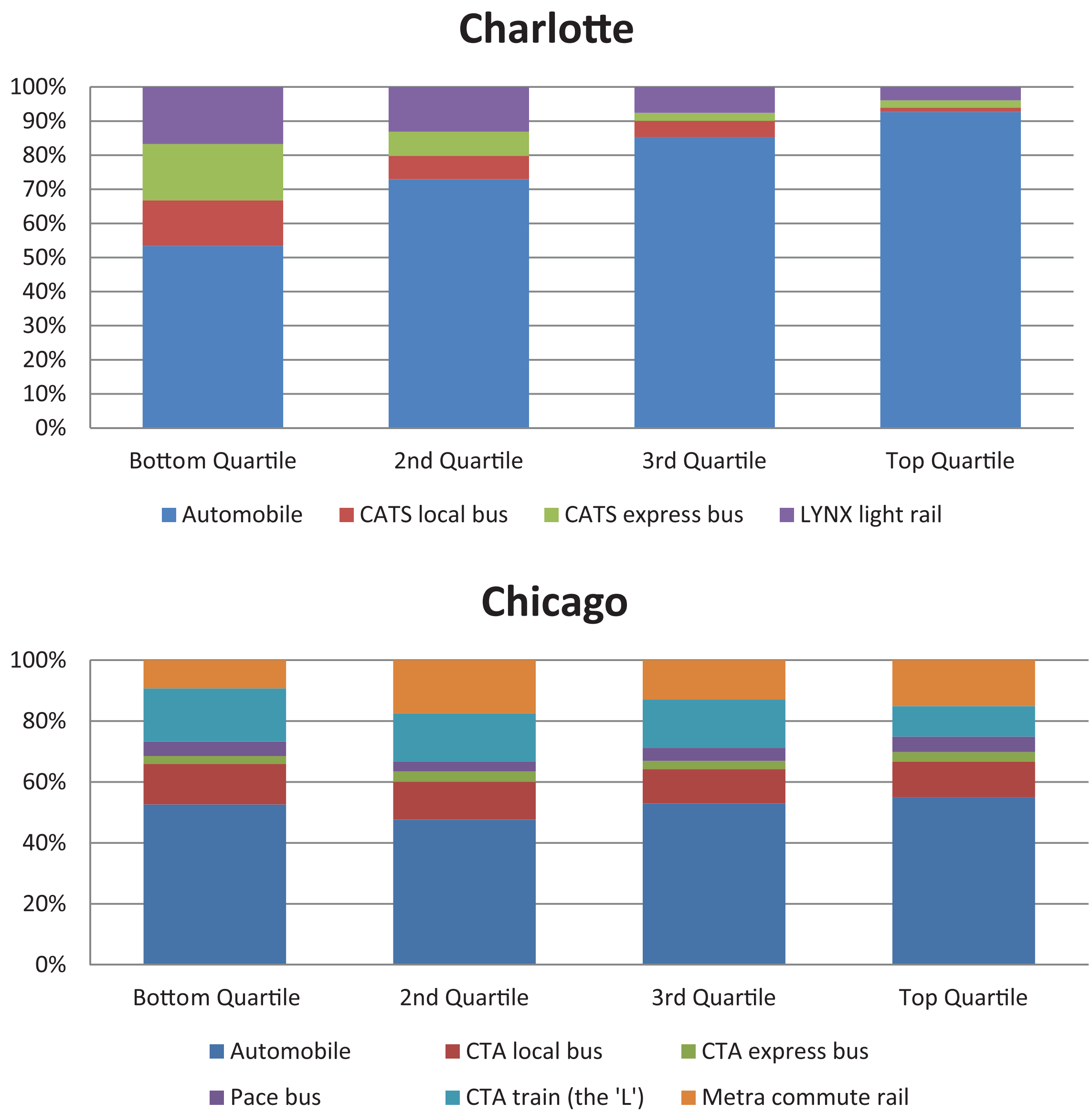


FIGURE G-13. Modal shares by factor score quartiles—low transit comfort level attitudinal factor.

between this factor and mode choice may be attributed to the fact that Chicago has greater and better transit service and hence the level of discomfort with transit is generally lower in Chicago than it is in Charlotte. The factor score for Charlotte auto users on this factor (Low Transit Comfort Level) is substantially greater (more positive) than that for the auto user segment in Chicago. In other words, auto users in Chicago are not as uncomfortable with the notion of using transit as are auto users in Charlotte. As a result, the mode shares do not show the same dramatic shift in the Chicago sample as seen in the Charlotte sample.

The pro-transit attitudinal factor is somewhat similar to the pro-car attitudinal factor with respect to the nature of its relationship with modal shares, except that the relationship is the reverse of what was seen in FIGURE G-11. The relationship between modal shares and the pro-transit attitudinal factor is shown in FIGURE G-14. In both the Charlotte and Chicago samples, this particular attitudinal factor is found to be strongly correlated to modal shares. As the pro-

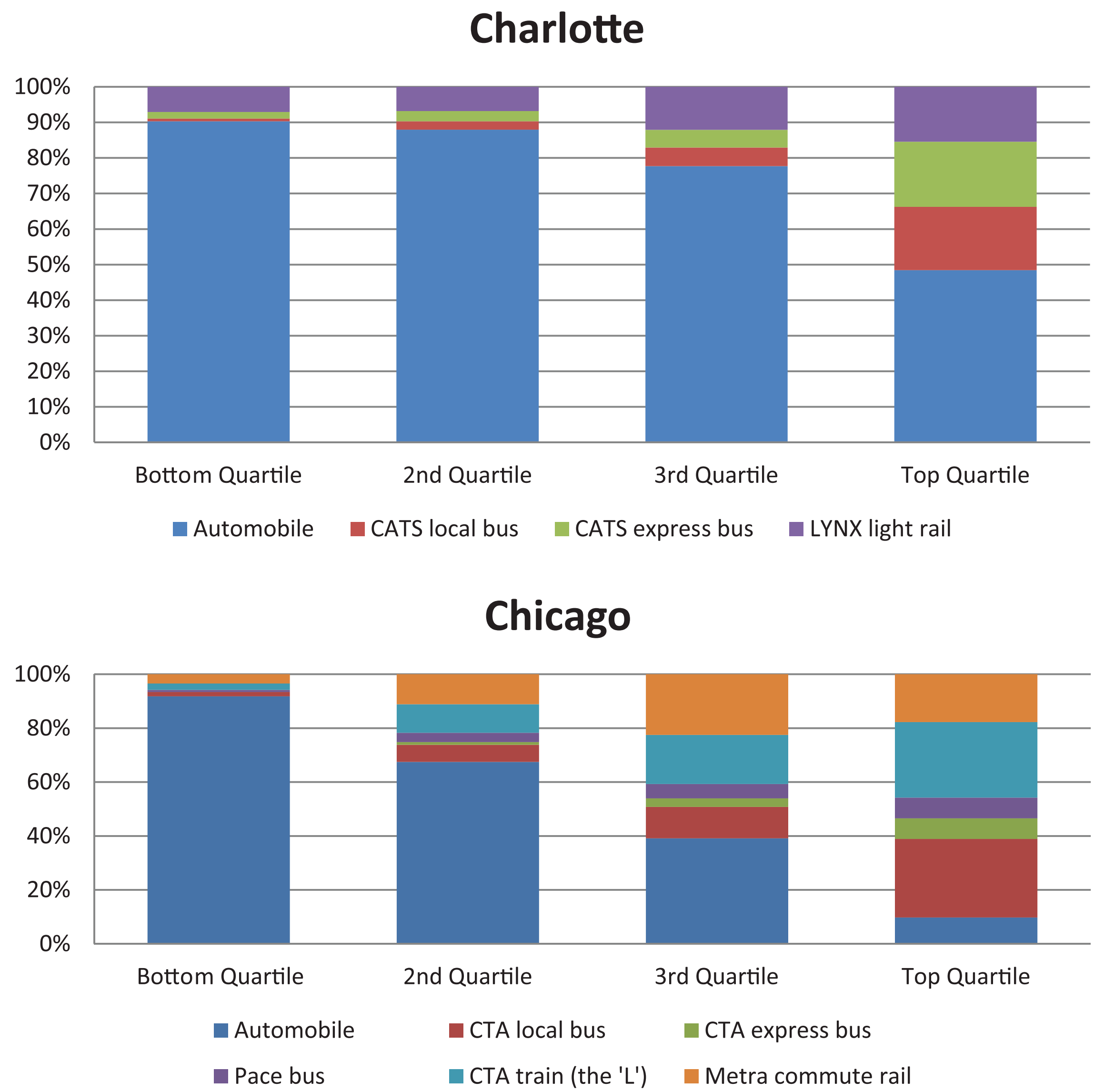


FIGURE G-14. Modal shares by factor score quartiles—pro-transit attitudinal factor.

transit attitudinal factor increases, there is a very intuitive and noticeable shift in mode splits, with those in the higher quartiles showing lower auto mode shares and concomitant increases in transit mode shares. The tendency is particularly strong in the Chicago data set, where presumably the greater and better levels of transit service further contribute to an amplification of the relationship between the pro-Transit attitude factor and transit mode shares.

Finally, in the case of the "transit averse" factor, it is found that the relationship between the factor score and the modal shares is not as strong as that seen in some of the other charts. FIGURE G-15 shows the variation of modal shares across the quartiles for this particular factor. In the case of the Charlotte data set, there is a modest trend that is consistent with expectations for the first three quartiles. The auto mode share increases as the transit aversion factor increases; this finding is reasonable. However, surprisingly, the auto mode share decreases for the highest quartile, and it is not immediately clear why this may be the case. Perhaps the higher light rail share for this quartile contributes somewhat to this finding. It is likely, as mentioned

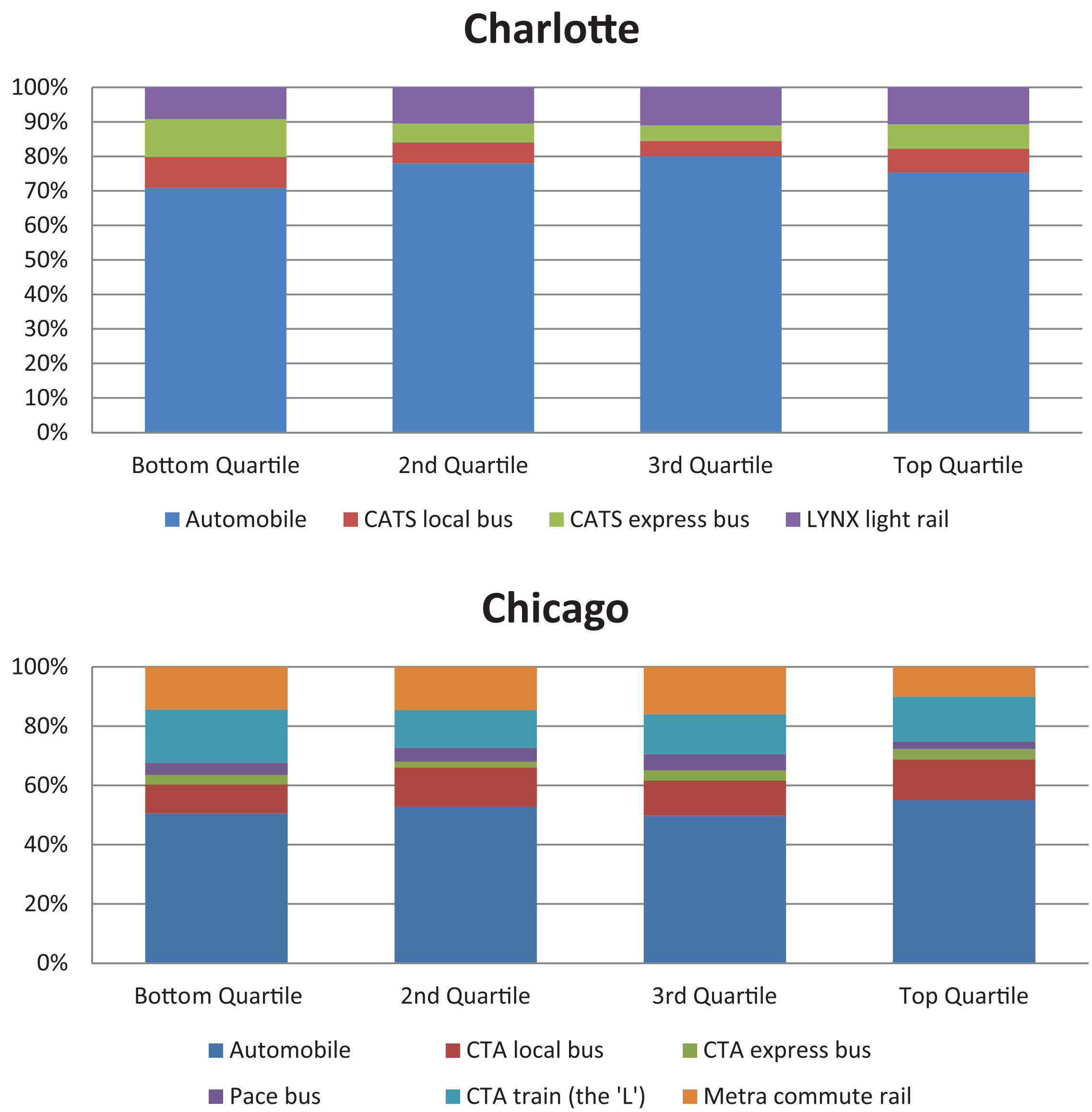


FIGURE G-15. Modal shares by factor score quartiles—transit averse attitudinal factor.

before, that even transit-averse individuals are inclined to use light rail, as they view light rail as a premium transit service different from traditional transit modes.

In the case of the Chicago sample, the relationship between modal shares and the transit aversion factor is even weaker. The modal shares do not show a clear trend when proceeding from lower levels of the factor to higher levels of the factor (although one would expect an increasing auto mode share). For Chicago in particular, it appears that the transit averse attitudinal factor (which includes two variables in the Chicago case, privacy being important and transit being considered dirty) is only weakly related to mode choice behavior. This observation is consistent with the earlier findings where it was noted that the differences in mean factor scores across different modal segments for this particular factor are extremely small. In Chicago, it is found that different modal segments are not all that different from one another with respect to their transit-averse attitude. Given the transit-rich context of Chicago, it is plausible that there is less variance in transit aversion across the population than in a less transit-rich environment such as Charlotte. As a result, the relationship between this factor and mode choice is more tenuous in Chicago. It is possible that this particular factor will not affect mode choice in the Chicago context, but will do so in the Charlotte context.

Results

The research team conducted an exploratory factor analysis for both the Chicago and Charlotte data sets on a number of attitudinal variables dealing with how respondents view public transit and auto modes of travel. Standard factor analysis techniques involving the extraction of principal components and the use of varimax rotation were employed to obtain factors that were orthogonal with one another where the association (loading) of different variables to various factors was as unambiguous as possible. In some cases, even with the use of varimax rotation techniques, there is some ambiguity as to the association of variables to different factors (as a variable may be loaded somewhat equally to multiple factors), and the research team has had to apply qualitative interpretations to explain the factors. However, such situations (where variables load equally to multiple factors) do not necessarily present any problem from a modeling standpoint. The results of the factor analysis are presented in summary form under the heading "Number of Factors."

Number of Factors

Chicago and Charlotte

The choice of number of factors is driven by a number of considerations. In an exploratory factor analysis such as that conducted in this effort, the analyst is not necessarily approaching the factor analysis with any preconceived ideas about the number and nature of factors that summarize the data; rather the analyst is depending on estimates of factor scores and goodness-of-fit statistics to identify the factors that emerge. The project team considered a number of possibilities in developing the factors for the Chicago and Charlotte data sets. While it may be reasonable to expect that two or three factors would suffice, the project team chose to retain and use a larger number of factors so that attitudinal variables were captured in the choice models at a greater level of fidelity. The project team adopted the scheme with attitudinal variables loaded onto five factors. Although this larger number of factors provided a greater level of detail and fidelity in the representation of attitudinal variables, it also increases the level of ambiguity and overlap across factors. Attitudinal variables may load virtually equally across multiple factors and multiple factors may have rather similar interpretations. The intent of the factor analysis is to effectively capture the effects of attitudinal variables on choice set formation and mode choice. From that standpoint, the exact number of attitudinal factors is not of primary importance. Rather, the factor analysis (particularly in this study) is merely intended to provide a set of factors that are correlated with mode choice patterns and can be included in the mode choice models.

In TABLE G-1, the factors are given names by the analyst based on the nature of the variables that loaded most heavily on a particular factor. For example, the first factor, referred to as "pro-car attitude," includes variables about how an individual views the private automobile. These variables loaded most heavily on this particular factor as opposed to all other factors. There are some differences between the Charlotte and Chicago data sets with respect to the nature of the exact variables that loaded against each factor, but there are also many interesting similarities across the data sets that provide for the use of an identical set of factors in subsequent

TABLE G-1. Results of factor analysis.

Factor	Charlotte Attitudinal Variables	Chicago Attitudinal Variables
Pro-car attitude	▪ Car is king! Nothing will replace my car as my main mode of transportation. ▪ *My days of taking transit are over.** ▪ *Privacy is important to me when I travel.* ▪ My car reflects who I am.	▪ Car is king! Nothing will replace my car as my main mode of transportation. ▪ My car reflects who I am.
Pro-transit attitude	▪ I currently make an effort to take public transit whenever I can. ▪ I'm the kind of person who rides transit. ▪ *As long as I am comfortable when traveling I can tolerate delays.*	▪ I currently make an effort to take public transit whenever I can. ▪ I'm the kind of person who rides transit. ▪ *It's easy to plan a trip using transit.* ▪ *NEGATIVE: My days of taking transit are over.* ▪ *If I wanted to I could use public transit more often.* ▪ *I am not afraid to ride transit.*
Transit averse	▪ Transit is often dirty. ▪ *NEGATIVE: I am not afraid to ride transit.*	▪ Transit is often dirty. ▪ *Privacy is important to me when I travel.*
Low transit comfort level	▪ Getting to and from transit is not pedestrian friendly and is very unpleasant. ▪ I have to drive to get to transit anyway, so I may as well just drive my car the whole way. ▪ *NEGATIVE: It's easy to plan a trip using transit.* ▪ *NEGATIVE: If I wanted to, I could use public transit more frequently.*	▪ Getting to and from transit is not pedestrian friendly and is very unpleasant. ▪ I have to drive to get to transit anyway so I may as well just drive my car the whole way.
Consciousness	▪ I am willing to carpool or take public transit to reduce air pollution and carbon emissions from my vehicle. ▪ Protecting the environment is very important to me. ▪ If it would save time, I would change my form of travel. ▪ More than saving time, I prefer to be productive when traveling.	▪ I am willing to carpool or take public transit to reduce air pollution and carbon emissions from my vehicle. ▪ Protecting the environment is very important to me. ▪ If it would save time, I would change my form of travel. ▪ More than saving time, I prefer to be productive when traveling. ▪ *As long as I am comfortable when traveling, I can tolerate delays.* ▪ *I am willing to pay higher tolls if they are used to reduce congestion.*

* The attitudinal variables in italics are unique for each city, while the remaining attitudinal variables are similar for both cities.

choice model specification and estimation efforts. The pro-car, transit averse, and low transit comfort attitudes tend to favor auto modes, and the pro-transit and Consciousness attitudes tend to favor transit modes, but to varying degrees depending on the attitudinal factor.

The first factor captures those variables representing a pro-car attitude while the second factor captures those representing a Pro-transit attitude. In the second factor, there are several variables representing an individual's propensity to use or consider transit as a mode of transportation. In the case of one variable in the Chicago case, the variable corresponding to "my days of using transit are over" has a negative loading on this particular factor, suggesting that this variable has a strong inverse relationship with the Pro-transit factor (which is intuitively reasonable). The third factor captures a few variables representing transit aversion of individuals, while the fourth factor represents a low level of comfort on the part of the individual to access and use transit. There are two variables that measure the extent to which individuals feel that they can access transit and the implications for using transit. In the case of Charlotte, there are two additional variables with negative loadings in this particular factor. In the case of the Chicago data set, these two additional variables had loaded more strongly positive in the Pro-transit factor. The fifth factor captures a smorgasbord of attitudes dealing with people's consciousness. This factor includes variables that measure the willingness of individuals to carpool or pay tolls to reduce congestion, or change mode to protect the environment, and reflect the awareness of the individual of his or her own inner traits (e.g., importance of productivity over time savings when traveling).

The rotated factor matrix for Charlotte is shown in TABLE G-2, while that for Chicago is shown in TABLE G-3. The interpretation of the factor names is as follows:

- PCA: pro-car attitude
- Cons: consciousness
- LTCL: low transit comfort level
- PTA: pro-transit attitude
- TAv: transit averse

The factor loadings that are used to interpret each of the factors are highlighted in each of the tables to show how the research team developed the qualitative interpretation of the factors. However, that does not mean that only those factor loadings are used to compute the value of each factor for each respondent in the data sets. All of the factor loadings are used to compute factor scores for the five different factors, thus maximizing the use of information contained in the data set. Negative factor loadings imply an inverse relationship between the variable and the factor.

TABLE G-2. Rotated factor matrix for Charlotte.

Respondents' Agreement with Attitudinal Statements	Factor				
	Pro-Car Attitude	Pro-Transit Attitude	Transit Averse	Low Transit Comfort Level	Consciousness
For me, car is king! Nothing will replace my car as my main mode of transportation.	0.681	-0.192		0.194	-0.191
My days of taking transit are over.	0.560	-0.251		0.276	-0.262
Privacy is important to me when I travel.	0.440		0.196		
My car reflects who I am.	0.421				

TABLE G-2. (Continued).

Respondents' Agreement with Attitudinal Statements	Factor: Pro-Car Attitude	Pro-Transit Attitude	Transit Averse	Low Transit Comfort Level	Consciousness
I am willing to carpool or take public transit more frequently to reduce air pollution and carbon emissions from my vehicle.	-0.289			-0.131	0.670
Protecting the environment is very important to me.					0.584
If it would save time, I would change my form of travel.	-0.281			0.143	0.425
More than saving time, I prefer to be productive when traveling.		0.153			0.315
I am willing to pay higher tolls if they are used to reduce congestion.					0.288
Getting to and from transit stations/stops is not pedestrian friendly and is very unpleasant.	0.135		0.155	0.542	
I have to drive to get to transit anyway, so I may as well just drive my car the whole way.	0.303	-0.189		0.525	
It's easy to plan a trip using transit.		0.454	-0.117	-0.488	0.154
If I wanted to, I could use public transit more frequently.		0.119		-0.208	0.184
I currently make an effort to take public transit whenever I can.	-0.356	0.625		-0.259	0.222
I'm the kind of person who rides transit.	-0.472	0.561		-0.238	0.280
As long as I am comfortable when traveling, I can tolerate delays.		0.260	-0.144	-0.162	0.226
Transit is often dirty.	0.306		0.498	0.364	
I am not afraid to ride transit.	-0.302	0.250	-0.370		0.285

TABLE G-3. Rotated factor matrix for Chicago.

Respondents' Agreement with Attitudinal Statements	Factor: Pro-Car Attitude	Pro-Transit Attitude	Transit Averse	Low Transit Comfort Level	Consciousness
I'm the kind of person who rides transit.	-0.357	0.742		0.172	0.205
It's easy to plan a trip using transit.	-0.111	0.701	-0.116	-0.150	0.180
I currently make an effort to take public transit whenever I can.	-0.340	0.615		0.152	0.328
My days of taking transit are over.	0.469	-0.492	0.166		-0.150
If I wanted to, I could use public transit more frequently.		0.437			0.164
I am not afraid to ride transit.		0.341	-0.194		0.161
For me, car is king! Nothing will replace my car as my main mode of transportation.	0.715	-0.340	0.180		-0.158
My car reflects who I am.	0.497		0.111		
I am willing to carpool or take public transit more frequently to reduce air pollution and carbon emissions from my vehicle.	-0.170	0.201	-0.113		0.668
Protecting the environment is very important to me.				-0.123	0.621
If it would save time, I would change my form of travel.		0.204		0.238	0.336
More than saving time, I prefer to be productive when traveling.		0.242			0.306
As long as I am comfortable when traveling, I can tolerate delays.		0.168	-0.103		0.254
I am willing to pay higher tolls if they are used to reduce congestion.	0.220			0.139	0.244
Privacy is important to me when I travel.	0.313		0.493		
Transit is often dirty.			0.475		

TABLE G-3. (Continued).

Respondents' Agreement with Attitudinal Statements	Factor: Pro-Car Attitude	Pro-Transit Attitude	Transit Averse	Low Transit Comfort Level	Consciousness
I have to drive to get to transit anyway, so I may as well just drive my car the whole way.	0.480	-0.414	0.145	0.256	
Getting to and from transit stations/stops is not pedestrian friendly and is very unpleasant.	0.163	-0.310	0.412	0.328	

It should be noted that the total variance in the data set (in the attitudinal variables) can only be captured or explained 100% if one has as many factors as attitudinal variables (i.e., each and every attitudinal variable becomes its own factor). However, because such a system of factors would not provide much value from the standpoint of dealing with a smaller, manageable set of factors that captures the information in the attitudinal variables, a balance must be struck between the number of factors extracted from the data set and the percent of variance in the attitudinal variables explained by the extracted set of factors. In the case of these data sets, the team attempted to extract anywhere between four and seven factors, and after much consideration of the interpretation of the factors and the goodness-of-fit statistics of the factor analysis, five factors were extracted.

The extracted factors may be interpreted in similar qualitative terms between the two data sets analyzed. However, as one would expect the variance of attitudinal responses to differ between the two geographical contexts, the attitudinal variables load onto these factors in different ways in the data sets. For example, in Chicago, the variable "I am not afraid to ride transit" loads positively onto the pro-transit attitudinal factor. In Charlotte, on the other hand, the same variable loads negatively onto the attitudinal factor dubbed "transit averse". Someone who says that he or she is not afraid to ride transit is not likely to be transit averse. As such, it makes sense for this variable to have an inverse relationship with this attitudinal factor. Having multiple transit attitudinal factors (pro-transit attitude, transit-averse attitude) may lead to such occurrences where variables representative of a person's outlook toward transit could load onto either transit-oriented factor, with the sign being dependent on the relationship between the variable in question and the other variables that comprise the factor.

The goodness-of-fit statistics are presented in TABLE G-4 and TABLE G-5. In both data sets, the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (which is between 0 and 1) and the Bartlett's Test of Sphericity—Approx. Chi-Square (Williams et al. 2010) provide excellent measures of fit, suggesting that the five-factor approach is satisfactory from a statistical fit perspective. In both data sets, the set of five factors captures between 35% and 40% of the variance in the attitudinal variables, which is quite consistent with factor analyses results reported in the literature. Each additional factor captures a decreasing amount of additional variance in the data set, thus setting in diminishing returns by resorting to larger numbers of factors (not to mention the loss of interpretive strength). As such, the trade-off of number of

TABLE G-4. Factor analysis goodness-of-fit statistics for Charlotte.

Test			Result
Kaiser-Meyer-Olkin Measure of Sampling Adequacy			0.879
Bartlett's Test of Sphericity–Approx. Chi-Square			6345.764; df 153; Sig. 0.000
Total Variance Explained—Charlotte			
Factor	Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
Pro-car attitude	4.274	23.747	23.747
Consciousness	0.996	5.534	29.280
Low transit comfort level	0.684	3.799	33.080
Pro-transit attitude	0.391	2.173	35.253
Transit averse	0.272	1.510	36.763

TABLE G-5. Factor analysis goodness-of-fit statistics for Chicago.

Test			Result
Kaiser-Meyer-Olkin Measure of Sampling Adequacy			0.871
Bartlett's Test of Sphericity—Approx. Chi-Square			6787.285; df 153; Sig. 0.000
Total Variance Explained—Chicago			
Factor	Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
Pro-transit attitude	4.293	23.851	23.851
Pro-car attitude	1.180	6.553	30.404
Consciousness	0.607	3.371	33.775
Transit averse	0.510	2.836	36.611
Low transit comfort level	0.284	1.580	38.191

factors versus the percent of variance explained is one that the analyst must make from a qualitative interpretive standpoint while considering the values of the two goodness-of-fit statistics.

In the case of the Charlotte data set, it is found that the pro-car attitude factor captures the greatest extent of variance in the attitudinal variables; in the Chicago data set, it is found that the pro-transit attitude factor captures the greatest extent of variance in the attitudinal variables. This difference in findings between the two data sets is quite intuitive and consistent with the very different modal service in the two areas. While Charlotte has lower levels of transit and modal split is highly auto-dominated, Chicago has much higher levels of transit service (than does Charlotte), with considerably higher transit modal split than Charlotte. According to descriptive statistics presented in Appendix C, 35% of respondents in Charlotte never used any transit; the corresponding percentage for Chicago respondents is less than one-half of that figure at just 14%. The mode splits in Appendix C also support the notion that respondents in Chicago are likely to be more transit-oriented; in a transit-oriented survey of the nature administered in this project, a factor that captures attitudes toward transit is likely to explain more of the variance in the attitudinal variables for respondents with greater awareness and usage of transit.

The ultimate goal is to use the factors in mode choice models to better capture the influence of attitudes and values on people's mode choices. In order to assess the extent to which the extracted factors are correlated with mode choice, further exploratory analysis was conducted on the extracted factors.

Salt Lake City

There were 1,543 individuals (about 76% of the survey respondents) who reported using transit at least once in the past 12 months in Salt Lake City. These individuals were asked six attitudinal questions to which they had five response options—"Strongly Disagree," "Disagree," "Neutral," "Agree," and "Strongly Agree." The responses were then given positive or negative numerical values based on whether the responses were positive or negative. Factor analysis was used to group correlated variables together and then used to score how respondents are grouped under these factors based on their answers to the statements presented in the survey. Once this had been done, the factors and their scores were used to create composite attitudinal variables for use in the choice model effort.

There were 474 non-transit users who reported not using transit even once in the past 12 months. These respondents were asked nine attitudinal questions. Unlike the transit users, they also had an option to choose "Don't Know" as a response. This led to unusable responses for 31% of the cases.

The factor analysis for respondents who indicated they had used transit in the last year resulted in following two factors:

Factor 1: Convenience/Inclination Factor

- I currently make an effort to take public transit whenever I can.
- The transit system makes it easy for me to purchase my fare.
- When waiting for transit, I know when the next bus or train is scheduled to arrive.

Factor 2: Service Availability Factor

- If I wanted to, I could use public transit more frequently.
- I am able to take transit from my neighborhood to downtown Salt Lake City.
- I am able to take transit from my neighborhood to important and useful destinations (e.g., places I work, shop, go to school, run errands).

For individuals that used transit in the last year, the responses to the statements listed under Factor 1 were scored to respondents, and the statements listed under Factor 2 were also scored to respondents. These factors and respondents' scores were analyzed and seemed generally to make sense. These factors were cross-tabulated with choices made in the stated preference experiments to understand how individual attitudes about transit or auto correlate with stated mode preferences in the SP experiments.

The analysis for individuals who are not transit users resulted in the following three factors:

Factor 1: Inclination Factor

- I'm the kind of person who rides transit.
- For me, car is king! Nothing will replace my car as my main mode of transportation.
- I'm not afraid to ride transit.
- I would take transit if the environment in and near the stations/stops was improved with nice lighting, benches, and convenient vendors, like coffee shops, dry cleaners, clean restrooms, etc.

Factor 2: Discomfort and Inaccessibility Factor

- Transit is often dirty.
- Getting to and from transit stations/stops is not pedestrian friendly and is very unpleasant.
- I have to drive to get to transit anyway, so I may as well just drive my car the whole way.

Factor 3: Inconvenience Factor

- It's easy to plan a trip using transit.
- There's just not enough transit frequency or hours of service for transit to be convenient.

There were 430 non-transit choosers. These were respondents who fell into one of the following categories:

- Did not select a transit mode even once in each of eight CBC experiments
- Did not choose an available transit alternative in spite of being aware of it
- Indicated unwillingness to consider an available transit alternative about which they were unaware.

Analysis of non-transit choosers resulted in the following two factors:

Factor 1: Discomfort Factor

- Not safe enough
- Too crowded
- Uncomfortable
- Transit is too dirty

Factor 2: Inconvenience Factor

- Travel time too long
- Doesn't fit my schedule
- Less reliable than driving
- Too difficult to get to transit station/stop
- Transit doesn't go where I need to go
- It would require too many transfers to make the trip

Analysis of Factor Scores by Mode

TABLE G-6 (Charlotte) and TABLE G-7 (Chicago) offer a first indication of how the different factor scores vary by travel mode choice. In each data set, the mean factor scores are compared across the different modal segments in the sample. The factor scores are computed as linear combinations of the attitudinal variables for each respondent using the factor loadings provided in TABLE G-2 and TABLE G-3. The factor loadings (coefficients) represent the correlation of each attitudinal variable with the factor upon which it is loaded. Thus the factor loadings have neat interpretations. Once the linear combinations are computed to form factor scores, it is not straightforward to draw quantitative interpretations of the factor scores from a behavioral standpoint. However, relative values of factor scores provide insights into the extent to which different segments exhibit attitudinal traits. Factor scores are standardized with zero mean and standard deviation of one. The mean factor score for each modal segment then represents how the specific modal segment differs from other modal segments with respect to its attitudinal traits. The magnitude of the difference is indicative of how different the specific modal segment is in relation to other modal segments.

TABLE G-6. Comparison of mean factor scores across modal segments for Charlotte.

Mode	Sample Size	Pro-Car Attitude	Pro-Transit Attitude	Transit Averse	Low Transit Comfort Level	Conscious-ness
		Mean	Mean	Mean	Mean	Mean
Automobile	1162	0.08771	-0.16012	0.00972	0.14578	-0.03740
CATS local bus	100	-0.14257	0.78110	-0.08913	-0.48904	0.28130
CATS express bus	107	-0.62394	0.62386	-0.09511	-0.59140	0.14270
LYNX light rail	158	-0.13227	0.26071	0.04935	-0.36211	0.00035
TOTAL	1527					

In Charlotte (TABLE G-6), it is found that the mean factor scores vary across modal segments in an intuitive way:

- For the pro-car attitude factor, the automobile mode segment of the respondents has the highest mean value, while the CATS express bus segment has the lowest value. In other words, auto users have a higher value for the pro-car attitude factor (which is consistent with expectations), while those who use the express bus service have the most negative value (also consistent with expectations as it is likely that the express bus users are the least auto-oriented).

- With respect to the pro-transit attitude factor, the bus users have high positive factor score means, light rail users also exhibit a positive (but lower) value, and auto users exhibit a negative mean score. This progression in factor score means across modal segments is consistent with expectations; it probably takes individuals with a very Pro-transit attitude to use the bus in a city such as Charlotte, where transit service is not necessarily provided at a high level (when compared with more transit-rich cities, such as Chicago).

- With respect to the transit averse attitude factor, it is found that the automobile users and light rail users both have positive values with the light rail segment having a higher positive mean score. It appears that both auto users and light rail users are transit averse; in other words, the users of light rail do not associate light rail with "traditional" transit modes, such as bus and express bus. Even traditionally transit-averse people use light rail service, possibly because it is viewed as a premium transit mode.

- With respect to the low transit comfort level (in terms of access and use) attitude factor, the auto users have the highest mean score, which is consistent with expectations. Auto users are likely to exhibit the lowest level of transit comfort levels because they do not use transit. Transit users have uniformly negative factor scores for this factor, indicating a high level of comfort with transit. Consciousness is a factor and it is the local bus users who have the highest positive value on this factor and automobile users who have lowest value—once again consistent with expectations. It may be expected that bus users are most conscious about the environment and their own desire for productivity while traveling; in the case of Charlotte, it is found that local bus users have the highest value among transit users while light rail users have the lowest value among transit users.

TABLE G-7, providing a comparison for the Chicago sample, offers a similar interpretation across the board:

- Auto users show the highest positive value for the pro-car attitude factor while all transit segments show negative mean scores for this factor. In general, bus users are found to be more pro-Transit than the train and commuter rail users.

- Transit users show positive values on the pro-transit attitude factor while auto users show a negative mean score.

- The findings with respect to the transit averse attitude factor exhibit an element of ambiguity. Auto users have a positive value on this mean factor score, as expected. The Pace Bus and rail users have negative scores, which are intuitively reasonable. However, local and express bus users have positive values, which is somewhat counter-intuitive, as one would expect bus users to be *not* transit averse. However, it is possible that at least some of the bus users are "captive" and they are forced to ride transit even though they are intrinsically transit averse. This may be contributing to the positive mean scores for these two modal segments.

TABLE G-7. Comparison of mean factor scores across modal segments for Chicago.

Mode	Sample Size	Pro-Car Attitude	Pro-Transit Attitude	Transit Averse	Low Transit Comfort Level	Consciousness
		Mean	Mean	Mean	Mean	Mean
Automobile	787	0.24159	-0.50454	0.02097	0.00176	-0.10052
CTA local bus	184	-0.39846	0.70578	0.05568	-0.03586	0.06800
CTA express bus	45	-0.01205	0.81306	0.01348	-0.01287	0.26234
Pace bus	65	-0.34256	0.52178	-0.10203	0.04688	0.25157
CTA train (the 'L')	224	-0.33317	0.53239	-0.04786	-0.05673	0.06895
Metra commuter rail	207	-0.09359	0.37417	-0.04833	0.07466	0.11110
TOTAL	1512					

- For the last factor, representing low transit comfort level, the auto modal segment depicts a positive mean score, which is consistent with expectations. However, surprisingly, the Pace Bus and Metra Commute Rail segments also exhibit positive values for this factor, suggesting that these segments use these transit modes even though they intrinsically feel that transit is difficult to access and use. It should be noted that these two modal segments have the lowest positive mean scores on the pro-transit attitudinal factor. In other words, it appears that these two segments are not as strong in their Pro-transit attitude, suggestive of a lower transit comfort level relative to other transit mode segments.
- Those using bus services (express and Pace) show greater mean values for the Consciousness factor, once again suggesting that bus users are more conscious about the environment and their need/desire for productivity while traveling.

Summary of Results

In summary, the factor analysis effort has resulted in the extraction of five factors that capture the range of attitudes and values that people may have regarding the different modes of transport. The factors have intuitively appealing interpretations and, for the most part, are found to be strongly correlated with modal shares. This suggests that they would be good candidate factors for inclusion in models of mode choice that aim to accurately capture the effects of socioeconomic, demographic, level-of-service, and attitudinal variables on traveler choice behavior.

The factor analysis in Salt Lake City resulted in the extraction of two factors for transit users, three factors for non-transit users, and two factors for non-transit choosers that capture the range of attitudes and values that people have regarding modes. The number of attitudinal questions was increased significantly for Chicago and Charlotte, and the pool of respondents was not segmented for transit users and non-users, based on the analysis of this Salt Lake City data. All of the factors were tested in the mode choice models, but only the two factors for transit users were significant.

APPENDIX H

Integrated Choice and Latent Variable Models

Contents

Underlying attitudes and perceptions are potentially a key driver in explaining respondents' choices in real-world scenarios as well as in hypothetical settings. The survey work captured respondents' answers to a number of attitudinal questions. However, it should be clear that attitudes are unobserved (or latent), and that an analyst can only capture indicators of these attitudes. The reasoning is thus that any answers to attitudinal questions provided by a respondent are merely a function rather than a direct measure of the true underlying and unobserved attitudes. Directly incorporating such *indicators* in the utility function would put the research at risk of measurement error as well as endogeneity bias if the responses to attitudinal questions are correlated with other unobserved components.

These issues with measurement error and endogeneity bias can be avoided in a sequential modeling approach such as that discussed this far, in which a number of factors are estimated in a first stage, explaining the answers to the attitudinal questions, and where these factors are then used as explanatory variables in the utility functions of the choice model. However, the estimation of the factors is in this case informed only by the data on attitudinal questions, through calibration of a set of measurement equations that explain the answers to these questions, and not by the observed choices for the respondents. It should be clear that choices in the stated preference component are similarly influenced by these underlying attitudes, and not allowing the data on actual choices to contribute to the estimation of the factors can be seen as a disadvantage (reduced information), not helped by the fact that the researchers have only a single observation per respondent and per attitudinal question.

In this stage of the work, the research team makes use of a relatively recent addition to the family of mathematical models for explaining decision making processes. In these models, commonly referred to as hybrid choice models or more specifically integrated choice and latent variable (ICLV) models (Ben-Akiva et al. 1999; Ben-Akiva et al. 2002; Bolduc et al. 2005), the researchers explicitly allow for the impact of underlying attitudes on behavior. The attitudes themselves are treated as latent, and are hypothesized to influence both the observed choices and answers to any attitudinal questions. In contrast with the earlier work using separately estimated factors, the estimation of the latent attitudes is thus *informed* by the choice behavior in addition to the answers to the attitudinal questions.

Another advantage of ICLV models is their applicability in forecasting. Indeed, a key shortcoming of any sequential approach is that the factors would need to be modeled separately for forecasting purposes. In the ICLV model, the estimation produces parameters for the distribution of the latent variables, and these can then be directly used in model application. If the latent variable has sociodemographic interactions, as is the case in our empirical work, then forecasting can make use of adjusted sociodemographic variables that are in line with likely future population composition, thus producing more reliable measures of the latent attitudes. The fact that answers to attitudinal questions were included in model estimation will have contributed to the specification of the latent variables for use in model application and forecasts will only be produced for the choices. It should be acknowledged that this approach is based on the assumption that the deterministic relationship between any sociodemographic variables and the latent attitudes is stable over time, although the random component does allow for some additional flexibility.

Model Formulation

In an ICLV model, simultaneous estimation of measurement equations (explaining the observed answers to the attitudinal questions) and the choice model (explaining the stated or revealed choices) means that both components contribute to the estimation of the latent variables that now represent the attitudes. In particular, let α_n be a set of S different latent variables for respondent n. This establishes that the s^{th} latent variable for respondent n is defined as:

$$\alpha_{ns} = \gamma_s z_n + \eta_{ns} \qquad (1)$$

where γ_s is a vector of estimated parameters and z_n is a vector of characteristics of respondent n. The interaction between these parameters and characteristics forms the deterministic component of the latent variable, with the random component being η_{ns}, which can be defined to be a standard Normal variate (i.e., with a mean of zero and a standard deviation of 1).

Let $LC_n(\beta)$ be the probability of the observed sequence of choices for respondent n, conditional on a vector of parameters β that are to be estimated, where $LC_n(\beta)$ would often be given by a product of separate logit probabilities. This can be rewritten as $LC_n(\beta,\alpha_n)$, to recognise that the choices made by the respondent are influenced not just by the vector of parameters β, but also the vector of latent attitudes α_n. Typically, the role of the latent attitudes will be as interactions with a subset of the parameters in β, where in our case, it will be the alternative specific constants for the train and bus alternatives. In other words, whereas the utility of alternative j for respondent n would previously have been given by:

$$V_{nj} = f(\beta, x_{nj}, z_n) \qquad (2)$$

where x_{nj} is a vector of attributes of alternative j as faced by respondent n, and where allowance is made for interactions with sociodemographic characteristics z_n, the equation can be rewritten as:

$$V_{nj} = f(\beta, x_{nj}, z_n, \alpha_n, \tau) \qquad (3)$$

where τ is a vector of interaction parameters that explain the influence of α_n on V.

At the same time, the latent variables are also used to model the answers by respondents to the indicators, typically in the form of attitudinal questions. It is generally assumed that only one of the S latent variables is used for a given indicator k, where, typically, a given latent variable is used for more than one indicator. Assume that latent variable α_{ns} is used to explain the value for indicator k. In the majority of applications, the responses to the attitudinal questions are treated as continuous variables, that is, writing the value for the k^{th} indicator for respondent n as:

$$I_{nk}=\delta_k+\zeta_{sk}\alpha_{ns}+\nu_{kn} \quad (4)$$

where δ_k is a constant that captures the mean value of I_k in the sample population, ζ_{sk} is an estimated parameter capturing the impact of α_{ns} on I_k, and ν_{kn} is an error term, with a mean of zero and a standard deviation of σ_k. It can be noted that by subtracting the sample population mean of I_k from each I_{nk}, the need to estimate δ_k is avoided. With this specification, a positive estimate for ζ_{sk} would mean that an increase in the latent attitude α_{ns} leads to a higher value for I_{nk}, which, depending on the data could for example mean stronger agreement with the attitudinal statement.

The probability of the observed value for indicator k can then be written as a normal density, as follows:

$$LI_{nk}=\varphi(I_{nk}) \quad (5)$$

where $A(I_{nk}=q)$ is equal to 1 if $I_{nk}=1$, Q is the number of possible levels for the indicators, e.g. 5, and it is established that $\mu_{k,Q}$ = +∞ and $\mu_{k,0}$ = -∞ , such that the probability for an indicator value of 1 is given by $\frac{e^{\mu_{k,1}-\varsigma_{sk}\alpha_{ns}}}{1+e^{\mu_{k,1}-\varsigma_{sk}\alpha_{ns}}}$ and the probability for an indicator value of Q is given by $1-\frac{e^{\mu_{k,Q-1}-\varsigma_{sk}\alpha_{ns}}}{1+e^{\mu_{k,Q-1}-\varsigma_{sk}\alpha_{ns}}}$.

The thresholds in an ordered logit specification are increasing by definition. They control for the distribution of the different possible outcomes, in this case the different values for the indicators.

With the above specification, the probability of a given outcome is determined not just by the thresholds, but also by where on the distribution of the Q-1 thresholds the value $\varsigma_{sk}\alpha_{ns}$ falls. As an example, as the value of $\varsigma_{sk}\alpha_{ns}$ increases, it will gradually exceed the values of the individual thresholds, and the probability for a higher value of the indicator will increase. It should be noted that there is a risk of identification issues if all Q-1 thresholds are estimated plus the parameter ς_{sk}. In the present work, the researchers make use of a simplified structure in which ς_{sk} is constrained to a value of 1 for all k. This means that it is assumed that the impact of latent variable α_{ns} is positive for all the indicators where it is used in the measurement equations. For this reason, it is important that all indicators associated with a given latent variable are specified to act in the same direction, a condition that applies in the present study. The model is still able to allow for the strength of the impact of the latent variable α_{ns} to vary across the different indicators through the spacing of the thresholds. However, it is not possible for the analyst to determine what part of the variance of the thresholds is caused by the observed distribution for the indicators and what part is caused by the differential impacts of the latent variable α_{ns} on different indicators.

Independently of the specific functional form used for LI_{nk}, it is thus established that this probability is a function of α_n, rewritten as $L_{nk}(\alpha_n)$, and the probability of the observed values for the entire set of K indicators is given as follows:

$$LI_n(\alpha_n)=\prod_k LI_{nk}(\alpha_n) \quad (6)$$

where possible additional layers of integration need to be added if random heterogeneity not linked to the latent variables is to be introduced in the model.

The estimation of an ICLV model thus entails maximizing the joint likelihood of the observed choices and the observed answers to attitudinal questions. Both are a function of the latent variables, the estimation of which is thus informed by both model components when simultaneous estimation is used. By carrying out the integration jointly over the different model components, correlation is created between the responses to the attitudinal questions and the choices for a given respondent (i.e., this process ensures that the same value for the latent attitudes is used for the different model components for a given individual).

Specification of Latent Variables

For this set of 20 indicators, a total of seven different latent variables were employed for which a generic specification was used across the four subsets of the data (i.e., Chicago and Charlotte, each time split into commuters and non-commuters). In contrast with the earlier factor analysis, the estimation of the measurement equations was carried out separately for the two purpose segments in each city, rather than using a joint model. An exception to this arises in the case of the non-commute segment for Charlotte (discussed in a later section of this appendix).

In each segment, each of the latent variables is also used in an interaction with the constants for bus and train. The specification used is as follows:

α_1: Level of (Un-)Informedness

- This latent variable is used to explain the value of a single indicator, namely the stated level of informedness, which has five levels, where an ordered logit specification was used. The use of an ordered logit specification with the required increasing thresholds means that increases in the latent variable correspond to increases in the indicator. Here, it is important to note that a higher value for this indicator corresponds to a <u>lower stated level of informedness (i.e., higher uninformedness)</u>. Four threshold parameters were used (Threshold 1 for level of uninformedness, Threshold 2 for level of uninformedness, Threshold 3 for level of uninformedness, Threshold 4 for level of uninformedness).
- A single sociodemographic characteristic was used in the deterministic component of this latent variable, namely whether a respondent had lived in the area for more than 5 years.
- In the choice model, this latent variable was interacted with the constants for bus and train. Here, a positive value for these interaction parameters would mean that a higher value for the latent variable also leads to a more positive constant for the transit modes, with the opposite applying for negative estimates.

α_2: Willingness to Walk

- This latent variable is used to explain the value of a single indicator, namely the stated willingness to walk. This is a continuous variable, and a continuous specification was thus used, where, after subtracting the sample mean from the indicator for each person, only two parameters are estimated, namely a parameter capturing the impact of the latent variable on the indicator, and a parameter capturing the standard deviation of the indicator.

- Eight sociodemographic characteristics were used in the deterministic component of this latent variable, namely:

  - whether a respondent is a full-time student;
  - whether a respondent is employed full-time;
  - whether a respondent is retired;
  - whether a respondent is female;
  - whether a respondent is aged over 55 years;
  - the log of household income;
  - whether a respondent has lived in the area for more than 5 years; and
  - whether a respondent has reduced mobility.

- In the choice model, this latent variable was interacted with the constants for bus and train.

α_3: Pro-Transit Attitude

- This latent variable is used to explain the value of the following five indicators:

  - respondent's agreement with: I am not afraid to ride transit;
  - respondent's agreement with: I'm the kind of person who rides transit;
  - respondent's agreement with: I currently make an effort to take public transit whenever I can;
  - respondent's agreement with: If I wanted to, I could use public transit more frequently; and
  - respondent's agreement with: It's easy to plan a trip using transit.

- Each of these has five levels, and an ordered logit specification was used, with four thresholds each.

- Eight sociodemographic characteristic were used in the deterministic component of this latent variable, namely:

  - whether a respondent is a full-time student;
  - whether a respondent is retired;

- whether a respondent is female;
- whether a respondent is aged under 35;
- the number of vehicles in the respondent's household;
- the log of household income;
- whether a respondent has reduced mobility; and
- whether a respondent's household has more drivers than vehicles.

• In the choice model, this latent variable was interacted with the constants for bus and train.

α_4: Pro-Car Attitude

• This latent variable is used to explain the value of the following six indicators:

- respondent's agreement with the statement, For me, car is king! Nothing will replace my car as my main mode of transportation;
- respondent's agreement with the statement, Getting to and from transit stations/stops is not pedestrian friendly and is very unpleasant;
- respondent's agreement with the statement, I have to drive to get to transit anyway, so I may as well just drive my car the whole way;
- respondent's agreement with the statement, Transit is often dirty;
- respondent's agreement with the statement, My car reflects who I am; and
- respondent's agreement with the statement, My days of taking transit are over.

• Each of these has five levels, and an ordered logit specification was used, with four thresholds each.

• Six sociodemographic characteristic were used in the deterministic component of this latent variable, namely:

- whether a respondent is retired;
- whether a respondent is female;
- the number of vehicles in the respondent's household;
- the log of household income;
- whether a respondent has reduced mobility; and
- whether a respondent's household has more drivers than vehicles.

• In the choice model, this latent variable was interacted with the constants for bus and train.

α_5: Productivity Attitude

- This latent variable is used to explain the value of the following two indicators:
  - respondent's agreement with the statement, More than saving time, I prefer to be productive when traveling; and
  - respondent's agreement with the statement, If it would save time, I would change my form of travel.
- Each of these has five levels, and an ordered logit specification was used, with four thresholds each.
- Two sociodemographic characteristic were used in the deterministic component of this latent variables, namely:
  - whether a respondent is employed full-time; and
  - the log of household income.
- In the choice model, this latent variable was interacted with the constants for bus and train.

α_6: Environment Attitude

- This latent variable is used to explain the value of the following three indicators:
  - respondent's agreement with the statement, Protecting the environment is very important to me;
  - respondent's agreement with the statement, I am willing to carpool or take public transit more frequently to reduce air pollution and carbon emissions from my vehicle; and
  - respondent's agreement with: I am willing to pay higher tolls if they are used to reduce congestion.
- Each of these has five levels, and an ordered logit specification was used, with four thresholds each.
- Two sociodemographic characteristic were used in the deterministic component of this latent variable, namely:
  - whether a respondent is aged under 35 years; and
  - the number of vehicles a respondent's household owns.
- In the choice model, this latent variable was interacted with the constants for bus and train.

α_7: Privacy and Comfort Attitude

- This latent variable is used to explain the value of the following two indicators:
  - respondent's agreement with the statement, As long as I am comfortable when traveling, I can tolerate delays; and
  - respondent's agreement with the statement, Privacy is important to me when I travel.
- Each of these has five levels, and an ordered logit specification was used, with four thresholds each.
- Three sociodemographic characteristic were used in the deterministic component of this latent variable, namely:
  - whether a respondent is female;
  - the number of vehicles a respondent's household owns; and
  - whether children are present in the household.
- In the choice model, this latent variable was interacted with the constants for bus and train.

Model Estimation Procedure

The utility specifications from earlier parts of the research were reused for the choice model component of the ICLV model, with the following exceptions:

- Any coefficients associated with factors were removed, as were coefficients associated with stated high level of informedness and coefficients associated with different levels of stated willingness to walk.
- The grocery stop variable dropped from the Chicago commuter MNL models was retained.
- The additional fourteen interaction terms between latent variables and constants were added to the models.

The actual estimation consisted of simultaneous maximization of the likelihood from the two model components (i.e., the choice model and the measurement equations). The models were coded in Ox. In contrast with the simple MNL models, the ICLV models directly account for the repeated choice nature of the data. The results presented here make use of robust standard errors (i.e., using the sandwich estimator as opposed to the classical covariance matrix), thus accounting for effects of model mis-specification.

Given experience from the MNL analysis highlighting low value of time measures in the RP part of the data, the research team again proceeded by first estimating models on the stated preference data only, and then constraining the value of time in the joint RP/SP models to that from the SP only models.

In comparison with the MNL models, the numerical cost of estimating the ICLV models is very high, with models taking on average two days to reach convergence, which is a result of the need for simulation to approximate the value of the multi-dimensional integral, and also as a result of the very large number of parameters. With this in mind, it was not possible to use an iterative approach in which insignificant parameters were gradually removed, and consequently, the results presented here retain all parameters, even if not statistically significant. These will be further refined during model calibration and application to reduce variables to only those that are significant and important for policy purposes.

Model Exploration for Awareness and Consideration

An additional model investigation was carried out as part of this analysis, making use of latent variable models, in which were jointly modeled not just the choices and responses to attitudinal questions, as in the above, but also the responses to the awareness and consideration questions.

To this extent, the likelihood of the observed value for awareness for bus for respondent n was modeled as:

$$LAW_{nb} = \frac{AW_{nb}\left(e^{\delta_{WAb}+\tau_{AWb,\alpha_{n1}}\alpha_{n1}+\tau_{AWb,\alpha_{n3}}\alpha_{n3}}\right)+1-AW_{nb}}{1+e^{\delta_{AWb}+\tau_{WAb,\alpha_{n1}}\alpha_{n1}+\tau_{AWb,\alpha_{n3}}\alpha_{n3}}}$$

making it a function of the latent uninformedness attitude (α1) and the latent pro-transit attitude (α_3). A respondent will indicate that he is aware or not of bus, and this response (AW_{nb} being either 1 or 0) will be modeled as a binary logit model, with the utility for *not aware* being fixed to zero for normalization. In this utility, δ_{AWb} is a constant that captures the sample level mean of stated awareness for bus. The two τ parameters capture the impact of the latent variables on the probability of stated awareness.

Similarly, the likelihood of the observed value for consideration for bus for respondent n was modeled as:

$$LCON_{nb} = \frac{CON_{nb}\left(e^{\delta_{CONb}+\tau_{CONb,\alpha_{n2}}\alpha_{n2}+\tau_{CONb,\alpha_{n3}}\alpha_{n3}+\tau_{CONb,\alpha_{n4}}\alpha_{n4}}\right)+1-CON_{nb}}{1+e^{\delta_{CONb}+\tau_{CONb,\alpha_{n2}}\alpha_{n2}+\tau_{CONb,\alpha_{n3}}\alpha_{n3}+\tau_{CONb,\alpha_{n4}}\alpha_{n4}}}$$

making it a function of the latent willingness to walk attitude (α_2), the latent pro-transit attitude (α_3), and the latent pro-car attitude (α_4), where CON_{nb} is the observed response to the bus consideration question for respondent n, and where the remainder of the notation follows the same conventions as for awareness.

Similar functions were defined for the train option, labeled as LAW_{nt} and $LCON_{nt}$. The combined likelihood is now written as:

$$L_n=\int_\eta LC_n(\beta,\alpha_n)\, LI_n(\alpha_n) LAW_{nb}^{AVnb}\, LAW_{nt}^{AVnt}\, LCON_{nb}^{AWnb}\, LCON_{nt}^{AWnt}\, \varphi(\eta)d\eta,$$

Here, the additional exponents on LAW and LCON are needed as the awareness component of the model is only included when the mode in question was actually available (AV_{nb}=1 means that bus was available to respondent 1) while the consideration component is only included when the respondent had indicated previously that he/she was aware of the mode in question (AW_{nb} as previously defined).

Modeling Choice Set Generation

In all models included in the present report, be they MNL or ICLV, modes are included in the RP component of the choice model as a function of stated consideration. This is common practice and as such is entirely defensible. However, the actual consideration of a mode is arguably not observed but is itself latent, with the stated consideration being merely an indicator of actual consideration.

Very preliminary work was also conducted to explore the potential for modeling choice set generation in the present context. Specifically, the latent level of consideration of any unchosen RP alternative, say bus, could be written as:

$$\alpha_{CONb} = \delta_{CONb} + \tau_{CONb,\alpha_{n2}}\alpha_{n2} + \tau_{CONb,\alpha_{n3}}\alpha_{n3} + \tau_{CONb,\alpha_{n4}}\alpha_{n4},$$

noting that the latent consideration is itself a function of other latent variables from the overall model (and a constant), and is in fact equal to the denominator of the above latent consideration probability. This modeled probability of consideration is then used inside a probabilistic choice set generation model, thus no longer relying on the inclusion of an *unchosen* RP alternative in the model being determined by the *stated* 0-1 consideration variable. No successful estimations were carried out using this specification to date, but this approach remains an important area for future work

Summary of Latent Variables

For the present analysis, a set of 20 different indicators were used. In addition to the 18 attitudinal questions that were modeled by the factor analysis earlier in this study, the research team also treated the responses to the *willingness to walk* and the *level of informedness* questions as indicators of unobserved underlying attitudes. The researchers thus hypothesize that the actual willingness to walk and the actual perceived level of informedness are not observed by the analyst. Thus, while the earlier multinomial models used a mix between a sequential treatment of attitudes through factor analysis and a deterministic treatment of the stated level of informedness and the stated willingness to walk, all components in the ICLV models are represented through latent variables that are estimated jointly on the choice data and the indicator data.

There were seven latent variables included in the integrated choice and latent variable models, and each was represented by demographic characteristics that were significant in model estimation, as shown in TABLE H-1. This table also identifies the type of variable that is included and, for the attitudinal statements, how many levels are represented in each. The level of informedness variable also has five levels, where the willingness to walk variable is continuous.

TABLE H-1. Description of latent variables.

Latent Variable	Type*	Lived 5 years in area	Full-time student	Employed full-time	Retired	Female	Age under 35 years	Age over 55 years	Log of Household Income	Vehicles in Household	More Drivers Than Vehicles	Reduced Mobility	Households with Kids
Informed about transit	5 levels	√											
Willingness to walk	Continuous	√	√	√	√	√	√	√	√		√	√	√
Pro-transit factor	5 statements with 5 levels each		√		√	√	√		√	√	√	√	√
Pro-car factor	6 statements with 5 levels each				√	√			√	√	√	√	√
Productivity factor	2 statements with 5 levels each			√					√				
Environment factor	3 statements with 5 levels each							√		√			
Privacy and comfort factor	2 statements with 5 levels each					√				√			√

*The attitudinal statements used in each factor are documented in Appendix G.

Chicago Models

Separate models were estimated for commuters and non-commuters for the Chicago sample. Each time, the estimation involved the maximization of the joint likelihood for the stated choices and the observed answers to attitudinal questions, with both model components making use of the full set of latent variables.

Initial Observations

First examined are summary statistics for the two models (TABLE H-2). The overall log-likelihood for the models cannot be compared to that for the simple MNL model as it relates to the joint likelihood of the choice model and measurement equations component. However, it is possible to factor out the part of the log-likelihood relating to the choice component of the model only, conditional on the latent variable specification estimated jointly from the two parts. Here it is noted that in both segments, the log-likelihood for the choice model component is noticeably higher than what was obtained from the simple MNL models, with a difference by 671.5 units for commuters and 376.4 units for non-commuters. No formal tests of significance are possible given the different specification for the choice model component in the ICLV model compared to the simple MNL model, but the differences in fit clearly suggest an improvement in prediction capability.

Some differences also are noted in the scale parameter estimated for the SP part of the data when compared to the simple MNL model. Indeed, for both segments, the differences between the RP and SP scales are substantially larger than was the case in the simple MNL models. Additionally, both segments show higher scale for SP than for RP, where this was only the case for the commuter segment in the simple MNL model. Furthermore, both scale parameters are different from the base of one (1) at high levels of confidence, where this was not the case in the MNL models. In general, higher scale parameters for SP as opposed to RP are in line with expectations in joint RP/SP modeling, so these results are deemed reasonable and in support of the ICLV structure.

TABLE H-2. Summary statistics for the ICLV model in Chicago.

	Commuters		Non-Commuters	
Individuals	808		693	
Choice scenarios	7,272		6,237	
Overall log-likelihood	-30,082.90		-25,859.40	
Overall parameters	156		151	
Log-likelihood for choice model component	-5,128.00		-4,357.81	
Parameters for choice model component	48		43	
	Estimate	**Robust t-ratio**	**Estimate**	**Robust t-ratio**
rho	1.62	2.49	1.98	2.49

Base Utility Parameters

Next, those parameters that the choice model component of the ICLV model has in common with the simple MNL model are examined—those not interacted with the latent variables (TABLE H-3). The ICLV models specifically followed the same model specification for the base utility parameters as the MNL models to allow for comparative analysis. Looking first at the commuter results, it is apparent that all parameters retain the same sign, with the following exceptions:

- The constant for train becomes negative, but it is important to remember that this is now only the mean value which is interacted with a latent variable that does not necessarily have a zero mean given the sociodemographic interactions.

- The impact of the number of vehicles in a household on the utility of bus and train becomes positive, but is not statistically significant—this effect is now captured by the latent variables.

- The interaction between weekend travel and the constant for train becomes positive, but this parameter is not significant in either the MNL model or the ICLV model.
- Being a long-term resident now has a negative impact on the constant for train, where this effect is possibly now also captured by the latent variables.

A number of changes to significance levels also are noted, with fluctuations for most parameters, but where few of these involve a change from significance to non-significance (or vice versa), with some exceptions, as follows:

- The fixed mean parameters for both alternative specific constants are no longer statistically significant, most likely as these effects are now captured in the variation in these constants in interaction with the latent variables.
- The coefficient for parking cost for car is now statistically significant, which is a desirable development.
- The interaction between travel time sensitivity and the provision of amenities is no longer significant at the higher levels. It is not clear how this can easily relate to the addition of the interaction terms with latent variables.
- The reliability coefficient for train is now only significant at reduced levels.

Reductions in significance for many of the sociodemographic interactions also are observed, with several becoming insignificant. This is to be expected, as these interactions are now also captured in the latent variables.

For non-commuters, only two parameters change sign, namely:

- Having more drivers than vehicles in a household now shows a negative impact on the utility of bus and train, but this is no longer statistically significant, with its effect being captured by the latent variables.
- The interaction between being retired and the constant for train becomes positive, but is not significant in either model.

In terms of significance levels, a number of fluctuations are again observed, and the expected reductions for sociodemographic interactions. A number of key observations are that:

- The constant for train is now statistically significant.
- The impact of the number of vehicles on the utility for bus becomes insignificant, with its effect now being captured in the latent variables.
- The interaction between reduced mobility and the utility for bus and train becomes significant.

TABLE H-3. Base utility parameters for ICLV model in Chicago.

	Commuters						Non-Commuters					
	Auto		Bus		Train		Auto		Bus		Train	
Explanatory Variables	Est.	Rob. t-rat.	Est.	Rob. t-rat.	Est.	Rob. t-rat.	Est.	Rob. t-rat.	Est.	Rob. t-rat.	Est.	Rob. t-rat.
Alternative specific constant			0.1418	0.14	-1.6677	-1.49			2.5366	2.68	2.1539	2.38
Level of Service												
Access time (min.)†			-0.0348	-3.22	-0.0685	-4.68			-0.0423	-3.56	-0.0423	-3.56
Access time (min.) x Access mode (= walk)†			0.0210	2.45	0.0321	3.86			0.0192	2.66	0.0113	1.76
IVTT (min.)	-0.0182	-6.44	-0.0182	-6.44	-0.0182	-6.44	-0.0160	-4.93	-0.0160	-4.93	-0.0160	-4.93
Wait time (min.)			-0.0402	-5.40	-0.0294	-4.65			-0.0212	-4.20	-0.0212	-4.20
Fare ($)†			-0.5158	-3.80	-0.5158	-3.80			-0.5211	-3.35	-0.3721	-3.20
Auto cost($)	-0.2314	-3.69					-0.2437	-3.44				
Parking cost ($)†	-0.1073	-3.98	-0.0270	-0.54	-0.0123	-0.77	-0.1256	-4.37			-0.0429	-1.37
Access mode (walk over drive)†												
Span of service (all day v. only peak)†			0.4786	5.80	0.4786	5.80			0.3880	4.26	0.4779	4.92
Reliability (% on time)†			0.0986	2.46	0.0829	1.83	0.0420	0.71	0.0678	1.90		
No transfer			0.2556	4.82	0.2556	4.82			0.1375	3.38	0.1375	3.38
Premium on-board (prem. over standard)†			0.1220	2.84	0.1220	2.84			0.1746	2.92		
IVTT (min.) x amenities†					0.0024	1.73						
Premium stop design (prem. over standard)†			0.0955	2.91	0.0955	2.91			0.0806	2.72	0.0806	2.72

TABLE H-3. (Continued).

	Commuters						Non-Commuters					
	Auto		Bus		Train		Auto		Bus		Train	
Explanatory Variables	**Est.**	Rob. t-rat.	Est.	Rob, t-rat.	Est.	Rob. t-rat.	Est.	Rob. t-rat.	Est.	Rob. t-rat.	Est.	Rob t-rat.
Individual Demographics												
Full-time student									0.2250	0.77	0.2250	0.77
Full-time employed			0.7245	1.02	0.7245	1.02						
Homemaker											-0.1004	-0.92
Retired											0.2246	1.04
Female			-0.0615	-0.09	-0.0788	-0.11						
Longtime resident (5+ years)					-0.2300	-1.83			-0.1770	-1.85		
Has mobility problem			0.3300	1.78					0.6880	2.27	0.6880	2.27
Age less than 35 years			0.1298	0.56								
Age between 35 and 55 years					-0.1640	-0.73						
Age more than 55 years					-0.1329	-0.51						
Household Demographics												
Number of vehicles in household			0.0109	0.12	0.0109	0.12			-0.0069	-0.14		
Family income (In Income)			-0.1820	-3.10					-0.1388	-1.36	-0.1388	-1.36
More drivers than vehicles									-0.5589	-0.77	-0.5589	-0.77
Children (kids) present			0.2734	1.28	0.2734	1.28					0.1912	1.83
Trip Characteristics												
Group travel									-0.1851	-1.59	-0.1851	-1.59
Weekend trip					0.0238	0.20					0.0264	0.39
Makes stop for groceries			0.3258	1.54	0.3258	1.54			-0.3335	-2.48	-0.3335	-2.48
Makes stop for other			-0.1774	-0.95	-0.1774	-0.95						

Value of Time Measures

As a next step, the estimates from the two models are used to compute value of time measures for the two segments and the three different modes of travel (TABLE H-4). Drops in both segments compared to the MNL results are observed, with reductions in the value of time by around 30% for bus and train in the commuter segment, and by 34% for car, with drops by 30% for car and train in the non-commuter segment, and by 20% for bus. These drops can potentially be explained on the basis of the ICLV model being able to better capture underlying modal preferences (by allowing for heterogeneity) that could otherwise have unduly influenced the generic (across modes) travel time coefficient. As an example, if a large enough share of respondents have a strong dislike of bus and train, and if these modes are slower than car, then this could lead to an overestimation of the travel time sensitivity, and hence higher values of time.

TABLE H-4. Value of time ($/hour) for ICLV model in Chicago.

	Commuters		Non-Commuters	
	Estimate	Robust t-ratio	Estimate	Robust t-ratio
Auto	4.73	3.20	3.95	2.82
Bus	2.12	3.27	1.85	2.77
Train	2.12	3.27	2.59	2.69

Equivalent Valuations

The equivalent valuation is shown in minutes of in-vehicle time TABLE H-5 of various other service characteristics (both desirable and undesirable), where separate relative valuations are shown for train services with and without amenities for commuters (given the impact on in-vehicle time sensitivity). For each mode, the appropriate time coefficient is used. It is also of interest to compare the sensitivity to the different cost components, where results show lower sensitivity to parking costs than to auto cost or fare, where it is important to remember that the sensitivity to parking cost was not statistically significant for bus or train (and was not estimated for bus in the non-commuter segment).

Latent Variable Components

The key aspect of the ICLV models is the role of the latent variables in explaining both the answers to the attitudinal questions as well as their impact on the constants for bus and train in the choice model component. The different latent variables will be examined in turn.

The first latent variable (level of lack of transit information) is interacted with a single indicator where the use of an ordered logit specification means that increases in the indicator correspond to increases in the latent variable (TABLE H-6). Positive impacts on the value of this latent variable for longer term residents are observed. This suggests, maybe rather surprisingly, that respondents who have lived in the area for more than 5 years are more likely to indicate a lower level of transit information about public transit options. This applies to both commuters

TABLE H-5. Equivalent IVTT (in minutes) for various attributes of ICLV model in Chicago.

	Commute				Non-Commute		
Explanatory Variables	Auto	Bus	Train Basic	Train with Amenities	Auto	Bus	Train
Alternative specific constant	-	(7.78)	(91.52)		-	(158.06)	(134.22)
Level of service							
Access time (min.) if walking	-	1.91	3.76	4.33	-	2.64	2.64
Access time (min.) if not walking	0.75	2.00	2.00	2.30		1.44	1.94
Wait time (min.)	-	2.21	1.62	1.86	-	1.32	1.32
Fare ($) *			2.12			1.85	2.59
Auto cost ($) *	4.73				3.95	-	-
Parking cost ($) *	10.19	40.46	88.78		7.67	-	22.43
Span of service (all day v. only peak)	-	(26.26)	(26.26)	(30.24)	-	(24.17)	(29.78)
Reliability (% on time)	-	(5.41)	(4.55)	(5.24)	(2.62)	(4.23)	-
No transfer	-	(14.03)	(14.03)	(16.15)	-	(8.57)	(8.57)
Premium on-board (prem. over standard)†	-	(6.69)	(6.69)	(7.71)	-	(10.88)	-
Premium stop design (prem. over standard)	-	(5.24)	(5.24)	(6.04)	-	(5.02)	(5.02)
Individual Demographics							
Full-time student	-	-	-			-	(14.02)
Full-time employed	-	(39.76)	(39.76)			-	-
Homemaker	-	-	-			-	-
Retired	-	-	-			-	-
Female	-	3.38	4.33			-	-
Longtime resident (>5 years)	-	-	12.62			-	11.03
Has mobility problem	-	(18.11)	-			-	(42.87)
Age less than 35 years	-	(7.12)	-			-	-
Age between 35 and 55 years	-	-	9.00			-	-
Age more than 55 years	-	-	7.29			-	-
Household Demographics							
Number of vehicles in household	-	(0.60)	(0.60)			-	0.43
Family income (in income)	-	9.98	-			-	8.65
More drivers than vehicles	-	-	-			-	34.83
Children present	-	(15.00)	(15.00)			-	-
Trip characteristics							
Group travel	-	-	-			-	11.53
Weekend trip	-	-	(1.31)			-	-
Makes stop for groceries	-	(17.88)	(17.88)			-	20.78
Makes stop for other reasons	-	9.73	9.73			-	-

* In the case of fare, auto cost, and parking cost, the values are in units of $/hour of IVTT.

TABLE H-6. α1: Level of lack of transit information.

	Commuters		Non-Commuters	
α_1: Level of Lack of Transit Information	Estimate	Robust t-ratio	Estimate	Robust t-ratio
Threshold 1 for level of lack of transit information	-0.6426	-5.29	-0.7945	-5.20
Threshold 2 for level of lack of transit information	1.7650	13.46	1.6866	10.38
Threshold 3 for level of lack of transit information	2.4887	17.25	2.3336	13.50
Threshold 4 for level of lack of transit information	3.5295	19.37	3.3753	16.62
Impact on latent variable for respondents who have lived in the area for more than 5 years	0.6792	4.41	0.8023	4.28
Impact of latent variable on bus constant	-0.4973	-3.49	0.0883	0.53
Impact of latent variable on train constant	0.0243	0.19	0.0049	0.02

and non-commuters. However, no impact of this latent variable is observed for non-commuters for either mode, or for train in the commuter segment. The only significant impact is on the utility of bus in the commuter model, where the effect is negative, suggesting that a lower level of transit information (remembering that a higher value for the indicator means being less informed) leads to a rejection of bus as a commute option.

The second latent variable explains the value of the stated duration that a respondent is willing to walk (TABLE H-7). This measurement equation used a continuous specification, where a higher value for the latent variable is seen to be associated with an increase in the indicator, where this effect is stronger for non-commuters.

In the commute segment, higher values for the latent variable for full-time students and respondents who have been living in the area for longer than 5 years are observed; however, both interactions are only significant at reduced levels of confidence. In the non-commuter segment, the latent variable is higher for full-time students, while it is lower for retired respondents and respondents with reduced mobility.

Both segments show a positive impact of the latent variable on the utility for bus and train, indicating that a greater willingness to walk leads to increased utility for public transport, where this effect is similar for the two modes for commuters, while, for non-commuters, it is much stronger for train than for bus.

TABLE H-7. α2: Willingness to walk.

	Commuters		Non-Commuters	
α_2: Willingness to Walk	Estimate	Robust t-ratio	Estimate	Robust t-ratio
Impact of latent variable on stated willingness to walk	1.5860	2.56	3.0835	4.93
Standard deviation of stated willingness to walk	10.3590	11.81	11.9250	11.01
Impact on latent variable for full-time students	0.3804	1.72	0.5634	1.88
Impact on latent variable for respondents in full-time employment	-0.1061	-0.21	0.0248	0.16
Impact on latent variable for retired respondents	-		-0.8362	-2.22
Impact on latent variable for female respondents	-0.0081	-0.02	-0.1112	-0.91
Impact on latent variables for respondents aged over 55 years	0.0121	0.08	0.1211	0.69
Impact on latent variable of log of household income	-0.0186	-0.34	0.0332	1.25
Impact on latent variable for respondents who have lived in the area for more than 5 years	0.1922	1.75	-0.2312	-1.02
Impact on latent variable for respondents with reduced mobility	-0.0667	-0.40	-0.6056	-2.67
Impact of latent variable on bus constant	1.3683	6.13	0.2877	1.61
Impact of latent variable on train constant	1.4634	6.04	0.7218	3.76

The third latent variable (pro-transit attitude) is interacted with five indicators in an ordered logit specification, meaning that increases in the indicators (i.e., stronger agreement with the attitudinal statements) correspond to increases in the latent variable (TABLE H-8). Positive impacts on the latent variable for full-time students in both segments are observed, indicating a stronger pro-transit attitude. The opposite is the case for retired respondents in the non-commuter segment, possibly related to walking issues, as well as for female respondents, where this is only significant at usual levels in the non-commuter segment, and where this could possibly be explained on personal safety grounds. Younger respondents are more pro-transit, although this effect is not highly significant. In both segments, respondents with more vehicles have a more negative value for the latent attitude, with the same applying to respondents with reduced mobility, although this is not highly significant in the non-commute segment. Two additional interactions are significant in the commute segment. A higher value for the pro-transit latent attitude is observed for respondents from households with more drivers than vehicles, which is consistent with intuition. More surprisingly, a positive impact on the latent attitude for higher income respondents is seen. This could possibly be explained on the grounds of higher income commuters having their workplaces located in areas where transit is a good option.

TABLE H-8. α3: Pro-transit attitude.

	Commuters		Non-Commuters	
α_3: Pro-Transit Attitude	Estimate	Robust t-ratio	Estimate	Robust t-ratio
Threshold 1 for Attitudinal Statement 1	-2.7976	-4.08	-5.0266	-6.39
Threshold 2 for Attitudinal Statement 1	-1.3331	-2.01	-3.6149	-4.69
Threshold 3 for Attitudinal Statement 1	-0.2912	-0.44	-2.5739	-3.36
Threshold 4 for Attitudinal Statement 1	1.4676	2.22	-0.7417	-0.98
Threshold 1 for Attitudinal Statement 2	-1.4078	-2.11	-3.4610	-4.48
Threshold 2 for Attitudinal Statement 2	-0.1418	-0.21	-2.2320	-2.93
Threshold 3 for Attitudinal Statement 2	1.4713	2.23	-0.7899	-1.03
Threshold 4 for Attitudinal Statement 2	3.0135	4.53	0.6484	0.84
Threshold 1 for Attitudinal Statement 3	-0.9054	-1.37	-3.1546	-4.07
Threshold 2 for Attitudinal Statement 3	0.2734	0.41	-1.9427	-2.54
Threshold 3 for Attitudinal Statement 3	1.5124	2.30	-0.6794	-0.89
Threshold 4 for Attitudinal Statement 3	3.1649	4.76	0.9070	1.18
Threshold 1 for Attitudinal Statement 4	-0.7827	-1.19	-3.2362	-4.20
Threshold 2 for Attitudinal Statement 4	0.4491	0.68	-1.8392	-2.39
Threshold 3 for Attitudinal Statement 4	1.6248	2.47	-0.8738	-1.14
Threshold 4 for Attitudinal Statement 4	3.2941	4.94	0.8358	1.08
Threshold 1 for Attitudinal Statement 8	-1.7725	-2.68	-4.0429	-5.17
Threshold 2 for Attitudinal Statement 8	-0.2294	-0.35	-2.5545	-3.31
Threshold 3 for Attitudinal Statement 8	1.1191	1.70	-1.2826	-1.67
Threshold 4 for Attitudinal Statement 8	3.0295	4.55	0.8211	1.08
Impact on latent variable for full-time students	0.5203	2.47	0.7730	3.80
Impact on latent variable for retired respondents	-		-0.7732	-4.60
Impact on latent variable for female respondents	-0.1644	-1.48	-0.4332	-3.69
Impact on latent variables for respondents under the age of 35 years	0.2084	1.64	0.2403	1.60
Impact on latent variable of the number of vehicles a household owns	-0.4224	-7.86	-0.5015	-7.35
Impact on latent variable of log of household income	0.1512	2.51	-0.0248	-0.34
Impact on latent variable for respondents with reduced mobility	-0.4644	-1.95	-0.2886	-1.51
Impact on latent variable if respondent's household has more drivers than vehicles	0.7005	2.78	0.1255	0.36
Impact of latent variable on bus constant	0.6617	4.71	0.4749	3.98
Impact of latent variable on train constant	0.6440	4.40	0.4020	3.47

In terms of the impact on the choice model, a positive effect of the latent variable on the utility for both bus and train is seen in both segments, consistent with intuition, where this effect is quite similar for the two modes.

The fourth latent variable (pro-car attitude) is interacted with six indicators in an ordered logit specification, meaning that increases in the indicators (i.e., stronger agreement with the attitudinal statements) correspond to increases in the latent variable (TABLE H-9).

The research team notes negative impacts for higher income respondents in the commute segment, consistent with the results for the pro-transit attitude, along with a negative effect for respondents from households with more drivers than vehicles, where this also applies in the non-commute segment, though to a lesser effect. Both segments show an intuitively correct positive effect on the latent attitude if the number of cars in a household is higher, along with positive effects for respondents with reduced mobility, and retired non-commuters.

The impact of this latent variable on the bus and train constants in the choice model component is negative as expected, where it is slightly stronger for train than for bus for commuters, with the opposite applying for non-commuters.

The productivity latent attitude (TABLE H-10) is used to explain the values of two indicators in an ordered logit specification, once again meaning that higher values for the latent variable correspond to stronger agreement with the attitudinal statements. Neither of the two sociodemographic interactions is significant for commuters, though the positive sign for income is arguably consistent with intuition, with higher income respondents desiring better time-use. For non-commuters, a positive impact on the latent variable for full-time employees is seen. In both segments, the latent variable has the expected positive effect on the utility for bus and train, where there is a stronger effect for train than for bus in the case of commuters, reflecting the greater ability to use time productively when traveling by train.

The pro-environment latent attitude (TABLE H-11) is used to explain the values of three indicators in an ordered logit specification, once again meaning that higher values for the latent variable correspond to stronger agreement with the attitudinal statements. Positive impacts on the latent attitude for younger respondents are noted, as are negative impacts (albeit not significant) for respondents from households with more vehicles. For commuters, there is a positive impact of the latent variable on the utility for both bus and train, where this is stronger for bus. For non-commuters, the impact is also positive, but not significant at usual levels of confidence.

The privacy and comfort latent attitude (TABLE H-12) is used to explain the values of two indicators in an ordered logit specification, with increases in the latent variable corresponding to increases in the indicator. The only significant interaction is a positive effect for female respondents (i.e. a stronger attitude) in the non-commute segments. For commuters, the expected negative impact of this latent variable on the utility for bus—and to a lesser extent train (where privacy and comfort are maybe less important)—is observed. For non-commuters, the effect is surprisingly positive, and this is possibly caused by the same reasons as the positive effect of the low transit comfort level in the earlier MNL models.

TABLE H-9. α4:Pro-car attitude.

α_4: Pro-Car Attitude	Commuters		Non-Commuters	
	Estimate	Robust t-ratio	Estimate	Robust t-ratio
Threshold 1 for Attitudinal Statement 5	-2.7496	-4.07	-1.0568	-1.49
Threshold 2 for Attitudinal Statement 5	-1.4490	-2.16	-0.0312	-0.04
Threshold 3 for Attitudinal Statement 5	-0.1436	-0.21	1.0446	1.48
Threshold 4 for Attitudinal Statement 5	1.2601	1.84	2.3447	3.33
Threshold 1 for Attitudinal Statement 6	-3.3346	-4.93	-1.7270	-2.42
Threshold 2 for Attitudinal Statement 6	-1.7956	-2.66	-0.1576	-0.22
Threshold 3 for Attitudinal Statement 6	-0.2533	-0.37	1.2671	1.78
Threshold 4 for Attitudinal Statement 6	1.5004	2.19	2.8200	3.90
Threshold 1 for Attitudinal Statement 7	-2.3557	-3.49	-0.8605	-1.21
Threshold 2 for Attitudinal Statement 7	-1.3533	-2.00	0.2893	0.41
Threshold 3 for Attitudinal Statement 7	-0.2656	-0.39	1.4004	1.98
Threshold 4 for Attitudinal Statement 7	1.2121	1.77	3.0951	4.32
Threshold 1 for Attitudinal Statement 9	-4.3738	-6.26	-3.0784	-4.10
Threshold 2 for Attitudinal Statement 9	-2.6438	-3.91	-1.0733	-1.51
Threshold 3 for Attitudinal Statement 9	-1.0739	-1.60	0.4469	0.63
Threshold 4 for Attitudinal Statement 9	1.0853	1.60	2.7033	3.79
Threshold 1 for Attitudinal Statement 17	-2.8095	-4.12	-0.8638	-1.21
Threshold 2 for Attitudinal Statement 17	-1.6074	-2.38	0.0948	0.13
Threshold 3 for Attitudinal Statement 17	0.1126	0.17	1.7994	2.53
Threshold 4 for Attitudinal Statement 17	1.8755	2.70	3.5402	4.93
Threshold 1 for Attitudinal Statement 18	-2.0140	-2.97	-0.3131	-0.45
Threshold 2 for Attitudinal Statement 18	-0.8247	-1.22	0.7984	1.14
Threshold 3 for Attitudinal Statement 18	0.6791	1.01	1.9415	2.75
Threshold 4 for Attitudinal Statement 18	1.9281	2.81	3.1040	4.39
Impact on latent variable for retired respondents	-		0.2967	1.81
Impact on latent variable for female respondents	0.0927	0.83	0.1366	1.47
Impact on latent variable of the number of vehicles a household owns	0.3319	6.80	0.3303	5.62
Impact on latent variable of log of household income	-0.1590	-2.54	-0.0191	-0.29
Impact on latent variable for respondents with reduced mobility	0.7653	3.85	0.3649	2.49
Impact on latent variable if respondent's household has more drivers than vehicles	-0.7390	-2.75	-0.6117	-1.77
Impact of latent variable on bus constant	-0.7412	-5.20	-0.8602	-4.74
Impact of latent variable on train constant	-0.8211	-5.15	-0.7077	-4.62

TABLE H-10. α5:Productivity attitude.

	Commuters		Non-Commuters	
α_5: Productivity Attitude	Estimate	Robust t-ratio	Estimate	Robust t-ratio
Threshold 1 for Attitudinal Statement 10	-2.1225	-2.47	-2.5204	-2.64
Threshold 2 for Attitudinal Statement 10	-0.6918	-0.82	-0.9899	-1.05
Threshold 3 for Attitudinal Statement 10	1.2376	1.47	0.9942	1.05
Threshold 4 for Attitudinal Statement 10	3.3041	3.83	3.1192	3.23
Threshold 1 for Attitudinal Statement 11	-1.8626	-2.18	-2.2673	-2.38
Threshold 2 for Attitudinal Statement 11	-0.9276	-1.10	-1.1916	-1.26
Threshold 3 for Attitudinal Statement 11	0.5278	0.63	0.4025	0.43
Threshold 4 for Attitudinal Statement 11	2.5097	2.95	2.3419	2.46
Impact on latent variable for respondents in full-time employment	-0.0725	-0.55	0.3360	2.43
Impact on latent variable of log of household income	0.0918	1.18	0.0529	0.61
Impact of latent variable on bus constant	0.3548	1.97	0.4378	2.99
Impact of latent variable on train constant	0.5721	2.95	0.4586	3.24

TABLE H-11. α6: Environment attitude.

	Commuters		Non-Commuters	
α6: Environment Attitude	Estimate	Robust t-ratio	Estimate	Robust t-ratio
Threshold 1 for Attitudinal Statement 13	-3.6948	-16.59	-3.9488	-15.46
Threshold 2 for Attitudinal Statement 13	-2.6164	-15.56	-2.8520	-15.35
Threshold 3 for Attitudinal Statement 13	-0.5779	-4.33	-0.6616	-4.48
Threshold 4 for Attitudinal Statement 13	1.4916	10.57	1.4324	9.08
Threshold 1 for Attitudinal Statement 14	-2.6839	-15.34	-2.5873	-14.13
Threshold 2 for Attitudinal Statement 14	-1.4966	-10.36	-1.3835	-8.84
Threshold 3 for Attitudinal Statement 14	0.2765	2.06	0.0580	0.40
Threshold 4 for Attitudinal Statement 14	1.9672	12.65	1.9443	11.67
Threshold 1 for Attitudinal Statement 15	-1.3468	-9.59	-1.2308	-8.04
Threshold 2 for Attitudinal Statement 15	-0.0749	-0.57	-0.1462	-0.99
Threshold 3 for Attitudinal Statement 15	1.2892	9.65	1.2312	7.93
Threshold 4 for Attitudinal Statement 15	3.2276	16.67	3.3821	14.87
Age < 35	0.2384	1.97	0.2634	1.93
Impact on latent variable of the number of vehicles a household owns	-0.0303	-0.63	-0.0648	-1.07
Impact of latent variable on bus constant	0.3837	3.07	0.1252	1.19
Impact of latent variable on train constant	0.2625	2.07	0.1843	1.48

TABLE H-12. α7: Privacy and comfort attitude.

	Commuters		Non-Commuters	
α7: Privacy and Comfort Attitude	Estimate	Robust t-ratio	Estimate	Robust t-ratio
Threshold 1 for Attitudinal Statement 12	-2.7560	-14.75	-2.7412	-13.93
Threshold 2 for Attitudinal Statement 12	-1.0573	-6.93	-0.9883	-6.25
Threshold 3 for Attitudinal Statement 12	0.2878	1.92	0.2883	1.86
Threshold 4 for Attitudinal Statement 12	2.6292	13.88	2.8887	13.94
Threshold 1 for Attitudinal Statement 16	-3.5766	-15.68	-3.3760	-14.94
Threshold 2 for Attitudinal Statement 16	-1.8383	-11.57	-1.6515	-10.28
Threshold 3 for Attitudinal Statement 16	-0.0155	-0.11	0.0198	0.13
Threshold 4 for Attitudinal Statement 16	1.8808	11.20	1.8754	10.78
Impact on latent variable for female respondents	-0.0701	-0.58	0.2173	2.01
Impact on latent variable of the number of vehicles a household owns	-0.0246	-0.48	-0.0263	-0.40
Impact on latent variables if children are present in household	0.1556	1.40	0.0968	0.60
Impact of latent variable on bus constant	-0.8685	-4.22	0.9080	4.39
Impact of latent variable on train constant	-0.5121	-2.73	0.6854	4.04

Awareness and Consideration

Another advantage of the ICLV modeling approach is that awareness and consideration modeling can be jointly modeled with the traveler attitudes in mode choice. An exploration of this was undertaken in this project. While this has theoretical advantages because the choices are estimated jointly, the models were much more complex and were not successful using these specifications. It will be necessary to reduce complexity in some parts of the model to achieve a specification that can be estimated to include awareness and consideration within the model specifications (rather than as an input). This can be a focus of future work.

This model was only tested on the Chicago commuter segment. Furthermore, given the additional complexity of the structure, a simplified version of the measurement equations was used, with a continuous specification for all indicators, as opposed to the ordered logit approach. The resulting model produced a log-likelihood for the choice model component of the overall structure of -5,124 units, thus slightly better still than the ICLV model discussed earlier. This suggests that when additionally including the awareness and consideration components in the overall structure, a better explanation of the latent attitudes is obtained, which contributes to better fit for the choice model component.

Given the exploratory nature of this part of the work, the research team focused solely on the additional component of this model, rather than presenting all estimates (TABLE H-13). Positive constants are noted which represent the fact that on average, when used, more than 50% of respondents responded positively to the awareness question, with the same applying to the consideration question. For the latter, the response was even more positive on average, with the majority of respondents who indicated that they were aware of the mode also indicating that they had considered it.

TABLE H-13. Additional components of the ICLV model.

	Estimate	Robust t-ratio
Constant for bus awareness	0.6351	1.97
Constant for train awareness	2.2338	2.64
Constant for bus consideration	0.9166	4.71
Constant for train consideration	3.1874	6.02
Impact of latent level of lack of transit information on bus awareness	-0.1620	-0.75
Impact of latent pro-transit attitude on bus awareness	0.8161	4.74
Impact of latent level of lack of transit information on train awareness	-0.6043	-0.52
Impact of latent pro-transit attitude on train awareness	0.6734	2.92
Impact of latent willingness to walk on bus consideration	0.3054	0.59
Impact of latent pro-transit attitude on bus consideration	0.7358	2.20
Impact of latent pro-car attitude on bus consideration	-0.1255	-0.42
Impact of latent willingness to walk on train consideration	0.9032	1.13
Impact of latent pro-transit attitude on train consideration	0.5860	1.30
Impact of latent pro-car attitude on train consideration	-0.1238	-0.19

Turning to the interaction parameters, it is notable that while the sign of the interaction terms between the lack of transit information latent variable and the probability of stating awareness is negative as expected (i.e., if a respondent is less well informed, he/she is less likely to be aware), the interaction parameters are not statistically significant. On the other hand, a more positive pro-transit attitude leads to increases in the probability of stated awareness. In the consideration model, increased willingness to walk leads to increased probability of stated consideration for both modes, but the effect is not significant. Increases in the latent pro-transit attitude lead to a higher probability of stating that bus was considered, with the same applying for rail, where the effect is however not statistically significant. Finally, the sign of the impact of a pro-car attitude on the consideration for transit modes is negative as expected, but not statistically significant.

From the above discussion, it becomes clear that the inclusion of this additional model component produces reasonable model results, but that the effects are of low statistical significance. The main reason for this is the very high level of stated awareness and consideration. As an example, for Chicago commuters, 68.4% of respondents where bus was available stated to have been aware of it. Even more importantly, of those respondents who stated that they were aware of bus, 81.4% of respondents also stated that they had considered it. For train, the figures are even higher, with 87.7% stating awareness when available, and 97% stating consideration when aware. These high positive response rates mean that the majority of the response patterns are explained through the constants included in the awareness and consideration models. These problems were compounded in other segments, which led to abandoning this exploratory research—for example, in the Charlotte non-commuter segment, every respondent who had stated to be aware of train had also stated to have considered it. Furthermore, it should be remembered that the awareness component could only be included when the mode was actually available, where this for example applies to only 38% of Chicago commuters for bus, and 41% for train, leading to small sample sizes.

Despite these problems, the above model results are promising. For future research using these datasets, it is suggested that researchers model combined awareness and consideration (i.e., a positive response is when a respondent indicates he or she is aware of a mode and has considered it). This would lead to a less strong positive response overall, and would also avoid the issue of consideration being modeled separately, in which case, with it having to be conditional on awareness, the probability in the data is too close to one (1) to allow for separate analysis, given the above, and the sample size is also affected.

Charlotte Models

As with the Chicago data, separate models were estimated for commuters and non-commuters for the Charlotte sample. Each time, the estimation involved the maximization of the joint likelihood for the stated choices and the observed answers to attitudinal questions, with both model components making use of the full set of latent variables.

Initial Observations

Summary statistics are again examined for the two models (TABLE H-14). A comparison of the fits for the choice model component in the ICLV model and the earlier MNL models shows that, for the commuter segment, a substantially higher log-likelihood is again obtained by using the latent variable approach instead of the sequential factor analysis approach, with an increase by around 830 units. The estimated difference in scale between the SP and RP part of the data also is substantially larger than was the case in the MNL models, with a scale parameter of 4.49, compared to the earlier estimate of 1.46.

TABLE H-14. Summary statistics for the ICLV model in Charlotte.

	Commuters		Non-Commuters	
Individuals	1,041		465	
Choice scenarios	9,369		4,185	
Overall log-likelihood	-38,542.70		-18,042.30	
Overall parameters	153		150	
Log-likelihood for DCM component	-6,295.66		-3,577.66	
Parameters for DCM component	45		42	
	Estimate	**Robust t-ratio**	**Estimate**	**Robust t-ratio**
rho	4.49	3.38	1.68	0.26

Turning our attention to the results for non-commuters, the findings are more disappointing. The log-likelihood for the choice model component is lower by around 200 units. This means that, with this sample, the sequential approach leads to better performance, where the other distinction arises in the deterministic treatment of the stated level of transit information and the stated willingness to walk in the earlier models.

A closer study of the ICLV results for the non-commuter segment, which is to follow, shows a lack of impact of the latent variables in the choice model part of the overall structure. An initial hypothesis was that this could be caused by a low level of information contained in the measurement equations part of the overall model. To understand this, it should be remembered that, while the data for the choice model component contains 4,185 observations, only a single observation for each indicator is contained in the data used for the measurement equations (i.e., 465 observations per indicator). In the earlier models, the estimation of the factors was based jointly on the data for commuters and non-commuters (i.e., 1,501 observations per indicator). To test whether this is the source for the difference in performance, an additional model was estimated in which the choice component of the overall structure makes use of data from the 465 non-commuters only, while the measurement equations make use of data from all 1,501 respondents in the Charlotte sample. This thus means that while the link, by way of the latent variables, between responses to attitudinal questions and preferences in the choice model is only made for those respondents (i.e., non-commuters) included in both model components, the estimation of the latent variables themselves is also informed by the attitudinal data from the commuter segment.

The results for this new model however revealed no improvement in the ability to link preferences to latent variables, and in fact highlighted a small further drop in the fit for the choice model component. To some extent, this drop in fit is not completely unexpected—the weight of the measurement equations part of the model is increased in this new specification and, in joint estimation of the two components, this can have a detrimental impact on the choice model component. This would be especially the case when there is a lack of correspondence between the two types of data. In the remaining three segments of this study, there seems to be strong correspondence between the choice model and the measurement equations part of the model, and their joint estimation helps both components. This is not the case in the Charlotte non-commuter segment. One possible reason is that the actual specification of the models is at fault here, and that a structure that worked well for the remaining three segments is not as suitable for this segment, e.g. potentially calling for a different specification of the latent variables, in terms of which latent variables are used for which indicators. However, in the earlier MNL models, a generic specification was used for the factor analysis in the commute and non-commute segments, as well as for the impact on the constants in the choice models.

The actual reason for the disappointing performance of the models in the non-commuter segment thus remains unclear. The most likely explanation relates to the sample size for the choice model component, where this is smaller by 55% compared to the commuter segment, and 33% compared to the next smallest segment overall in the study, namely the non-commuter segment in the Chicago data. The same differences in sample size clearly also applied in the MNL models. However, a key distinction arises in the estimation procedure used for the models. In the MNL models, the smallest unit of contribution to the log-likelihood function is an individual observation (i.e., one choice). This means that the number of data points is equal to the number of choices. In the estimation of the ICLV models, integration over the distribution of the latent variables is required where this is carried out at the level of an individual respondent. This in turn means that the smallest unit of contribution to the log-likelihood function is the joint probability of the sequence of choices for a given respondent and the answers to all attitudinal questions. This thus leads to only 465 individual contributions to the log-likelihood function. This would not be an issue in MNL models, but in the models used here, the integration over the random component means that the distribution of that random component is characterized by only 465 individual 'data points'. Thus, while the percentage reduction in sample size compared to the other segments is clearly the same for the MNL models as for the ICLV models, the absolute number of points in the log-likelihood functions in the ICLV models seems to go beyond a 'tipping point' where it becomes difficult to adequately estimate the role of these random components.

Base Utility Parameters

Next to be examined are those parameters that the choice model component of the ICLV model has in common with the simple MNL model (i.e., those not interacted with the latent variables as shown in TABLE H-15). Given the obvious issues with the model for non-commuters, the discussion in this section focuses on the results from the commuter segment, with the non-commuter results also included in the table for reference.

Note that all parameters retain the same sign, with the following exceptions:

- The constant for train becomes negative, but is not statistically significant in either model (MNL or ICLV).
- The impact of being full-time employed on the utility for bus becomes negative, but is not statistically significant in either model.
- The interaction between being aged over 55 and the utility for bus is now negative, but no longer significant.
- The impact of income on the utility for bus is now positive, but no longer significant.
- A number of changes to significance levels occur, with fluctuations for most parameters. Notable observations include:
  - The constant for bus is no longer statistically significant, where it is important to remember that this now relates solely to the mean of the constant.
  - The utility of premium on-board services for bus is now statistically significant.
  - The effect of amenities on the in-vehicle travel time sensitivity for bus is no longer statistically significant.
  - The effect of being female on the utility for train is no longer statistically significant.
  - The effect of both age interactions on the utility of bus is no longer statistically significant.

Value of Time Measures

As was the case for the Chicago models, substantial drops in the value of time measures are observed, with a drop by 58% for auto, and by 33% for bus and train. For non-commuters, a drop in auto value of time by 20% is observed, but the actual value of time is no longer statistically significant (TABLE H-16).

TABLE H-15. Base utility parameters for ICLV model in Charlotte.

	Commuters						Non-Commuters					
	Auto		Bus		Train		Auto		Bus		Train	
Explanatory Variables	Est.	Rob. t-rat.	Est.	Rob. t-rat.	Est.	Rob. t-rat.	Est.	Rob. t-rat.	Est.	Rob. t-rat.	Est.	Rob. t-rat.
Alternative specific constant			0.4335	0.89	-0.2407	-0.85			2.3925	1.98	0.3334	1.14
Level of Service												
Access time (min.)†			-0.0083	-2.91	-0.0168	-3.32			-0.0227	-1.84	-0.0594	-1.59
Access time (min.) x Access mode (= walk)†					-0.0023	-0.42					0.0148	1.50
IVTT (min.)	-0.0108	-4.67	-0.0108	-4.67	-0.0108	-4.67	-0.0098	-2.09	-0.0037	-1.93	-0.0037	-1.93
Wait time (min.)			-0.0141	-4.38	-0.0141	-4.38			-0.0228	-2.44	-0.0257	-1.95
Fare ($)†			-0.1778	-3.76	-0.1778	-3.76			-0.5884	-0.67	-0.3185	-0.66
Auto cost ($)	-0.1196	-3.87					-0.0956	-1.50				
Parking cost ($)†	-0.0512	-3.37	-0.0934	-3.99	-0.0794	-3.84	-0.0905	-2.21	-0.0508	-1.42	-0.0894	-1.55
Access mode (walk over drive)†					0.0358	0.78						
Span of service (all day v. only peak)†			0.1450	3.93	0.1450	3.93			0.3849	2.12	0.3849	2.12
Reliability (% on time)†			0.0416	2.51								
No transfer			0.0991	3.84	0.0991	3.84			0.0958	1.59	0.0958	1.59
Premium on-board (prem. over standard)†			0.0607	2.16	0.0607	2.16			0.1166	1.94	0.1166	1.94
IVTT (min.) x amenities†			0.0008	0.93	0.0018	2.25						
Premium stop design (prem. over standard)†			0.0407	2.38	0.0232	1.43			0.1413	1.56		

TABLE H-15. (Continued).

	Commuters						Non-commuters					
	Auto		Bus		Train		Auto		Bus		Train	
Individual Demographics												
Full-time student			0.1531	1.72	0.1531	1.72						
Full-time employed			-0.7927	-0.39							0.1918	1.79
Homemaker											-0.3588	-2.00
Retired												
Female			-0.7057	-0.47	-0.0289	-0.53						
Longtime resident (5+yrs)					-0.0928	-1.13					-0.1057	-1.50
Has mobility problem									0.7207	1.74		
Age less than 35 years			-0.0926	-1.52	-0.0926	-1.52						
Age between 35 and 55 years												
Age more than 55 years			-2.3307	-0.65					0.0168	0.28	0.0168	0.28
Household Demographics												
Number of vehicles in household												
Family income(in income)			0.0319	0.12					-0.2073	-1.97		
More drivers than vehicles												
Children present												
Trip Characteristics												
Group travel			0.1055	1.89							0.0834	1.25
Weekend trip			0.1176	0.89	-0.0717	-0.68			-0.4350	-1.88	-0.1768	-1.89
Makes stop for groceries											-0.0105	-0.20
Makes stop for other									-0.0243	-0.26	-0.0105	-0.20

TABLE H-16. Value of time ($/hour) for ICLV model in Charlotte.

	Commuters		Non-Commuters	
	Estimate	Robust t-ratio	Estimate	Robust t-ratio
Auto	5.43	2.98	6.13	1.22
Bus	3.66	2.93	0.38	0.63
Train	3.66	2.93	0.70	0.62

Equivalent Valuations

For the equivalent valuations of service characteristics in minutes of in-vehicle time, higher valuations for services with amenities are noted, as would be expected (lower in-vehicle time sensitivity). The relative values for non-commuters are not reliable given the very low implied in-vehicle time for bus and train in this segment (TABLE H-17). For all three modes for commuters, the sensitivity to parking cost is substantially lower than the sensitivity to the main cost components (gas or fares). For non-commuters, the calculations are not reliable given the high associated standard errors.

TABLE H-17. Equivalent in-vehicle travel time (in minutes) for various attributes of ICLV model in Charlotte.

	Commute				Non-Commute		
Explanatory Variables	Auto	Bus	Train Basic	Train with Amenities	Auto	Bus	Train
Alternative specific constant	-	(40.02)	22.22		-	(642.90)	(89.60)
Level of Service							
Access time (min.) if walking	0.77	0.83	1.55	1.87	6.11	15.97	0.77
Access time (min.) if not walking	0.77	0.83	1.76	2.12	6.11	11.99	0.77
Wait time (min.)	1.30	1.40	1.30	1.56	6.14	6.90	1.30
Fare ($) *			3.66			0.38	0.70
Auto cost ($) *	5.43				6.13		-
Parking cost ($) *	0.43	0.53	0.45		0.95	0.09	0.28
Span of service (all day v. only peak)	13.39	14.40	13.39	16.08	103.42	103.42	13.39
Reliability (% on time)†	3.84	4.14	0.00	0.00	0.00	0.00	3.84
No transfer	9.15	9.84	9.15	11.00	25.73	25.73	9.15
Premium on-board (prem. over standard)†	5.60	6.03	5.60	6.73	31.33	31.33	5.60
Premium stop design (prem. over standard)	3.76	4.04	2.14	2.57	37.96	0.00	3.76

TABLE H-17. (Continued).

	Commute			Non-Commute		
Explanatory Variables	**Auto**	**Bus**	**Train**	**Auto**	**Bus**	**Train**
Individual Demographics						
Full-time student	-	(14.13)	(14.13)	-	-	-
Full-time employed	-	73.18	-	-	-	(51.53)
Homemaker	-	-	-	-	-	96.43
Retired	-	-	-	-	-	-
Female	-	65.15	2.67	-	-	-
Longtime resident (> 5 years)	-	-	8.56	-	-	28.40
Has mobility problem	-	-	-	-	(193.66)	-
Age less than 35 years	-	8.55	8.55	-	-	-
Age between 35 and 55 years	-	-	-	-	-	-
Age more than 55 years	-	215.17	-	-	(4.52)	(4.52)
Household Demographics						
Number of vehicles in household	-	-	-	-	-	-
Family income (in income)	-	(2.94)	-	-	55.70	-
More drivers than vehicles	-	-	-	-	-	-
Children present	-	-	-	-	-	-
Trip characteristics						
Group travel	-	9.74)	-	-	-	(22.40)
Weekend trip	-	(10.85)	6.62	-	116.90	47.50
Makes stop for groceries	-	-	-	-	-	2.82
Makes stop for other reasons	-	-	-	-	6.53	2.82

* In the case of fare, auto cost, and parking cost, the values are in units of $/hour of IVTT.

Latent Variable Components

Next to be considered are the results relating to the role of the latent variables in the ICLV model. For the latent variable describing the degree of lack of transit information (TABLE H-18), no significant sociodemographic interactions are observed in either segment, albeit an indication exists that long-term residents are more informed (less uninformed) about transit options in the commuter segment. A lower level of information (i.e., a higher value for the latent variable) leads to a lower utility for bus and train in the commuter segment. In the non-commuter segment, the latent variable has no impact in the choice model.

TABLE H-18. α1: Level of lack of transit information—Charlotte.

	Commuters		Non-Commuters	
α1: Level of Lack of Transit Information	Estimate	Robust t-ratio	Estimate	Robust t-ratio
Threshold 1 for level of lack of transit information	-1.9308	-15.19	-1.4272	-8.63
Threshold 2 for level of lack of transit information	0.7091	6.50	1.0464	7.15
Threshold 3 for level of lack of transit information	1.4226	12.36	1.7584	11.01
Threshold 4 for level of lack of transit information	2.6116	18.40	3.0052	14.31
Impact on first latent variable for respondents who have lived in the area for more than 5 years	-0.1491	-1.06	0.0833	0.48
Impact of latent variable on bus constant	-0.5153	-4.02	-0.2021	-0.57
Impact of latent variable on train constant	-0.5549	-4.22	0.3975	0.61

For the willingness-to-walk latent variable (TABLE H-19), the impact of this latent variable on the indicator (i.e., stated willingness) is not statistically significant in either segment. As a result, it is also not surprising to note that no sociodemographic interactions are significant. The significant and negative interaction term on the utility for bus for commuters simply reflects random variation in the utility for bus across respondents in the sample, where this is however not related to any sociodemographic characteristics, or linked to an underlying heterogeneity in the willingness to walk.

TABLE H-19. α2: Willingness to walk—Charlotte.

	Commuters		Non-Commuters	
α_2: Willingness to Walk	Estimate	Robust t-ratio	Estimate	Robust t-ratio
Impact of latent variable on stated willingness to walk	0.1894	0.66	0.5711	0.49
Standard deviation of stated willingness to walk	10.6960	9.26	12.0800	7.92
Impact on latent variable for full-time students	-0.12279	-0.47	4.917	0.37
Impact on latent variable for respondents in full-time employment	-3.9564	-0.45	-2.7195	-0.34
Impact on latent variable for retired respondents	-		0.82955	0.30
Impact on latent variable for female respondents	-3.1658	-0.48	-2.5378	-0.38
Impact on latent variables for respondents aged over 55	-10.709	-0.69	-3.2205	-0.52
Impact on latent variable of log of household income	0.61951	0.53	0.42462	0.42
Impact on latent variable for respondents who have lived in the area for more than 5 years	0.099842	0.28	-1.6282	-0.45
Impact on latent variable for respondents with reduced mobility	0.27487	1.03	-5.8419	-0.48
Impact of latent variable on bus constant	-0.2293	-4.17	0.0773	0.34
Impact of latent variable on train constant	-0.0023	-0.34	0.0588	0.41

Turning to the pro-transit latent attitude (TABLE H-20), a more positive attitude by full-time students is noted in the commuter segment, with negative impacts on the latent attitude (i.e., less pro-transit) in both segments for female respondents, respondents aged under 35 years, and for respondents from households with more vehicles. In addition, non-commuters with reduced mobility are observed to be less pro-transit, while commuters from households with more drivers than vehicles are more pro-transit. In terms of impact on the utilities in the choice model, a lack of impact in the non-commuter segment is again notable, while in the commuter segment the expected positive impact of a more pro-transit attitude on the utility of both bus and train is observed.

For the pro-car attitude (TABLE H-21), a more positive attitude is noted for female non-commuters, for respondents from households with more vehicles (in either segment), and for commuters with reduced mobility, albeit that this is not significant at the usual levels of confidence. The impacts on the utilities in the choice model are once again limited to the commuter segment, where it is seen that a more positive pro-car attitude has a negative impact on the utility of bus and train.

For the productivity latent attitude (TABLE H-22), no significant sociodemographic interactions are observed for commuters, whereas a positive and almost significant impact is observed for non-commuters who are in full-time employment. In the commuter segments, increases in the latent attitude lead to increases in the utility for bus, with no impacts in the non-commuter segment.

No significant sociodemographic interactions are observed for the environment latent attitude for commuters, but a surprising negative effect is noted for non-commuters aged under 35 years. In the non-commuter segment, there is once again no impact by this latent variable in the choice model, whereas for commuters a positive impact is noted on the utility of train. These results are shown in TABLE H-23.

Turning finally to the privacy and comfort latent attitude (TABLE H-24), we observe no significant sociodemographic interactions in either segment, and the impact of the latent variable on the utilities in the choice model is not statistically significant for either group.

TABLE H-20. α3: Pro-transit attitude—Charlotte.

	Commuters		Non-Commuters	
α_3: Pro-Transit Attitude	Estimate	Robust t-ratio	Estimate	Robust t-ratio
Threshold 1 for Attitudinal Statement 1	-3.3085	-4.27	-4.8456	-5.18
Threshold 2 for Attitudinal Statement 1	-1.9353	-2.55	-3.3918	-3.70
Threshold 3 for Attitudinal Statement 1	-1.0229	-1.35	-2.4092	-2.62
Threshold 4 for Attitudinal Statement 1	0.8699	1.15	-0.8247	-0.90
Threshold 1 for Attitudinal Statement 2	-1.8332	-2.41	-3.5054	-3.84
Threshold 2 for Attitudinal Statement 2	-0.4324	-0.57	-2.2199	-2.44
Threshold 3 for Attitudinal Statement 2	1.1152	1.47	-0.7126	-0.78
Threshold 4 for Attitudinal Statement 2	2.4900	3.25	0.7217	0.79
Threshold 1 for Attitudinal Statement 3	-1.0170	-1.34	-3.1551	-3.45
Threshold 2 for Attitudinal Statement 3	0.3576	0.47	-1.6218	-1.77
Threshold 3 for Attitudinal Statement 3	1.4134	1.87	-0.4070	-0.44
Threshold 4 for Attitudinal Statement 3	2.7056	3.52	0.9760	1.06
Threshold 1 for Attitudinal Statement 4	-1.7360	-2.28	-3.6965	-4.03
Threshold 2 for Attitudinal Statement 4	-0.3444	-0.46	-2.2071	-2.39
Threshold 3 for Attitudinal Statement 4	0.6577	0.87	-1.2573	-1.37
Threshold 4 for Attitudinal Statement 4	2.6028	3.40	0.8335	0.90
Threshold 1 for Attitudinal Statement 8	-1.8690	-2.46	-3.7167	-4.07
Threshold 2 for Attitudinal Statement 8	-0.0918	-0.12	-2.1167	-2.31
Threshold 3 for Attitudinal Statement 8	1.3583	1.79	-0.7480	-0.82
Threshold 4 for Attitudinal Statement 8	3.1580	4.10	1.2968	1.39
Impact on latent variable for full-time students	0.36454	1.89	0.2605	1.03
Impact on latent variable for retired respondents	-		-0.48111	-2.40
Impact on latent variable for female respondents	-0.19265	-1.88	-0.53454	-3.52
Age < 35	-0.17112	-1.66	-0.48155	-2.99
Impact on latent variable of the number of vehicles a household owns	-0.18601	-3.27	-0.23283	-2.66
Impact on latent variable of log of household income	0.037574	0.56	-0.04146	-0.50
Impact on latent variable for respondents with reduced mobility	-0.18912	-0.71	-0.76506	-3.61
Impact on latent variable if respondent's household has more drivers than vehicles	1.1925	1.88	0.25857	0.42
Impact of latent variable on bus constant	0.1243	2.87	0.1021	0.43
Impact of latent variable on train constant	0.1014	2.52	-0.1364	-0.52

TABLE H-21. α4: Pro-car attitude—Charlotte.

	Commuters		Non-Commuters	
α_4: Pro-Car Attitude	Estimate	Robust t-ratio	Estimate	Robust t-ratio
Threshold 1 for Attitudinal Statement 5	-2.6719	-3.77	-1.8935	-2.16
Threshold 2 for Attitudinal Statement 5	-1.2152	-1.72	-0.3930	-0.45
Threshold 3 for Attitudinal Statement 5	-0.0866	-0.12	0.6863	0.79
Threshold 4 for Attitudinal Statement 5	1.5574	2.20	2.2223	2.53
Threshold 1 for Attitudinal Statement 6	-3.5081	-4.92	-2.5243	-2.90
Threshold 2 for Attitudinal Statement 6	-1.9495	-2.77	-0.9906	-1.16
Threshold 3 for Attitudinal Statement 6	-0.4225	-0.60	0.6352	0.75
Threshold 4 for Attitudinal Statement 6	1.3094	1.85	2.2416	2.60
Threshold 1 for Attitudinal Statement 7	-2.6420	-3.71	-1.4529	-1.67
Threshold 2 for Attitudinal Statement 7	-1.6682	-2.37	-0.3337	-0.38
Threshold 3 for Attitudinal Statement 7	-0.5644	-0.80	0.8318	0.96
Threshold 4 for Attitudinal Statement 7	0.9195	1.30	2.5096	2.84
Threshold 1 for Attitudinal Statement 9	-3.7362	-5.25	-2.6331	-3.01
Threshold 2 for Attitudinal Statement 9	-1.8779	-2.66	-0.7769	-0.90
Threshold 3 for Attitudinal Statement 9	-0.1405	-0.20	0.7638	0.88
Threshold 4 for Attitudinal Statement 9	2.2468	3.20	3.0419	3.51
Threshold 1 for Attitudinal Statement 17	-2.3365	-3.32	-1.2958	-1.50
Threshold 2 for Attitudinal Statement 17	-1.1264	-1.60	-0.3084	-0.36
Threshold 3 for Attitudinal Statement 17	0.5295	0.75	1.2925	1.49
Threshold 4 for Attitudinal Statement 17	2.2033	3.09	3.0842	3.42
Threshold 1 for Attitudinal Statement 18	-2.1006	-2.99	-0.5254	-0.61
Threshold 2 for Attitudinal Statement 18	-0.7701	-1.10	0.6727	0.78
Threshold 3 for Attitudinal Statement 18	1.0743	1.53	2.0947	2.41
Threshold 4 for Attitudinal Statement 18	2.2625	3.19	3.1371	3.57
Impact on latent variable for retired respondents	-		-0.0114	-0.06
Impact on latent variable for female respondents	0.0692	0.73	0.3733	2.58
Impact on latent variable of the number of vehicles a household owns	0.1762	3.61	0.2429	3.19
Impact on latent variable of log of household income	-0.0968	-1.54	-0.0560	-0.70
Impact on latent variable for respondents with reduced mobility	0.3009	1.67	0.2589	1.22
Impact on latent variable if respondent's household has more drivers than vehicles	-0.4731	-1.07	0.5194	1.12
Impact of latent variable on bus constant	-0.3327	-4.11	-0.2201	-0.60
Impact of latent variable on train constant	-0.2939	-4.03	-0.1470	-0.51

TABLE H-22. α5: Productivity attitude—Charlotte.

α_5: Productivity Attitude	Commuters		Non-Commuters	
	Estimate	Robust t-ratio	Estimate	Robust t-ratio
Threshold 1 for Attitudinal Statement 10	-2.4332	-2.60	-2.5090	-2.86
Threshold 2 for Attitudinal Statement 10	-0.7589	-0.83	-1.1183	-1.32
Threshold 3 for Attitudinal Statement 10	1.2674	1.38	0.8054	0.95
Threshold 4 for Attitudinal Statement 10	3.4714	3.71	2.8084	3.22
Threshold 1 for Attitudinal Statement 11	-2.1657	-2.34	-2.5231	-2.91
Threshold 2 for Attitudinal Statement 11	-0.9542	-1.03	-1.4256	-1.66
Threshold 3 for Attitudinal Statement 11	0.2570	0.28	0.2148	0.25
Threshold 4 for Attitudinal Statement 11	2.2398	2.41	2.2209	2.58
Impact on latent variable for respondents in full-time employment	-0.1076	-0.77	0.3636	1.74
Impact on latent variable of log of household income	0.0813	0.98	0.0439	0.55
Impact of latent variable on bus constant	0.2233	2.99	0.3424	0.68
Impact of latent variable on train constant	0.0604	1.18	-0.1192	-0.60

TABLE H-23. α6: Environment attitude—Charlotte.

α_6: Environment Attitude	Commuters		Non-Commuters	
	Estimate	Robust t-ratio	Estimate	Robust t-ratio
Threshold 1 for Attitudinal Statement 13	-3.9674	-16.34	-4.9790	-11.35
Threshold 2 for Attitudinal Statement 13	-2.7292	-14.86	-3.2648	-12.56
Threshold 3 for Attitudinal Statement 13	-0.7210	-4.90	-1.1803	-5.92
Threshold 4 for Attitudinal Statement 13	1.5011	9.96	0.8799	4.27
Threshold 1 for Attitudinal Statement 14	-2.6962	-15.48	-3.1118	-11.80
Threshold 2 for Attitudinal Statement 14	-1.3384	-8.82	-1.9153	-8.77
Threshold 3 for Attitudinal Statement 14	0.1373	0.94	-0.2571	-1.29
Threshold 4 for Attitudinal Statement 14	2.4069	14.58	1.6972	7.93
Threshold 1 for Attitudinal Statement 15	-1.2691	-8.58	-1.8684	-9.06
Threshold 2 for Attitudinal Statement 15	0.0856	0.61	-0.5387	-2.77
Threshold 3 for Attitudinal Statement 15	1.4409	10.04	0.9351	4.51
Threshold 4 for Attitudinal Statement 15	3.5930	17.70	2.9876	10.80
Age < 35	0.1686	1.56	-0.5378	-3.09
Impact on latent variable of the number of vehicles a household owns	0.0219	0.41	-0.0095	-0.13
Impact of latent variable on bus constant	0.0539	1.17	-0.0618	-0.43
Impact of latent variable on train constant	0.1529	2.57	-0.2538	-0.57

TABLE H-24. α7: Privacy and comfort attitude—Charlotte.

	Commuters		Non-Commuters	
α7: Privacy and Comfort Attitude	Estimate	Robust t-ratio	Estimate	Robust t-ratio
Threshold 1 for Attitudinal Statement 12	-2.3907	-13.60	-2.7858	-8.42
Threshold 2 for Attitudinal Statement 12	-0.5756	-3.62	-1.1664	-3.66
Threshold 3 for Attitudinal Statement 12	0.3926	2.47	-0.1027	-0.32
Threshold 4 for Attitudinal Statement 12	3.1125	15.58	2.6669	7.26
Threshold 1 for Attitudinal Statement 16	-3.6148	-17.27	-2.9700	-9.07
Threshold 2 for Attitudinal Statement 16	-1.9117	-11.69	-1.7806	-5.75
Threshold 3 for Attitudinal Statement 16	-0.1660	-1.07	-0.1082	-0.35
Threshold 4 for Attitudinal Statement 16	1.6280	9.67	1.6094	5.09
Impact on latent variable for female respondents	-0.0704	-0.71	0.0036	0.02
Impact on latent variable of the number of vehicles a household owns	0.0062	0.11	-0.0201	-0.15
Impact on latent variables if children are present in household	-0.0630	-0.58	-0.0559	-0.39
Impact of latent variable on bus constant	0.0876	1.45	-0.1686	-0.53
Impact of latent variable on train constant	0.0619	1.29	0.0818	0.29

Summary of Model Results

We have demonstrated that ICLV models are possible and offer the following benefits compared to a more traditional multinomial or nested logit choice modeling structure:

- The use of the ICLV approach leads to a better statistical fit (demonstrated by the higher log-likelihood) for the choice model component of the hybrid structure (with the exception of the non-commuter segment of the Charlotte data). This is because the model obtains information on the underlying attitudes jointly from the observed choices and the answers to attitudinal questions and, to a smaller degree, because the model allows for sociodemographic interactions in the specification of the latent variables.

- The ICLV models provide further insights about the role of attitudes in the decision making, and also the key sociodemographic drivers behind these attitudes.

- The traditional multinomial or nested logit modeling structure requires that a separate model be developed to forecast traveler attitudes or latent variables, where the ICLV model forecasts these variables within the modeling structure from key sociodemographic drivers.

The primary reason not to use an ICLV model is the added complexity it contains for the latent variables of interest. In this context, the five attitudinal factors could have been limited to two or three factors and the latent variables could have been reduced as well. The use of ICLV in this study was as a proof of concept rather than a final solution for coefficients on latent variables.

The key findings relate to the role of the latent variables in the models, as shown in TABLE H-25. In this brief summary, we present the results in simplified table form, where +++/--- represent positive/negative effects that are significant at the 99% level of confidence, using ++/-- for the 95% level, and +/- for the 90% level. Any effects that are not significant above the 90% level are not shown in the tables. For the impact of the latent variable in ordered logit specifications, +* is used to indicate that the effect is positive, but it is not possible to determine the size or significance of the effect. In comparison with the MNL models, the ICLV models now provide further insights about the role of attitudes in the decision making, and also the key sociodemographic drivers behind these attitudes.

- For the level of lack of transit information, we find that longer term residents in Chicago are likely to be less well informed about transit, which may indicate that people are set in their ways over time and do not seek out transit information. We also show that a lower level of information (i.e. higher value for the latent variable) leads to a lower utility for bus for Chicago commuters and for both transit modes for Charlotte commuters, which is quite intuitive.

- For willingness to walk, we find a significant impact of the latent variable on the stated willingness only in the Chicago models, where increases in the willingness to walk variable lead to increased utility for both transit modes for commuters and for train for non-commuters. In the Charlotte models, there is no link between the latent variable and the indicator, and the negative interaction with the utility for bus simply captures random heterogeneity in the data.

- The ICLV models demonstrate a number of significant interactions between sociodemographic variables and the latent pro-transit attitude, which is associated with higher levels of agreement with five attitudinal statements, and which leads to increased utility for both transit modes in all segments except Charlotte non-commuters, where there is no effect.

- For the pro-car attitude, there are again a number of significant interactions, and the latent variable is associated with increases in the level of agreement with six attitudinal statements, and leads to reductions in the utility for the two transit options in all segments except Charlotte non-commuters, where there is no effect.

- For the productivity latent attitude, we find weak positive effects for full-time employees in both non-commute segments, where the latent variable is associated with increases in the level of agreement with two attitudinal statements, and leads to increases in the utility for the two transit options for both Chicago segments, and for bus in the Charlotte commute segment.

- The pro-environment latent variable is higher for younger respondents in Chicago, and lower for younger Charlotte non-commuters. It is associated with increases in the level of agreement with three attitudinal statements, and leads to increases in the utility for the two transit options for Chicago commuters, and for train for Charlotte commuters.

- Female non-commuters in Chicago have a higher value for the latent privacy and comfort attitude, which is associated with increases in the level of agreement with two attitudinal statements, and which leads to reductions in the utility for the two transit options for Chicago commuters, but increases for both options for Chicago non-commuters.

TABLE H-25. Summary of latent variable findings.

	Chicago		Charlotte	
	Commuters	Non-Commuters	Commuters	Non-Commuters
α_1: Level of Lack of Transit Information				
Lived in the area for more than 5 years	+++	+++		
Stated level of lack of transit information	$+^{*}$	$+^{*}$	$+^{*}$	$+^{*}$
Impact on utility of bus	---		---	
Impact on utility of train			---	
α_2: Willingness to Walk				
Full-time student	+	+		
Retired		--		
Lived in the area for more than 5 years	+			
Has reduced mobility		---		
Stated willingness to walk	++	+++		
Impact on utility of bus	+++		---	
Impact on utility of train	+++	+++		
α_3: Pro-Transit Attitude				
Full-time student	++	+++	+	
Retired		---		--
Female		---	-	---
Aged under 35 years			-	---
Number of vehicles	---	---	---	---
Log of income	++			
Has reduced mobility	-			---
More drivers than vehicles	+++		+	
Respondent's agreement with statement “I am not afraid to ride transit”	$+^{*}$	$+^{*}$	$+^{*}$	$+^{*}$
Respondent's agreement with statement “I'm the kind of person who rides transit”	$+^{*}$	$+^{*}$	$+^{*}$	$+^{*}$
Respondent's agreement with statement “I currently make an effort to take public transit whenever I can”	$+^{*}$	$+^{*}$	$+^{*}$	$+^{*}$
Respondent's agreement with statement “If I wanted to, I could use public transit more frequently”	$+^{*}$	$+^{*}$	$+^{*}$	$+^{*}$
Respondent's agreement with statement “It's easy to plan a trip using transit”	$+^{*}$	$+^{*}$	$+^{*}$	$+^{*}$
Impact on utility of bus	+++	+++	+++	
Impact on utility of train	+++	+++	++	

TABLE H-25. (Continued).

	Chicago		Charlotte	
	Commuters	Non-Commuters	Commuters	Non-Commuters
α_4: Pro-Car Attitude				
Retired		+		
Female				+++
Number of vehicles	+++	+++	+++	+++
Log of income	--			
Has reduced mobility	+++	++	+	
More drivers than vehicles	---	-		
Agreement with statement "For me, car is king! Nothing will replace my car as my main mode of transportation"	+*	+*	+*	+*
Agreement with statement "Getting to and from transit stations/stops is not pedestrian friendly and is very unpleasant"	+*	+*	+*	+*
Agreement with statement "I have to drive to get to transit anyway, so I may as well just drive my car the whole way"	+*	+*	+*	+*
Agreement with statement "Transit is often dirty"	+*	+*	+*	+*
Agreement with statement "My car reflects who I am"	+*	+*	+*	+*
Agreement with statement "My days of taking transit are over"	+*	+*	+*	+*
Impact on utility of bus	---	---	---	
Impact on utility of train	---	---	---	
α_5: Productivity Attitude				
Employed full-time		++		+
Agreement with statement "More than saving time, I prefer to be productive when traveling"	+*	+*	+*	+*
Agreement with statement "If it would save time, I would change my form of travel"	+*	+*	+*	+*
Impact on utility of bus	++	+++	+++	
Impact on utility of train	+++	+++		
A_6: Environment Attitude				
Aged under 35 years	++	+		---
Agreement with statement "Protecting the environment is very important to me"	+*	+*	+*	+*

TABLE H-25. (Continued).

	Chicago		Charlotte	
	Commuters	Non-Commuters	Commuters	Non-Commuters
Agreement with statement “I am willing to carpool or take public transit more frequently to reduce air pollution and carbon emissions from my vehicle”	+*	+*	+*	+*
Agreement with statement “I am willing to pay higher tolls if they are used to reduce congestion”	+*	+*	+*	+*
Impact on utility of bus	+++			
Impact on utility of train	++		++	
α_7: privacy and comfort attitude				
Female		++		
Agreement with statement “As long as I am comfortable when traveling, I can tolerate delays”	+*	+*	+*	+*
Agreement with statement “Privacy is important to me when I travel”	+*	+*	+*	+*
Impact on utility of bus	---	+++		
Impact on utility of train	---	+++		

There are many similarities in the base utility parameters between the ICLV and traditional multinomial logit choice models. One comparison that is different is that value of time estimates are smaller in the ICLV models than in the multinomial logit models, ranging from a 20% to a 58% reduction by market segment and city. This may be explained because the ICLV model can better capture modal preferences by allowing for heterogeneity that would otherwise have been captured in the travel time coefficient.

APPENDIX I

Transit Travel Time Analysis

Contents

Transit ridership forecasts generated by regional travel demand models are dependent on estimates of routing, travel time, and cost generated by network path-finding software. These estimates are key inputs to several travel forecasting model components, including:

- Transit trip assignment procedures that determine boarding stop, alighting stop, and transit route
- Mode split procedures that determine market shares for transit versus automobile and non-motorized modes, walk versus kiss-and-ride and park-and-ride access modes, and bus versus rail sub-modes
- Destination choice procedures that develop matrices of total travel demand (trip tables) when the denominator of the mode choice model is used as a measure of geographic separation between zones

Despite the importance of these data, it is not always certain that modeled representations of transit travel time portray the impedances associated with transit use in a manner that is consistent with how travelers perceive them. This appendix discusses a comparison of reported travel times obtained from the Charlotte (NC) and Chicago (IL) surveys to simulated time estimates generated by travel demand forecasting models and other path-building software. The results of this analysis are used to develop an understanding of the degree to which reported times match or vary from estimated travel times.

As the remainder of this appendix demonstrates, reported and modeled estimates of travel time are not highly related. In order to better understand the reasons for these differences, reported and modeled travel times were also compared to time estimates generated directly from reported origin and destination locations coupled with detailed stop-to-stop timetable information. Despite the fact that this schedule-based information was not subject to zone or time-of-day aggregation errors, this comparison determined that reported travel time estimates are no more correlated to timetable-based estimates than to MPO model estimates of travel time.

One possible explanation for reported times not matching simulated times is that survey respondents do not accurately portray their own travel time. Although this may occur in some cases, travel time reporting is one of easiest parts of the survey questionnaire and should not be assumed to be the sole cause of the mismatch. It is also possible that other elements of the surveyed trip (most notably origin and destination locations or routing) are inaccurately reported. If so, these errors could have significant implications for how survey data are used for model estimation and calibration.

To gain additional insights into time estimate differences, a manual review of survey- and timetable-based results was conducted. The survey did not include information on boarding and alighting stop location or transit routes used, so this review was only able to cross-check reported paths and times against possible paths that could have been used. It is recommended that future survey efforts include more detailed information to allow thorough consistency checking.

Nevertheless, the manual review of survey responses was sufficient to suggest a wide range of potential causes for reported times not matching simulated times. These include:

- Traveler-reported origin, destination, and routing can be inconsistent, raising the possibility that one or more of these responses is incorrect
- Even in cases where the paths appear to be consistent, geographic coding of reported origin and destination locations may not be accurately and precisely reported
- Survey respondents may travel between origin and destination on a path that uses a different routing from the modeled shortest path
- Survey respondents may not have accurately reported their travel times

The low correlation between reported and modeled travel times and the potential errors in reporting trip characteristics suggests that survey data needs thorough quality control checking before survey results are suitable for understanding traveler behavior. To be able to support this review, survey data collection efforts need to collect sufficient information on the trip itinerary (e.g., boarding and alighting stops and routes) to enable detailed review of the survey response.

Transit Path-Building Assumptions

Three sources were used in comparing survey-reported travel times to simulated travel times. Two are models used by the Metropolitan Planning Organizations in Charlotte, North Carolina and Chicago, Illinois as part of the regional long-range planning process. The third estimate of simulated travel time was developed from a custom-developed transit path-builder that reads detailed timetable information for Charlotte (in Google Transit Feed format) and computes the best path using specific bus and rail schedules. Key aspects of each modeled approach are as follows:

- **Charlotte Forecasting Model.** The Mecklenburg–Union Metropolitan Planning Organization (MUMPO) Metrolina Travel Demand Forecasting Model is currently being used by the Charlotte Area Transit System (CATS) to evaluate FTA New Starts projects in Charlotte. The model incorporates many recent advances in the state-of-the-practice for New Starts forecasting and is informed by local transit ridership patterns obtained from a 2009 Origin-Destination survey. This survey was conducted as part of the FTA Before and After Study of traveler response to the South Corridor light rail transit (LRT) line, which opened in the fall of 2007. Transit networks were validated by comparing modeled bus running times to timetable information and by assigning survey-derived transit trip tables to confirm that overall assigned survey trips generate ridership by station and route that match observed values. The model has undergone an extensive review by FTA travel forecasting staff.

- **Chicago Forecasting Model.** The Chicago Metropolitan Agency for Planning (CMAP) Standard Travel Demand and Emissions Model is used for most regional planning applications in the Chicago region, including demonstrating air quality conformity. It has not been used for recent FTA New Starts project support and, as a result, has not received the same level of FTA scrutiny as applied to the model developed for Charlotte. Although transit networks are carefully coded to represent existing and planned facilities, the resulting paths and travel time estimates have not been validated to confirm the accuracy of the level-of-service (skim) matrices. CMAP plans to perform a thorough network update as part of their migration to a new activity-based disaggregate travel demand model in the next 6 months. This network review will include a complete validation of transit paths and travel time estimates.
- **Charlotte Schedule-Based Estimates of Travel Times.** In conjunction with on-going research being conducted by the FTA, a procedure was developed for reading Charlotte bus and rail timetable information for the survey period and generating origin-to-destination estimates of travel time that are comparable to travel model skim matrices. Input data was obtained in Google Transit Feed (GTF) format from CATS for the survey period. The path-finding process was validated against the CATS on-line trip planner to confirm that the routing and travel time estimates conform to estimates available to the traveling public. The path-finding procedures developed for this analysis also include the capability to route park-and-ride and kiss-and-ride trips. The schedule-based path-building procedures differ from conventional travel model skims in that they attempt to represent, as faithfully as possible, the characteristics of a transit trip as experienced by each specific traveler beginning at a precise origin, ending at a precise destination, and departing at a specific time.

Spatial Issues

The survey asked travelers to describe the starting and ending points of a typical trip, the routing, and the time required to make the trip. Routing was reported in terms of transit sub-modes (e.g., bus or rail) used during the trip, with one mode coded for each transit vehicle boarded. Times were separately reported for walk access or egress, drive access or egress, waiting, and in-vehicle travel. Survey respondents coded their estimates of travel time using drop-down menus with time ranges organized into 2-minute or 5-minute increments (depending on which time component was requested). Although some problems were detected with geographic coding, the intended geographic precision of the survey is latitude and longitude to 1/10,000th of a degree.

Both the Charlotte and Chicago modeled estimates of travel time were developed from zone-to-zone skims. The resulting precision of these estimates is limited by the size and shape of each zone. As shown in FIGURE I-1, zone sizes in the Charlotte modeling system vary by location, with zones in the central business district (CBD) being comparatively small and zones in other urbanized parts of the region frequently being one-half mile or more in length. Zones in the Chicago model are generally multiple sections (sections in Northwest Land Survey states are 1 mile squares) in exurban areas, sections in close-in suburban locations and most of Chicago, quarter-sections in Central Chicago, and 1/16 sections in the CBD. In urban and suburban locations where most transit travel occurs, zone length is often equal to 1 mile.

Like most other travel forecasting models, paths are built from the zone centroid using access links that represent either average trip distances to any transit station/stop or specific centroid-to-node distances. Either approach is an abstraction of the conditions faced by individual trip-makers and could distort actual access distances by up to half of the typical zone dimension.

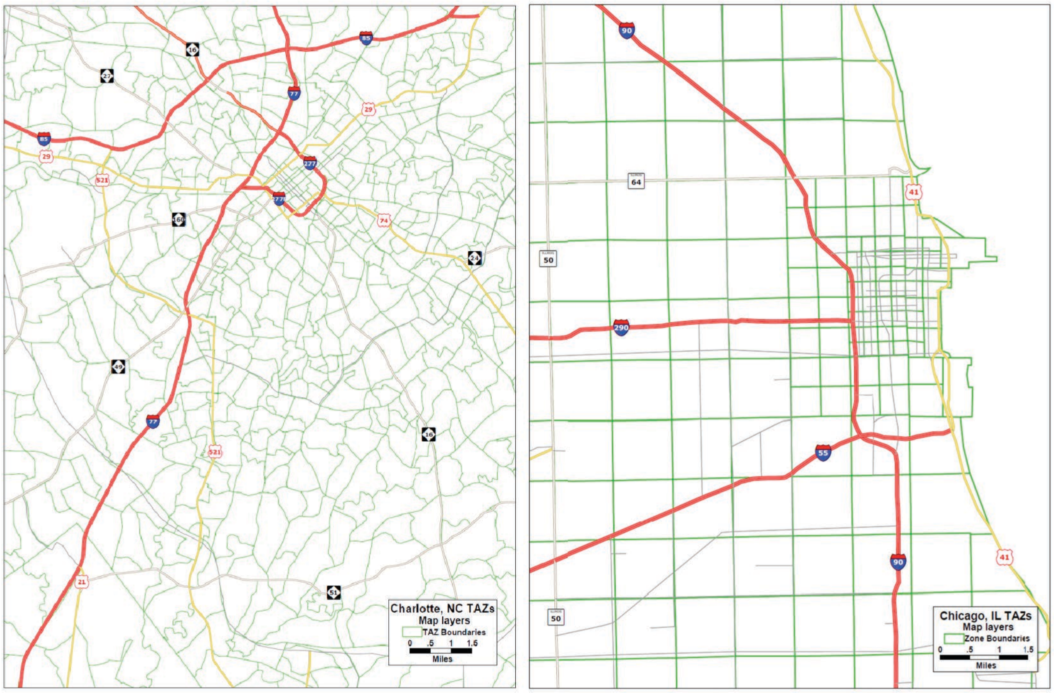


FIGURE I-1. Sample zone systems for urbanized areas in Charlotte and Chicago.

This lack of precision can affect estimated travel times in two ways:

- Estimates of zonal access distance can vary from actual access distances experienced by travelers. Zones with a length of 0.5 miles could have access links that, for some travelers, misstate distance by 0.25 miles or more. At the typical walk speed of 3 miles per hour, this distance requires 5 minutes to traverse. Using a typical out-of-vehicle weight of 2.5, this lack of precision could result in a path impedance that is 12.5 minutes more or less than the actual impedance experienced by the traveler. Zones with a length of 1.0 miles could result in a time error of 10 minutes or more and an impedance error of 25 minutes. These impedance errors are at least as large as the adjustments sometimes added to mode choice models to estimate fixed guideway ridership.
- Differences of 12.5 to 25 minutes of path impedance may lead to a modeled routing that is substantially different from the actual routing. These differences could result in inaccurate estimates of walk time versus in-vehicle time, number of transfers, and sub-modes used.

The GTF-based schedule analysis used survey-coded origin and destination locations rather than zone centroid locations. This approach removes the aggregation error associated with zonal centroids. A comparison of reported and GTF-modeled travel times was not significantly better than the comparison to conventional travel models. An analysis of the coded latitudes and longitudes revealed potential inaccuracies in the coordinates that characterize origin and destination. Identified problems include coordinates that appear to represent a small portion of the trip (e.g., home to boarding station) or coordinates that appear to be boarding and alighting stations rather than actual origin and destination locations. Details of this comparison are provided at the end of this appendix.

Path-Weighting

Path-weighting parameters for each model are presented in TABLE I-1. Both the Charlotte and Chicago models generally follow conventional practice with out-of-vehicle time being weighted between two and three times the weight assigned to in-vehicle time. The Charlotte model uses a range of weights to represent the perception that walking is easier and more common in densely developed urban areas, whereas automobile access is easier and more common in less-densely developed areas. The Charlotte model also weights rail in-vehicle times at 70% that of bus travel times. This factor was selected to allow assignment and mode choice procedures to compute the correct number of LRT trips and assign these trips correctly to the transit networks.

The Charlotte schedule-based paths use a somewhat different weighting structure that is tied to the use of timetable-based networks with specific stop-to-stop times for each bus and rail trip. A "trip" in this context is a scheduled trip made by a transit vehicle. A trip begins at one end of the route and continues to the terminus and corresponds to a set of published stop-to-stop time points for a single vehicle. Initial waiting time is valued by the schedule-based path-finder at 50% of the value associated with in-vehicle time. This factor was developed during model calibration to match the CATS on-line trip planner. The on-line tool appears to assign the highest value to paths that arrive at the destination as early as possible while leaving the origin as late as possible. Higher values of initial weight resulted in unrealistic paths that boarded the first available bus (thus minimizing wait time) even if that bus took longer to reach the eventual destination.

Other out-of-vehicle times are weighted more heavily than in-vehicle time but less than the weights used in traditional travel forecasting models. These values were selected to match the on-line trip planner and its trade-off between walking longer distances versus making additional transfers.

Modeled Path Choices

The Charlotte model builds separate peak and off-peak paths for the following access mode and transit line-haul sub-mode combinations:

- Walk access paths (production-end walk/attraction-end walk)
  - Walk to premium transit (all modes available, LRT required)
  - Walk to local transit (bus only)
  - Walk to premium-only transit (LRT only)
- Park-and-ride access paths (production-end park-and-ride/attraction-end walk)
  - Park-and-ride to premium transit (all modes available, LRT required)
  - Park-and-ride to local transit (bus only)
  - Park-and-ride to premium-only transit (LRT only)
- Kiss-and-ride access paths (production-end kiss-and-ride/attraction-end walk)
  - Kiss-and-ride to premium transit (all modes available, LRT required)
  - Kiss-and-ride to local transit (bus only)
  - Kiss-and-ride to premium-only transit (LRT only)

TABLE I-1. Path weighting parameters.

Attribute	Charlotte Model	Chicago Model	Charlotte Schedule
In-Vehicle Time			
Bus	1.00	1.0	1.00
Rail	0.70	1.0	1.00
Initial wait time	1.50	1.82	0.50
Transfer wait	2.00	1.82	1.00
Walk Time			
CBD areas	1.50	1.82	1.50
CBD fringe areas	2.00	1.82	1.50
Urban areas	2.50	1.82	1.50
Suburban areas	3.00	1.82	1.50
Rural areas	3.50	1.82	1.50
Drive Access Time			
Production in urban areas	1.50	2.00	1.50
Production in CBD fringe areas	3.00	2.00	1.50
Production in CBD areas	3.50	2.00	1.50
Boarding penalty (applied to fare in cents)		0.01	
Boarding penalty (minutes per boarding)			5.00
Transfer Penalty			
Walk access—bus-to-bus	2.00		
Walk access—bus-to/from-rail	0.00		
Auto access—bus-to-bus	6.00		
Auto access—bus-to/from-rail	2.00		

Source: AECOM, CMAP, and RSG

Consistent with many of the transit forecasting models employed today, the Charlotte model assumes that all egress from the transit alighting location to the ultimate attraction zone occurs by the walk mode only. This means that automobile egress to the attraction end of the trip is not considered by the current Charlotte model transit path-builder.

The Chicago model generates a single set of production-to-attraction walk access/walk egress transit peak period paths and uses the emme/2 matrix convolution process to generate park-and-ride level-of-service (skim) matrices. The convolution process reads a zone vector matrix that indicates which zones contain park-and-ride facilities. For each zone-to-zone interchange, the park-and-ride zone is selected that minimizes the total generalized cost to drive from the origin to the park-and-ride zone and the cost to take transit from the park-and-ride zone to the destination. Park-and-ride skims are calculated by summing times and costs for each stage of the trip. No separate off-peak skim is generated.

The Charlotte schedule path-builder operates on an origin-destination basis with a specific representation of trip departure time. It includes the capability to build paths for each of the following:

- Walk access, walk egress
- Kiss-and-ride access, walk egress
- Park-and-ride access, walk egress
- Walk access, kiss-and ride egress
- Walk access, park-and-ride egress

Transit Trip Characteristics

TABLE I-2 presents an overview of the mode shares and transit trip characteristics for the survey responses collected in Charlotte and Chicago. Both surveys have transit shares (24% in Charlotte and 48% in Chicago) that are much higher than observed regional transit utilization (0.6% in Charlotte (Metrolina Regional Model) and 12% in Chicago (CMAP Travel Demand Model Validation Report 2011). This difference is a result of the fact that the survey methodology was not controlled to represent the population of all trip-makers but rather was specifically designed to over-sample transit trips to better understand their travel characteristics.

The fact that the survey was not controlled to the traveling population also means that trip-making characteristics of transit trips do not match estimates from other sources. Key differences include:

- The surveyed transit trips are evenly distributed between the peak and off-peak periods in both the Charlotte and Chicago surveys. In Charlotte, a controlled origin-destination survey was conducted in spring 2009 that found that peak period travel comprises 58% of all daily transit travel (AECOM analysis of 2009 Charlotte Transit Origin-Destination Survey).
- In Charlotte, 57% of the surveyed records used park-and-ride to access transit. The spring 2009 origin-destination survey estimated this share to be approximately 25% of total transit trips (Ibid.). The Chicago survey found that 37% of travelers accessed transit using a drive mode. The Year 2000 validation of the Chicago New Starts model estimated that 25% of transit trips accessed the system using auto access modes (AECOM 2006a).
- Between 14 and 15% of surveyed trips reported a non-walk attraction-end egress mode (either park-and-ride or kiss-and-ride). Similar to most transit forecasting models currently employed, neither the Charlotte nor Chicago models consider any egress modes other than walk. In Charlotte, 33 of 54 records reported park-and-ride as both the access and egress mode, which might suggest confusion on the part of the respondent.

The differences between the current survey dataset and earlier controlled survey efforts (i.e., the 2009 Charlotte origin-destination survey) and other ridership data suggest that the sampled trips are not fully representative of the universe of transit trip-making. These differences should be taken into account when using survey results to characterize attributes of transit users.

TABLE I-2. Characteristics of surveyed trips in Charlotte and Chicago.

Trip Characteristic	Charlotte		Chicago	
	Trips	Percent	Trips	Percent
Automobile	1,162	76%	790	52%
Transit	365	24%	725	48%
Total	1,527	100%	1,515	100%
Transit Trips by Time Period				
Peak (7 a.m.–9:30 a.m./3:30 p.m.–6:30 p.m.)	183	50%	377	52%
Off-peak	182	50%	348	48%
Total	365	100%	725	100%
Transit Trips by Production-End Access Mode				
Walk	113	31%	437	60%
Kiss-and-ride (Drive Access)	35	10%	Not Available	
Park-and-ride (Drive Access)	209	57%	Not Available	
Subtotal drive access	244	67%	270	37%
Other	8	2%	18	2%
Total	365	100%	725	100%
Transit Trips by Attraction-End Egress Mode				
Walk	303	83%	606	84%
Kiss-and-ride (Drive Access)	19	5%	Not Available	
Park-and-ride (Drive Access)	35	10%	Not Available	
Subtotal drive access	54	15%	105	14%
Other	8	2%	14	2%
Total	365	100%	725	100%
Transit Trips by Transit Line-Haul Mode				
Bus only	191	52%	196	27%
Bus and rail	46	13%	225	31%
Rail only	128	35%	304	42%
Total	365	100%	725	100%

Source: AECOM analysis of Charlotte and Chicago Surveys

One intriguing finding from the Charlotte survey concerns frequency of travel as shown in TABLE I-3. The LYNX LRT line was used at least once during the last year by over 80% of survey respondents while less than 50% of respondents report using the region's bus system. This finding is particularly notable since the rail line operates in just one corridor and average daily ridership is less than 30% of total transit trips in Charlotte area. This suggests that the rail line has higher awareness and acceptance among occasional users of transit than the bus system.

TABLE I-3. Reported Charlotte Area Transit System (CATS) modes used at least once during the last year.

Mode	Used at Least Once During the Last Year	Never Used
CATS local bus	48.3%	51.7%
CATS express bus	44.3%	55.7%
CATS LYNX light rail	82.8%	17.2%

Source: AECOM analysis of CATS 2009 Origin-Destination Survey

Preparing the Data for Comparisons to Modeled Component Travel Times

The project team conducted a detailed review of the surveyed transit trip records to confirm that each response passed basic quality control and logic checks and represents travel that can be simulated by the demand forecasting models. These quality control checks included the following actions:

- Transit trips with stopovers were omitted from the analysis to prevent misinterpretation of reported travel times compared to modeled times.
- Records indicating use of the “other” access mode (other than park-and-ride, kiss-and-ride or walk access) were omitted from further analysis since the travel path was not known.
- Records for which no modeled transit path was found for the user-specified combination of transit line-haul, time-of-day and access mode were dropped from the analysis.
- Records for which the path-builder estimate of number of transfers did not match reported transfers were dropped from further analysis since the reported and modeled paths would not match. Such a mismatch could confuse any comparison of component travel times, such as walk time, wait time, and in-vehicle travel time (IVTT). This test was only performed for the Charlotte data set because the number of transfers was not included in the Chicago transit skims.
- Respondents reporting attraction-side drive egress were dropped from the analysis because paths are not generated for these types of trips.

TABLE I-4 and TABLE I-5 summarize the results of the quality control and trip comparability checks for Charlotte and Chicago, respectively. For the Charlotte survey, this process reduced the available sample size from 365 survey records to 154 records appropriate for comparing travel times. In Chicago, the sample size was reduced from 725 records to 234 records. In each city, the largest single reason that trips were dropped from the analysis was because survey respondents reported that they made a stopover during the trip. The prevalence of stopovers suggests that journey- or half-journey-based travel forecasting models may be important to fully represent the complexity of transit travel behavior. Neither the Charlotte nor Chicago models that generated the skim matrices are organized to generate journey travel time information.

The next largest reason for dropping survey records from the analysis involves cases where no transit skim existed for the access mode and zone-to-zone pair specified on the survey record. This situation occurred for about 15% of survey records in both cities. In these cases, no

TABLE I-4. Summary of usable records for survey-model comparisons in Charlotte.

Reference Trip Frequency	Surveyed Transit Trips	Records Deleted								Usable Records
		Stopover	Unrecognized Access Mode	No Skim				Different Path (unequal transfers)	Egress Mode Mismatch	
				Intra-zonal	Auto Egress	Other	Total			
5 + times per week	94	17	1	1	3	3	7	5	8	56
3-4 times per week	44	11	0	0	3	3	6	8	1	18
1-2 times per week	32	12	1	1	1	2	4	4	2	9
1-3 times per month	62	18	1	3	2	5	10	6	3	24
5-11 times per year	46	13	1	1	1	6	8	5	2	17
4 times or less per year	87	21	1	3	2	12	17	15	3	30
Total	365	92	5	9	12	31	52	43	19	154

TABLE I-5. Summary of usable records for survey-model comparisons in Chicago.

Reference Trip Frequency	Surveyed Transit Trips	Records Deleted								Usable Records
		Stopover	Unrecognized Access Mode	No Skim				Different Path (unequal transfers)	Egress Mode Mismatch	
				Intra-zonal	Auto Egress	Other	Total			
5 + times per week	168	46	2	3	1	4	8	112	168	46
3-4 times per week	101	36	1	3	1	1	5	59	101	36
1-2 times per week	106	42	0	3	0	3	6	58	106	42
1-3 times per month	102	32	4	6	2	0	8	58	102	32
5-11 times per year	95	38	2	2	0	3	5	50	95	38
4 times or less per year	153	40	7	11	4	3	18	88	153	40
Total	725	234	16	28	8	14	50	425	725	234

Note: Other reasons for no modeled skim include fringe parking-type trip, backtracking and illogical path.

comparison of skim and reported times is possible. Since this situation represents a complete failure of the model to represent reported behavior, these records were analyzed in more detail to understand why paths were not available. Key findings include:

- Nearly 20% of the transit paths not found by the transit path-builder (9 out of 52 for Charlotte and 23 out of 119 for Chicago) were reported as short-distance intra-zonal trips. Traditional forecasting techniques that use traffic analysis zones (TAZs) to represent spatial locations cannot capture such trips. It is not known whether these trips are actual very short trips on transit or whether they are the result of miscoding of origin and destination.
- Another 16 to 20% of transit trips used automobile attraction-end egress to complete their trip (12 out of 52 in Charlotte and 17 out of 119 in Chicago). This path type is not considered by either model.
- There appears to be a modest correlation between infrequent use of the transit system (three or fewer trips per month) and no skim path being available. Infrequent trips account for 48% to 53% of the total number of transit trip records in each city, while accounting for 57% to 67% of the instances where a valid transit path did not exist in the model.
- The remaining 60% of trips without a path were reviewed manually. Reasons for paths not building included:
  - Fringe downtown parking trips, for which travelers reported driving to private parking lots just outside the CBD and riding transit to complete their trip. This behavior is likely to occur but is not simulated by the path-building models in either city.
  - Some automobile access trips exhibited a large degree of “backtracking,” which is prevented by the drive access procedures employed in the Charlotte model.
  - Illogical trip end-locations. For a small portion of records, the geocoded trip ends were far outside the coverage area of the system, resulting in valid transit paths not being found by the model.

The overall result of this analysis is that for Charlotte and Chicago surveys, together, only 53% of reported transit trips could be matched to modeled travel times. The remaining 47% represent behaviors or circumstances that are not simulated by travel forecasting models. Whether this is due to errors in trip reporting or trip behaviors that are not covered by the model is not known with certainty. In either case, the fact that so many surveyed trips cannot be understood is a potential problem.

Respondent Perceptions of Travel Time Compared to Travel Model Paths

This section presents a comparison of reported travel times from each survey with level-of-service data from the Charlotte and Chicago travel demand forecasting models. In reviewing these results, it is important to note that the survey instrument allowed respondents to report their travel times to the nearest 2 minutes to 5 minutes, depending on the question being asked. This means that some variation between reported and modeled travel times is because of limitations in survey precision rather than any real difference between real and perceived times.

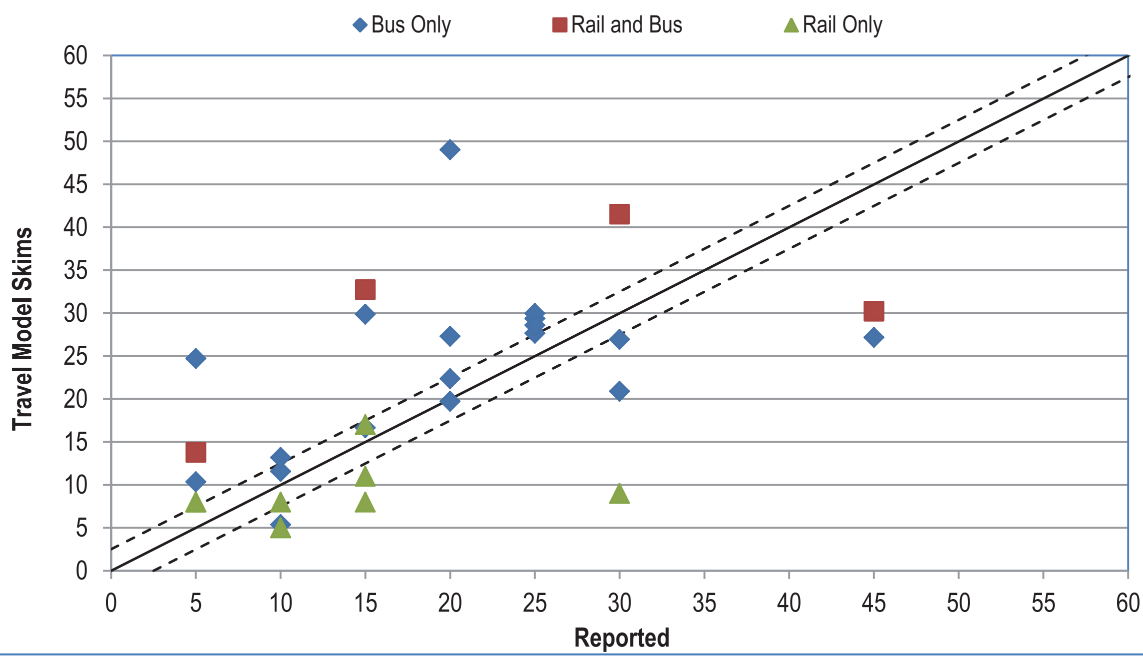
Transit In-Vehicle Travel Times

FIGURE I-2, FIGURE I-3 and FIGURE I-4 present a comparison of reported and modeled transit IVTT for walk and drive access trips in Charlotte and for total trips in Chicago. Survey observations are color coded according to mode reported to be used during the trip:

- Blue—bus only (trip contains bus time but no rail time)
- Red—rail and bus (trip contains both bus and rail time)
- Green—rail only (trip contains rail time but no bus time)

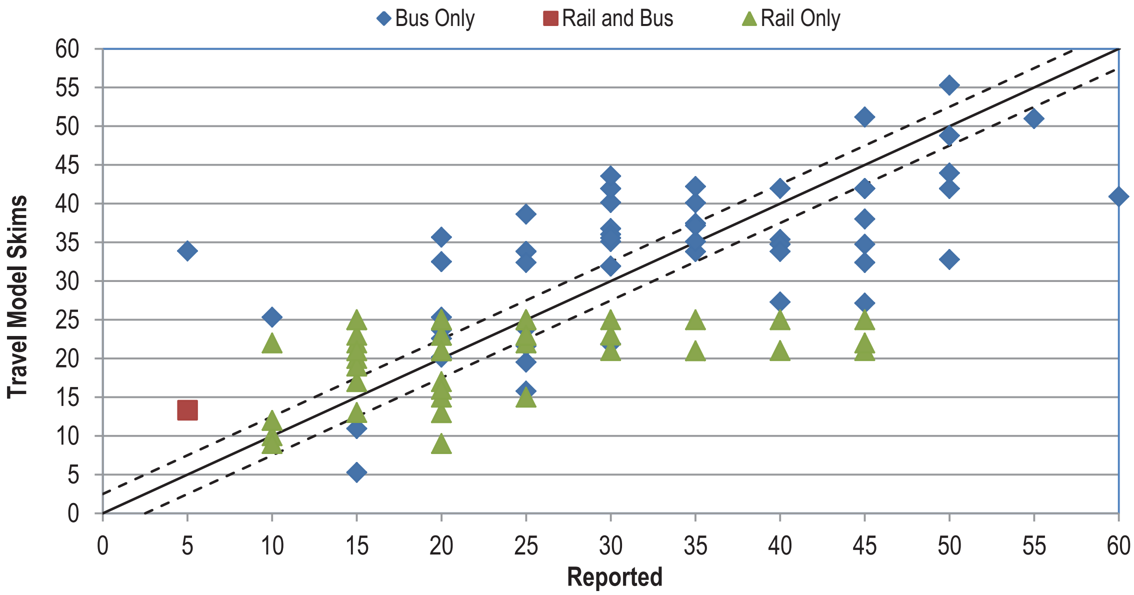
These figures show a relatively low correlation between reported and modeled in-vehicle trip times (r-squared ranging from 0.31 to 0.57). Correlations are slightly higher for the Charlotte networks, which have been the subject of path and travel time validation and within the Charlotte case, modeled and reported walk access in-vehicle times are more correlated than drive access in-vehicle times. Even so, the best r-squared value is under 0.6, suggesting that modeled and reported travel times still differ considerably.

FIGURE I-3 provides evidence that reported travel times can be widely divergent from schedule-based estimates of time. Out of 112 survey responses, 10 records show LRT times in excess of the 25-minute scheduled end-to-end travel time on the Charlotte LRT line. It is possible that some of these trips were on delayed trains. Thus, it is not known whether these outcomes are due to poor reporting on the part of survey respondents or are due to the fact that actual travel times do not always match scheduled times.



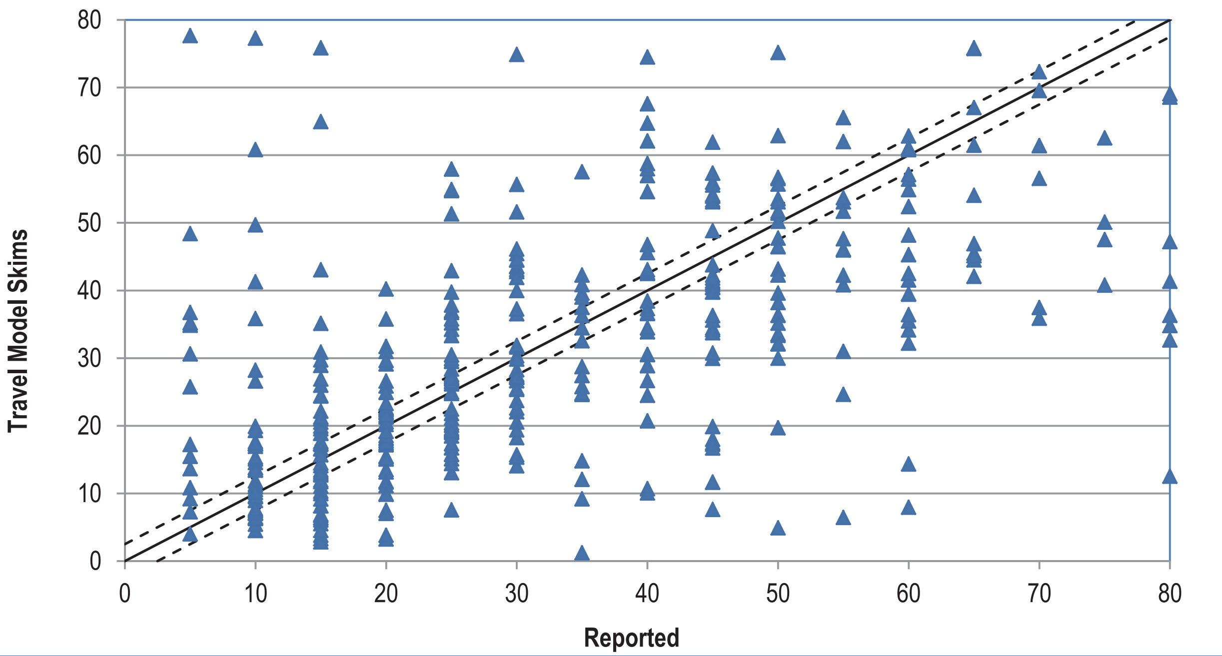
R-Squared = 0.57, Number of observations: 33

FIGURE I-2. Comparison of reported and modeled IVTTs for Charlotte walk access transit trips.



R-Squared = 0.48, Number of observations: 112

FIGURE I-3. Comparison of reported and modeled IVTTs for Charlotte drive access transit trips.



R-Squared = 0.31, Number of observations: 425

FIGURE I-4. Comparison of reported and modeled IVTT for Chicago best path transit trips.

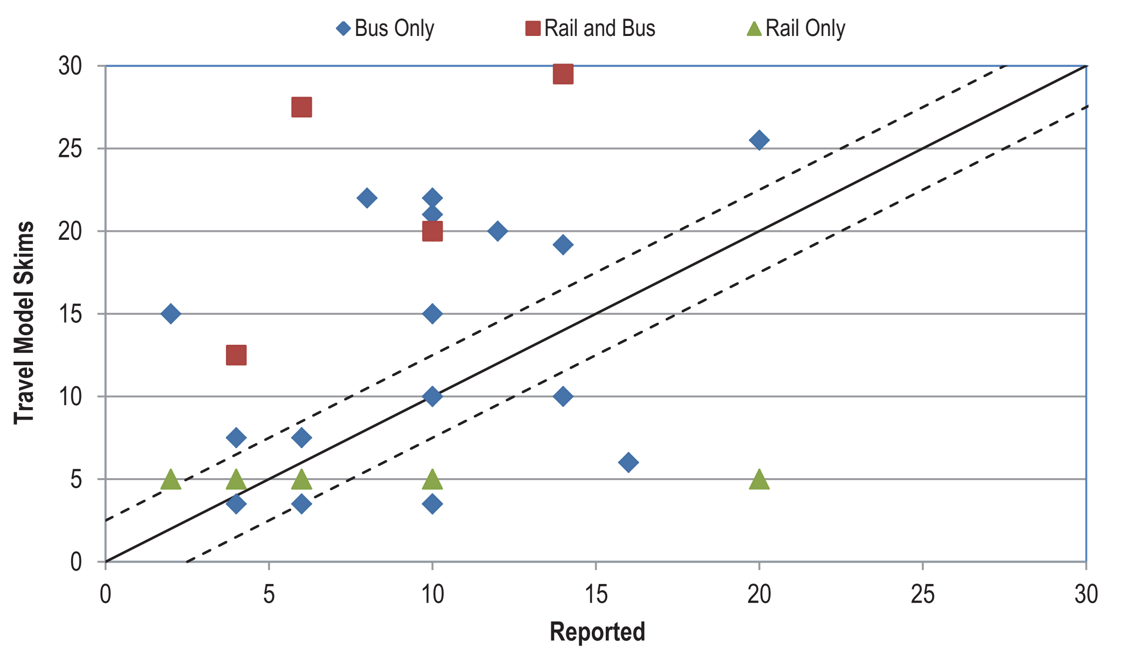
Transit Waiting Time

FIGURE I-5, FIGURE I-6, and FIGURE I-7 show a comparison of reported and modeled transit waiting times for walk access and drive access trips in Charlotte and waiting time for best paths in Chicago. This statistic includes both initial wait time and transfer wait time. Modeled times are based on the traditional computation that estimates waiting time to equal one-half of the headway for all routes that provide service between the boarding and alighting location.

In Charlotte, this headway represents the entire 2.5 hour a.m. peak period between 7:00 a.m. and 9:30 a.m. This estimate is an imperfect simplification of a complex phenomenon. Some services such as the LYNX LRT line operate on short, consistent headways throughout the AM peak period. Some bus routes offer inconsistent levels of service over the course of the peak period. Examples include:

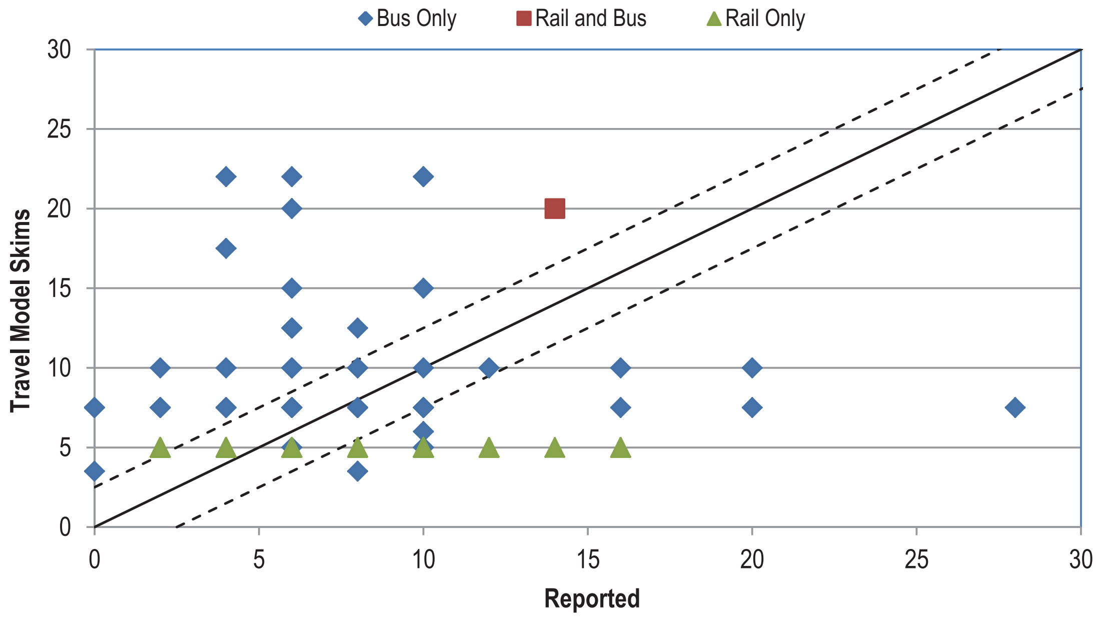
- The #7 Beatties Ford Bus Route from Northlake Mall offers 20-minute headway service (three trips per hour) during the peak hour but only two additional trips arrive in downtown Charlotte during the 1.5-hour-long peak shoulder.
- The 80x Concord Express bus arrives in downtown Charlotte two times each hour during the 6:00 a.m., 7:00 a.m., and 8:00 a.m. hours. However, the last trip of the morning arrives at 8:32 a.m., nearly an hour before the end of the peak period.

Given the known differences between actual and modeled waiting times it is not surprising that the comparisons of reported versus modeled transit waiting times in FIGURE I-5 through FIGURE I-7 show very little correlation between these estimates. Correlations range between 0.01 and 0.22, which suggests that while modeled wait time may be useful for helping to understand potential ridership, it should not be thought to be equivalent to waiting time. Instead, common practice should transition to calling this variable what it is, one-half of the effective headway, and assigning a coefficient value that represents the fact that this variable is not directly comparable to other components of travel time.



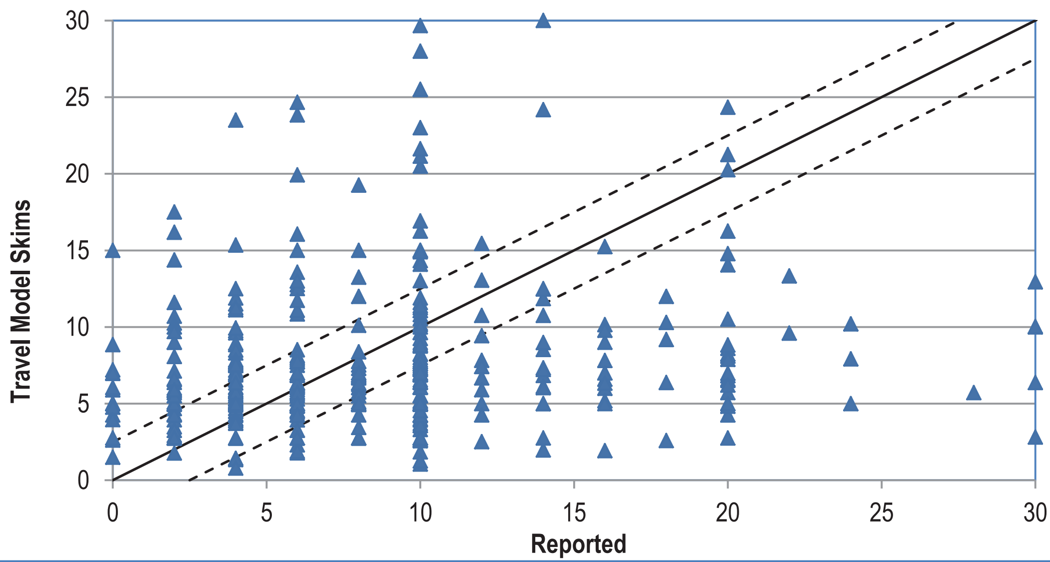
R-Squared = 0.22, Number of observations: 33

FIGURE I-5. Comparison of reported and modeled wait times for Charlotte walk access transit trips.



R-Squared = 0.01, Number of observations: 112

FIGURE I-6. Comparison of reported and modeled wait times for Charlotte drive access transit trips.



R-Squared = 0.02, Number of observations: 425

FIGURE I-7. Comparison of reported and modeled wait times for Chicago best path transit trips.

Transit Walk Times

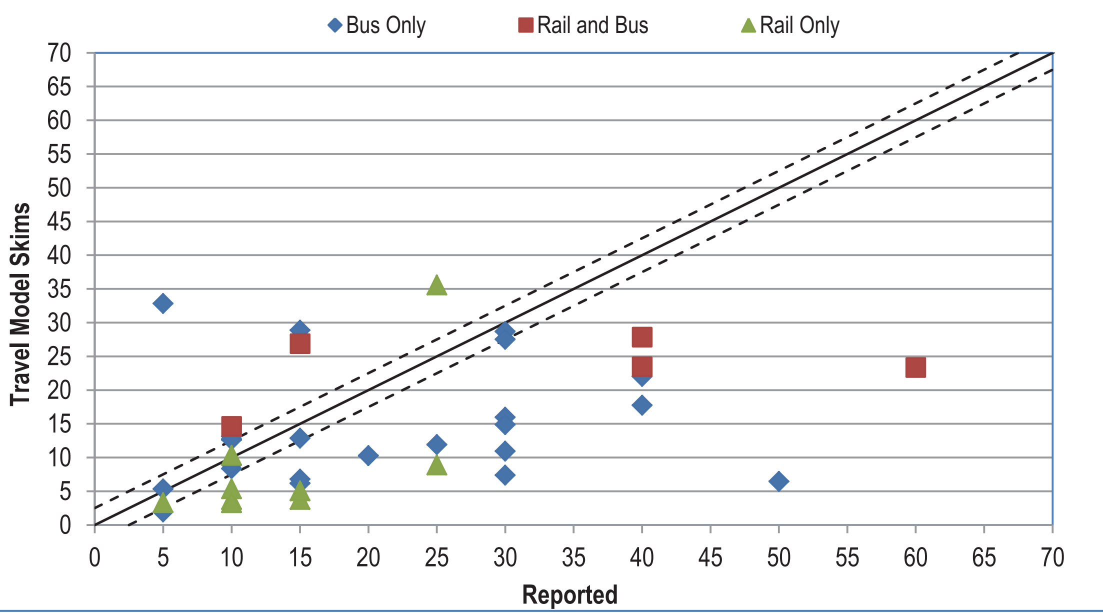
FIGURE I-8 and FIGURE I-9 present a comparison of reported and modeled walk times for walk access and drive access trips included in the Charlotte survey. No comparable information is available for Chicago trip records because the CMAP Chicago modeling process synthesizes walk access time as part of the demand models, and skimmed values of walk access time are not generated.

The Charlotte model estimates walk access time by connecting zone centroids to transit stations and stops using highway centroid connectors and highway network links. Walk time can also occur as customers making a transfer walk between bus or rail stops. Walk speeds are assumed equal to 3 miles per hour.

As discussed earlier in this appendix, zone aggregation can result in a loss of precision that could be equal to 5 or more minutes. The graphs presented in FIGURE I-8 and FIGURE I-9 show much larger variations, with the majority of the difference occurring where reported time is higher than estimated by the model. In many cases, reported travel times are 10 to 20 minutes longer than modeled walk. This is 2 to 4 times the error that would be expected if zonal aggregation errors were the only source of the difference between reported and modeled walk times. Multiple possible explanations exist for this difference, including:

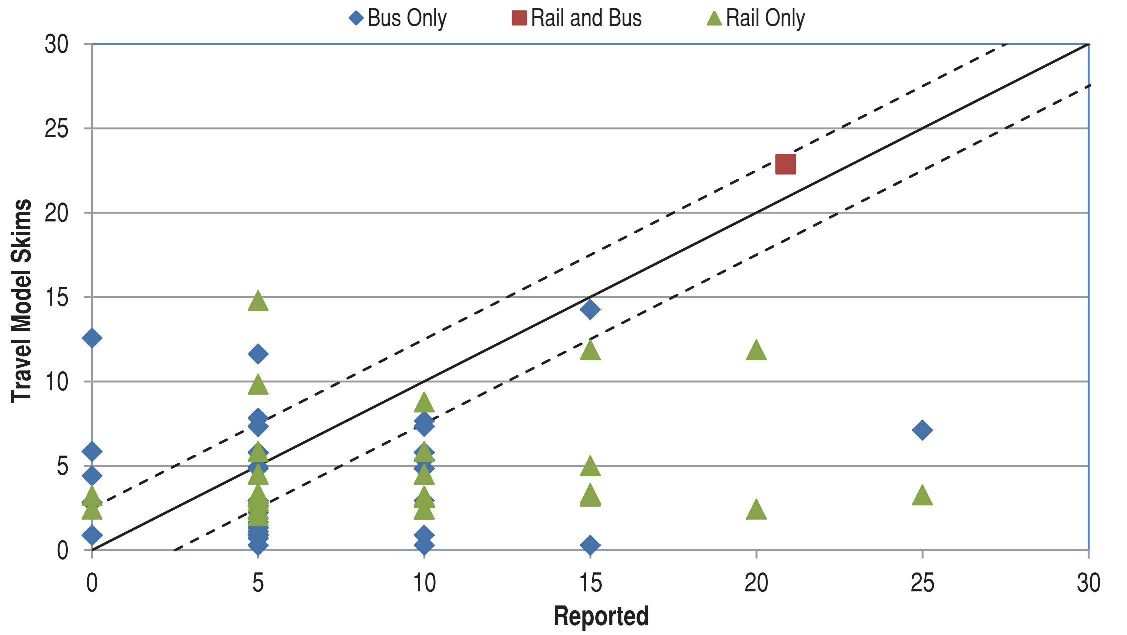
- The path-builder properly understood the origin and boarding stop locations but the traveler walked slower than the modeled speed of 3 mph.
- The path-builder weighted walk time too heavily, resulting in a selected path with a short walk connector to a less advantageous bus or rail route than was actually selected by the traveler.
- Reported walk times did not represent actual conditions.

The survey did not report stop or station boarding locations or specific transit routes, so it is not possible to understand which of these possibilities is more prevalent.



R-Squared = 0.16, Number of observations: 38

FIGURE I-8. Comparison of reported and modeled total walk times for Charlotte walk access transit trips.



R-Squared = 0.25, Number of observations: 115

FIGURE I-9. Comparison of reported and modeled total walk times for Charlotte drive access transit trips.

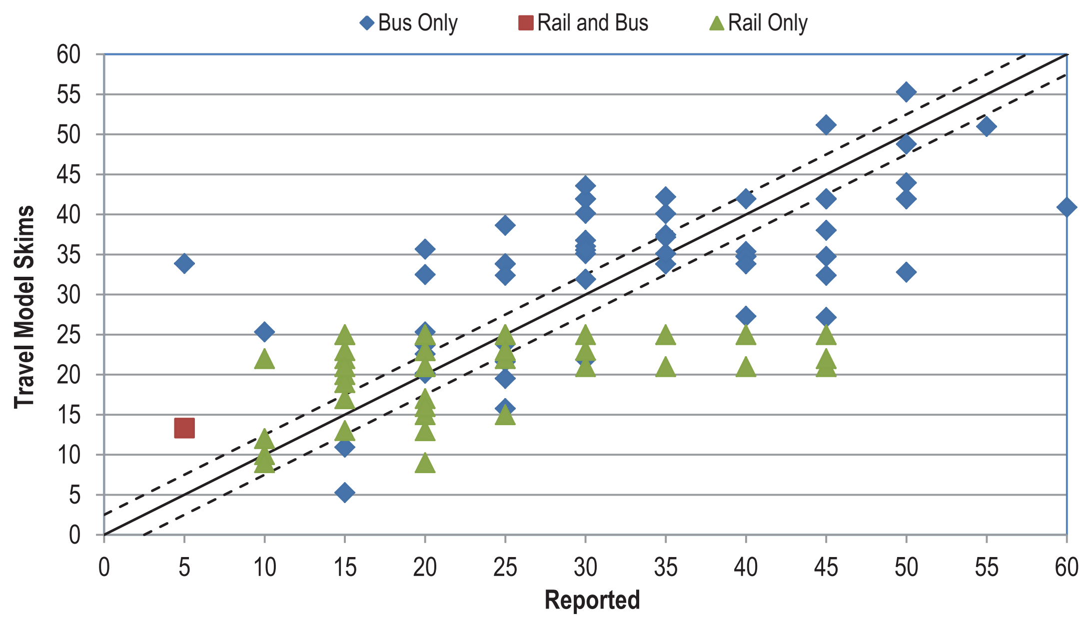
Drive Access Time

FIGURE I-10 presents a comparison of drive access times for the Charlotte survey. As is the case for walk access discussed in the previous section, drive access to transit times are also subject to zonal aggregation errors. However the fact that the drive access portion of the trip tends to be longer than the walk access portion of the trip and the fact that driving is significantly faster than walking suggests that drive time estimates should be much less affected by these aggregation problems than walk time estimates.

This assessment is borne out in the relationships presented in FIGURE I-10. The correlation between reported and modeled drive access time is equal to 0.48, nearly twice as high as the walk time correlation for drive access trips. Unlike the walk time comparisons, drive time estimates are more evenly distributed around the "x=y" line, signifying reported and modeled trips being equal. Nevertheless, positive and negative differences of up to 20 minutes are common suggesting that travelers have a wide range of different perceptions. Some prefer nearer neighborhood park-and-ride facilities, while others appear to be attracted to more distant facilities that may offer higher levels of transit service. It seems unlikely that a single set of parameters can capture this relationship, and other means should be identified for characterizing the full range of park-and-ride options.

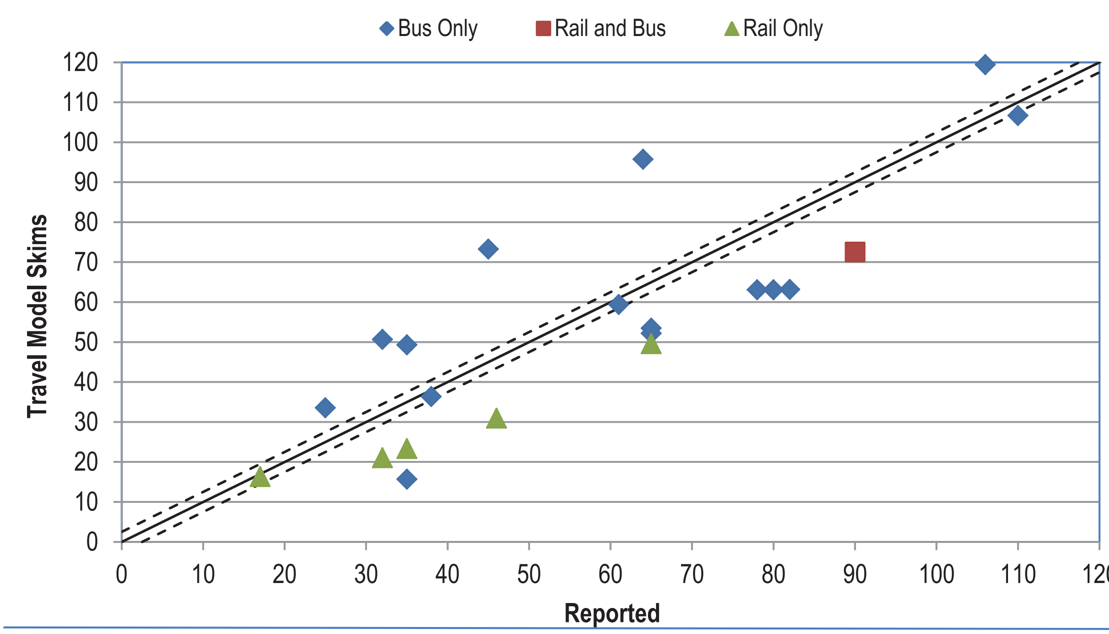
Total Travel Time

FIGURE I-11, FIGURE I-12, FIGURE I-13, and FIGURE I-14 present a comparison of reported and modeled total travel times (i.e., the sum of walk, drive access, wait, and in-vehicle times) for Charlotte walk access and drive access trips separated into peak and off-peak travel times. This comparison cannot be prepared for Chicago because skim data is not available for walk time—a key component of total transit travel times.



R-Squared = 0.48, Number of observations: 112

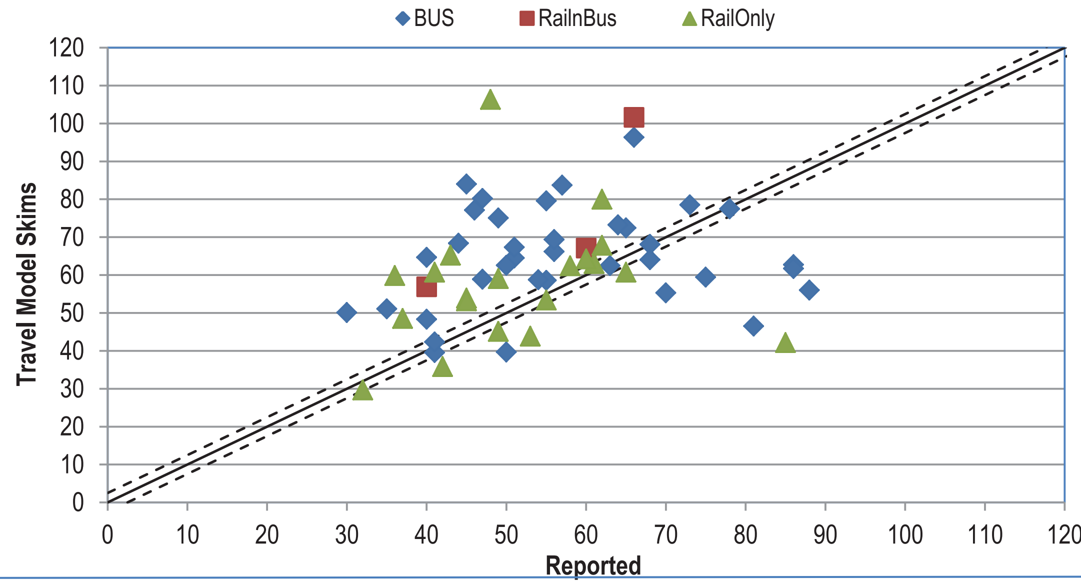
FIGURE I-10. Comparison of reported and modeled drive access time for Charlotte transit trips.



R-Squared = 0.62, Number of observations: 22

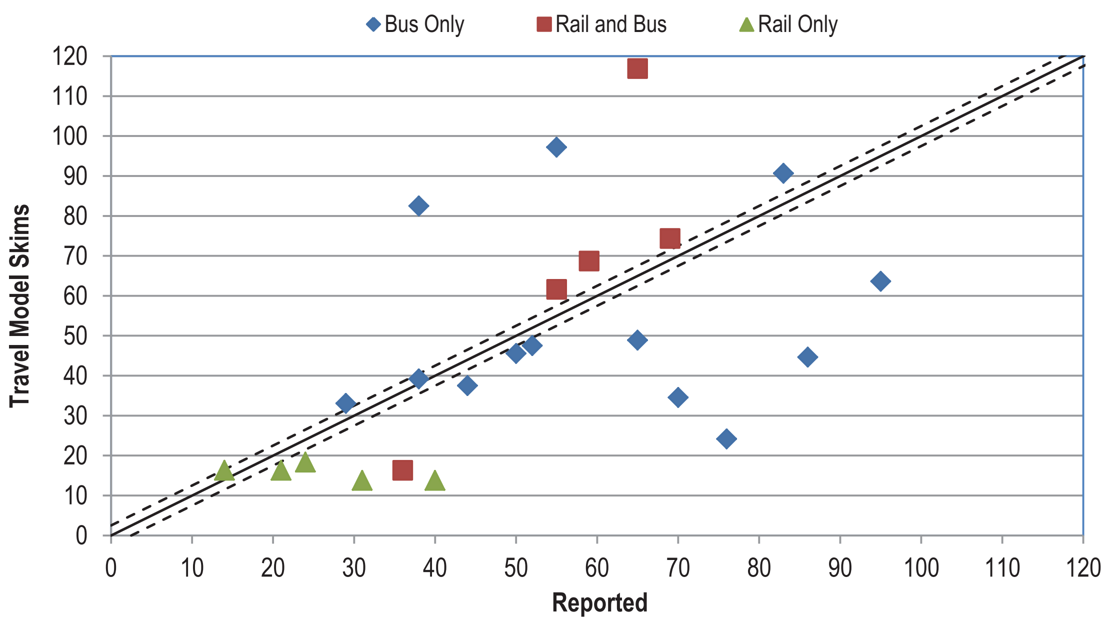
FIGURE I-11. Comparison of reported and modeled total travel time for Charlotte peak period walk access transit trips.

The very low correlations between reported and modeled total travel times (0.62 for peak walk-to-transit and under 0.25 for the remaining cases) suggest that the various errors associated with each component of travel time do not balance out. Such would be the case if travelers were trading off equal quantities of walk, wait, drive access, and in-vehicle times.



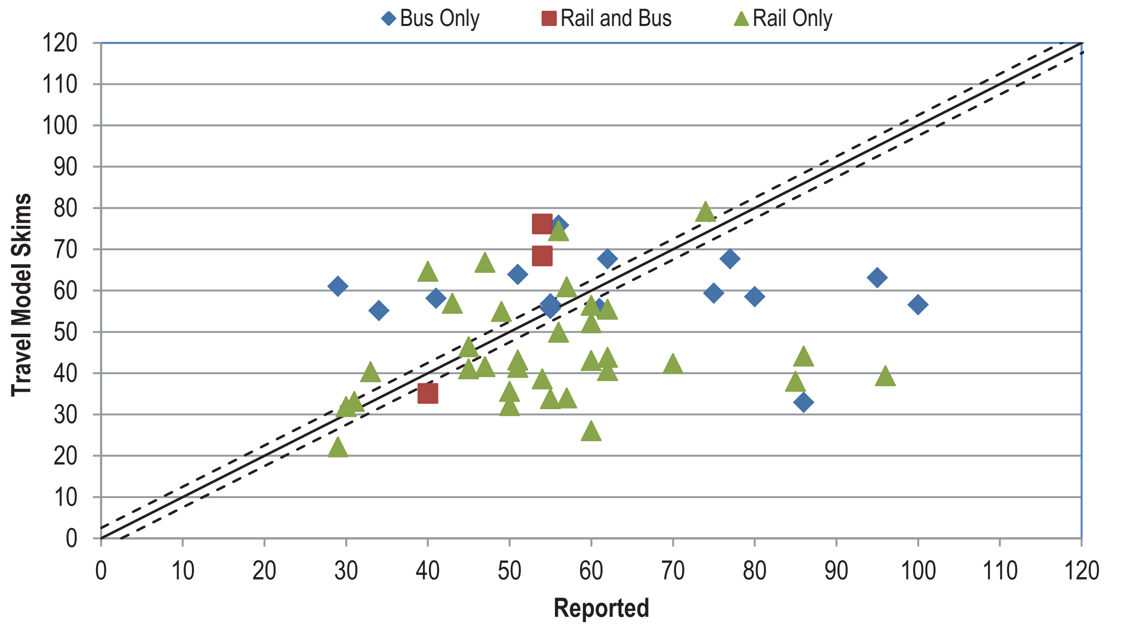
R-Squared = 0.09, Number of observations: 63

FIGURE I-12. Comparison of reported and modeled total travel time for Charlotte peak period drive access transit trips.



R-Squared = 0.22, Number of observations: 28

FIGURE I-13. Comparison of reported and modeled total travel time for Charlotte off-peak period walk access transit trips.



R-Squared = 0.02, Number of observations: 51

FIGURE I-14. Comparison of reported and modeled total travel time for Charlotte off-peak period drive access transit trips.

Respondent Perceptions of Travel Time Compared to Schedule-Based Paths

The variations between reported travel times and level-of-service (skim) matrices generated by validated travel model path-builders are sufficiently large to raise concern about the nature of these differences and whether modeled times are sufficiently accurate to support ridership forecasting models.

Differences between reported and modeled transit travel times could be the result of either:

- The inability or unwillingness of survey respondents to accurately complete questionnaires; or
- Modeled travel times not accurately reflecting actual travel conditions.

Both situations can negatively affect travel model development. To understand this issue more completely, a procedure was developed for reading Charlotte bus and rail timetable information for the survey period and generating origin-to-destination estimates of travel time that are comparable to travel model skim matrices. The path-finding process was validated against the CATS on-line trip planner to confirm that the routing and travel time estimates conform to estimates available to the traveling public. The path-finding procedures developed for this analysis also included the capability to route park-and-ride and kiss-and-ride trips.

The schedule-based path-building procedures differ from conventional travel model skims in that they attempt to represent, as faithfully as possible, the characteristics of a transit trip as experienced by each specific traveler beginning at a precise origin, ending at a precise destination, and departing at a specific time. Key aspects of this process that are different from typical travel model path-finding algorithms include:

- Origin and destination locations are based on the reported survey latitude and longitude for each point. Zone centroids were not used for this analysis. Access and egress travel times are based on origin to bus stop walk and drive times generated by both Microsoft® MapPoint and Google Maps. These times consider street connectivity for walk access and facility type, turn penalties and one-way operation for drive access.
- Departure times were used as coded on the survey record unless it was apparent that the respondent coded an a.m. time when a p.m. time was intended. This problem was assumed to exist when the trip purpose fields suggested that the traveler was returning home but the departure time was coded as being before 8:00 a.m. (e.g., 2:15 a.m.). In that case, the time was adjusted by adding 12 hours (e.g., 2:15 a.m. was recoded to 2:15 p.m.).
- Trips were routed on specific bus routes and scheduled trips (in this context a "scheduled trip" is that portion of a scheduled run that covers a specific set of time points from the route origin to route destination). Waiting times are computed as the time between arrival at a bus stop or rail station and departure on the appropriate scheduled trip. The concept of combined headways used in travel models is not applicable for routing on specific trips and was not used in this analysis.
- Travel times were based on timetable values rather than a function relating transit travel times to highway speeds.

A comparison of schedule-based and travel model-based travel time estimates (skims) are presented in FIGURE I-15. As these tables show, estimates of schedule-based and travel model-based in-vehicle time estimates are moderately correlated (r-squared of 0.70 for walk access and 0.55 for park-and-ride access). The moderate correlation confirms that the original time matrices were calibrated to match overall scheduled transit running times but that some variation remains between modeled and scheduled speeds.

Not surprisingly, access and waiting time estimates are poorly correlated (r-squared under 0.25) between travel model- and schedule-based paths. This is quite likely caused by the fact that travel models assume that all travel begins and ends at zone centroids and that waiting time is equal to one-half of the service headway. Neither assumption aligns well with the schedule-based path-finding algorithm or an intuitive assessment of how travelers experience a transit trip.

Schedule-based travel times were also compared to survey-reported travel times. This process began with a manual review of 73 walk access/walk egress and 150 park-and-ride access records in Charlotte (the entire survey sample of each access type with the exception of trips that included stopovers). The manual review examined the reported latitude/longitude, travel times, access mode, transit mode(s), and egress modes to determine whether the survey record appeared to be feasible.

FIGURE I-15. Comparison of travel model- and schedule-based estimates of transit travel time.

As shown in TABLE I-6, approximately one-quarter of all trips were discarded because the manual review concluded that the trip records that contained inconsistencies between origin location, destination location, and path that were unlikely to occur as reported. This percentage is similar to the fraction of trips that had no modeled skim time (19%).

Problems included very short origin-to-destination travel distances (under ½ mile for walk access trips and under 2 miles for park-and-ride trips) and unlikely combinations of origin location, destination location, modes, and travel times. In many cases, the root cause for these issues appears to be reported origin and destination locations that did not match likely trip beginning and ending locations. For example, some travelers appeared to report trip origins and destinations occurring at the boarding and alighting stations rather than at their homes or offices. Other respondents used the map pointing function to point to a general area of the trip end. In either case, it is possible that travelers wished to preserve their privacy by not reporting a specific beginning or ending location.

TABLE I-6. Frequency of survey records eliminated from further analysis due to inconsistencies with reported origins, destinations, and path characteristics for Charlotte.

	Walk Access Trips	Park-and-Ride Access Trips	All Trip Types
Total survey records	73	150	223
Records with inconsistencies	21	35	56
Very short distance between origin and destination	7	8	15
Departure time outside CATS hours of operation	0	5	5
Origin and destination not served by connecting transit at the stated time of departure	4	8	12
Park-and-ride access and egress	0	2	2
Access and egress not consistent with origin and destination	0	4	4
Path modes not consistent with origin and destination	9	12	21
Travel times not consistent with origin and destination	1	3	4

Note: Some records were excluded for multiple reasons.

The remaining records were examined to determine whether the schedule-based path-finder generally matched the reported paths. In cases where the reported paths included different modes or significantly different travel times, then schedules were manually reviewed to determine whether a different path existed that more closely matched reported results. The results of this analysis are presented in TABLE I-7.

Between 60 and 70% of usable surveys matched the automatically generated paths, while the remainder had a better match with the manually-prepared paths. Out of the 52 cases where manual paths matched reported paths better than the automatic process, five cases involved travelers

TABLE I-7. Frequency of survey records where automatic and manual paths best replicated reported paths and reasons for differences.

	Walk Access Trips	Park-and-Ride Access Trips	All Trips
Total survey records	73	150	223
Usable survey records	52	115	167
Records where automatic path-finder generally matched reported path	**32**	**83**	**115**
Records where manual path generally matched reported path. Most common differences:	**20**	**32**	**52**
Manual path had longer access distances		6	6
Manual path had fewer transfers	1 (on average, **increased** total travel time by 11.0 min.)	4 (on average, **reduced** total travel time by 34.6 min.)	5
Manual path had more transfers	1 (on average, **reduced** total travel time by 0.4 min.)	1 (on average, **increased** total travel time by 17.5 min.)	2
Manual path used bus while automatic path used rail	1 (on average, **increased** total travel time by 27.6 min.)	4 (on average, **increased** total travel time by 8.1 min.)	5
Manual path used rail while automatic path only used bus	10 (on average, **increased** total travel time by 6.0 min.)	4 (on average, **increased** total travel time by 9.6 min.)	14
Other reasons	4 (on average, **increased** total travel time by 4.9 min.)	1 (on average, **increased** total travel time by 0.9 min.)	5

appearing to prefer longer access times to save a transfer. In the case of park-and-ride trips, this generally occurred because the reported path involved much longer drive-to-parking distances than allowed in the path-finder. The path-finder assumed that the average distance to drive to an end-of-line LRT station was 10 miles, the average to drive to other LRT stations was 6 miles, and the average to drive to a bus park-and-ride was 3 miles. Although the majority of paths worked well with these limits, auto access distances of up to 17 miles were observed for both bus and rail trips.

Some travelers also appeared to select paths that avoided rail (five trips) while other travelers selected paths that included rail (14 trips) even though the selected path did not minimize travel time. In general, travel on the alternative path added between 6 minutes and 10 minutes to total travel time.

Not surprisingly, the manual paths introduced different characteristics in terms of total time and each constituent time component (e.g., access time, in-vehicle time, and waiting time). This variance is illustrated in FIGURE I-16, which compares the original automatic schedule-based path to the adjusted paths. In the trip records explored for Charlotte, the majority of adjusted paths are unchanged from the automatic times (33 out of 49 records for walk access and 83 out of 95 records for park-and-ride access), so the correlation between the automatic and adjusted paths is relatively high. The correlation for just those paths that changed is relatively low, with some long park-and-ride trips having changes of 30 minutes or 40 minutes of total travel time when adjusted times are substituted for automatic times.

Even after adjustment to account for alternative paths, reported and estimated total travel times are, at best, loosely correlated. This comparison is presented in FIGURE I-17. Total reported travel times compared to adjusted schedule-based travel times have an r-squared of 0.52 for walk access and 0.31 for drive access. The comparison of reported and schedule-based IVTT is more highly correlated (r-squared over 0.6 for both access types), while wait and walk times have a correlation under 0.5. As noted above, this outcome may be a result of problems associated with travelers accurately and precisely reporting their origin and destination locations.

Summary of Findings

The findings described in this appendix suggest that:

- A significant number of survey respondents (47%) report transit travel that is not represented by existing transit networks. There are several explanations for this, with the primary reason being these trips include a stopover that is not represented by many traditional trip-based travel forecasting models.
- Travel demand forecasting model path-builders struggle to represent transportation supply in a manner that is consistent with reported survey results. Modeled and reported IVTT are only moderately correlated. Reported out-of-vehicle times exhibit very little correlation with model-estimated times. This finding may account for problems that have been experienced generating reliable estimates of travel time coefficients in mode choice models, particularly as relates to out-of-vehicle time.

It is possible that one or both of these findings is a result of respondent errors in reporting travel. Errors may include inaccurate estimates of travel time or incorrect or imprecise descriptions of trip origins and destinations. The latter possibility is problematic for model developers. Without accurate and precise information on trip origins and destinations, it is not possible to generate accurate estimates of travel time using any path-finding algorithm. A manual review of survey records revealed that 25% of records appeared to be unusable because of problems with origin or destination locations or reported path-routing. It is possible that significant numbers of the remaining records have inaccurate origins, destinations, or paths that were not detected.

Future data collection procedures must collect additional data to support meaningful error detection and correction. This can be accomplished by collecting data on specific bus and rail routes, boarding station/stop, and alighting station/stop to enable reviewers to cross-check different elements of the survey response against timetable information.

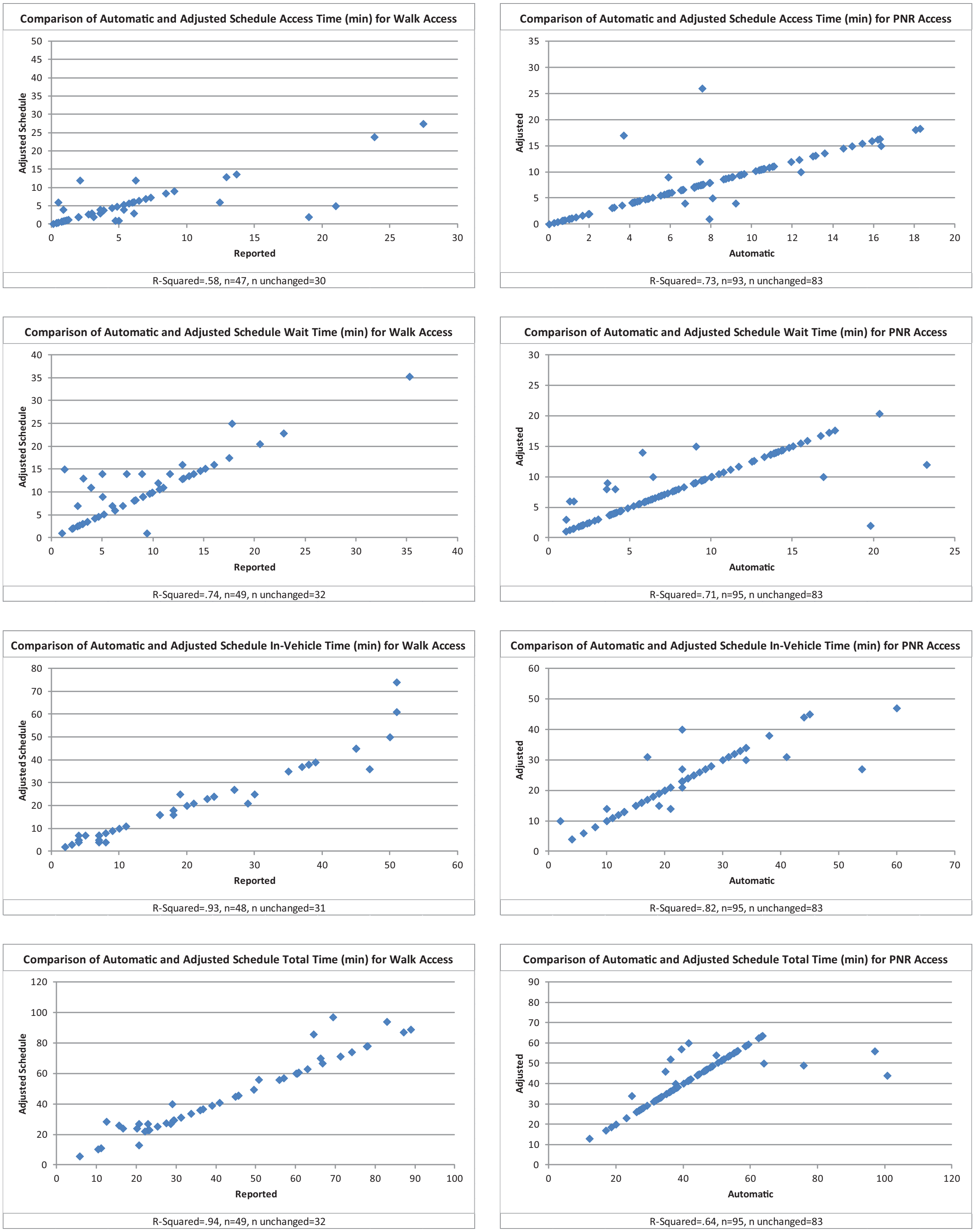


FIGURE I-16. Comparison of automatic and adjusted schedule travel times by travel time type.

FIGURE I-17. Comparison of reported and adjusted schedule travel times by travel time type.

APPENDIX J

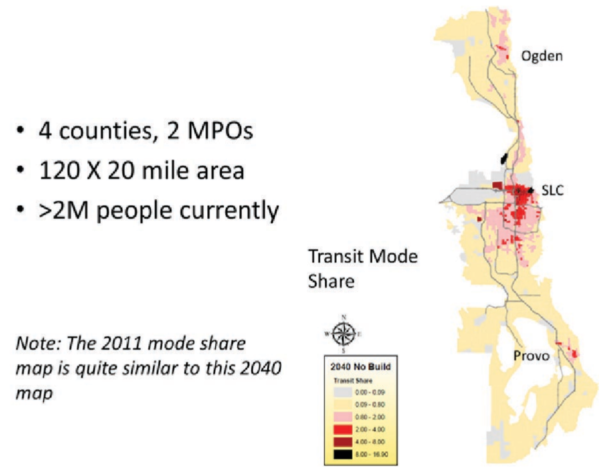
Model Implementation and Calibration

Contents

Overview

The purpose of the model implementation and calibration was to apply the scaled marginal rates of substitution or values in equivalent minutes of in-vehicle travel time (presented in the previous section) in a standard practice travel model and modify the mode choice model structure to recognize path choices rather than technology mode choices.The estimated values of non-traditional transit service attributes from the MaxDiff models were incorporated into an existing travel model's transit path-building and mode choice components to demonstrate their applicability in practice. This appendix describes in detail a process that was developed to implement and calibrate a mode choice model that accounts for the influence of non-traditional or premium transit service attributes.

The travel model for the Salt Lake City region was chosen for this demonstration. Transit mode shares for the Salt Lake City region are provided in FIGURE J-1. The Salt Lake City region is encompassed by two MPOs, which are the Wasatch Front Regional Council (WFRC) and the Mountainland Association of Governments (MAG). The two MPO planning areas are adjacent, and the agencies utilize the same travel model. The WFRC/MAG model region encompasses four counties—Weber, Davis, Salt Lake, and Utah. Bounded by the Great Salt Lake on the west and Wasatch mountain range on the east, the region is relatively narrow. Hence, most of the transit travel is in the north-south direction to and from Salt Lake City which is centrally located in the region. The transit system mainly consists of five service types—local bus, express/fast bus, bus rapid transit (BRT), light rail transit (LRT), and commuter rail transit (CRT) which together service approximately 150,000 boardings on a typical weekday.



SLC: Salt Lake City

FIGURE J-1. Regional overview of transit system in Salt Lake City.

Existing Salt Lake City Models

Before discussing the specifics of how the research methods were deployed and tested in Salt Lake City, it is useful context to understand the current model, and specifically aspects related to transit modeling. The following is a brief introduction to the existing transit path-finding and transit mode choice modeling processes, prior to any enhancements as part of this research effort.

The existing WFRC/MAG travel model has been implemented in Citilab's "CUBE" software environment and "TRNBUILD" is used for transit path-building and assignment. TRNBUILD constructs transit paths using transit routes and various path-building parameters as inputs. TABLE J-1 shows the parameters used by the transit path-building process in the existing model.

TABLE J-1. Path-building parameters: existing model.

Path-Building Parameter	Value
Maximum walk access/egress distance	0.75 mi.
Initial wait time weight	2 x IVTT*
Transfer wait time weight	3 x IVTT
Transfer penalty (1, 2+ transfers)	(10, 60) min.
Walk access\egress time weight	2 x IVTT
Drive access time weight	1.5 x IVTT
Minimum wait time (bus, rail)	(3, 5) min.
Maximum perceived path time	240 min.

*IVTT: in-vehicle travel time

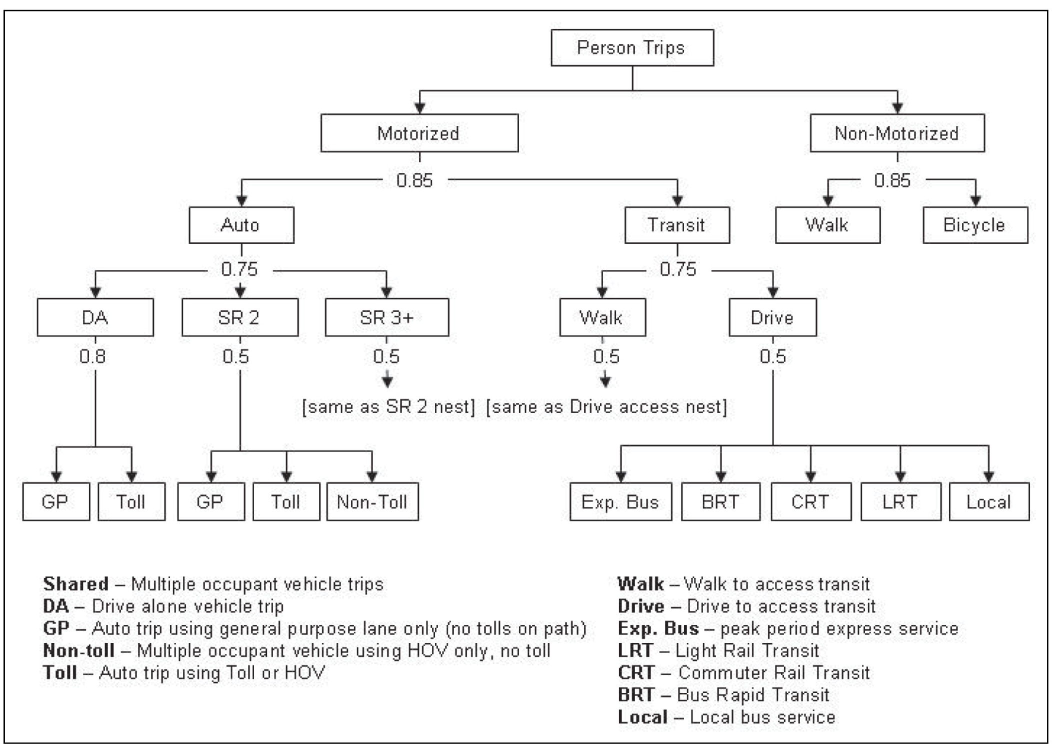
For each origin-destination (OD) pair, the path builder attempts to build up to 10 unique transit paths that are *mode-specific,* developing one path for each of the five "primary" modes—

local bus, express bus, BRT, LRT, and commuter rail—by each of the two access types (walk and drive). For each of the 10 path types, the shortest path is skimmed for every OD pair. These mode-based paths are available as alternatives for transit trips in the mode choice model. There is no formal kiss-and-ride (KNR) access modeled. TABLE J-2 defines the mode hierarchy for primary mode identification for a specific transit path. To illustrate, a transit path involving LRT and BRT would be called an LRT path because light rail is highest in the hierarchy of modes in the transit path.

In addition, the transit paths are built for two time periods—peak (6 a.m. to 9 a.m. and 3 p.m. to 6 p.m.) and off-peak (the rest of the day). A nested multinomial logit mode choice model is used to estimate the split among auto, walk/bike, and transit trips. The nesting structure and model parameters are shown in FIGURE J-2. The transit trips are further split into one of the 10 transit paths identified by the path builder.

TABLE J-2. Mode hierarchy by transit path type

		Mode Allowed				
		Local Bus	**BRT**	**Express Bus**	**Light Rail**	**Commuter Rail**
Path type	Local bus	Required	No	No	No	No
	BRT	Yes	Required	No	No	No
	Express bus	Yes	Yes	Required	Yes	No
	Light rail	Yes	Yes	No	Required	No
	Commuter rail	Yes	Yes	No	Yes	Required



Source: Wasatch Front Regional Council Mode Choice Model Documentation

FIGURE J-2. Existing mode choice model for Salt Lake City.

The mode choice model has been estimated separately for four trip purposes: (1) home-based work (HBW), (2) home-based other (HBO), (3) home-based college (HBC), and (4) non-home-based (NHB). All trips are segmented into three classes based on access to transit in the origin zone. The three access-to-transit segments are "no access to transit," "must drive to transit" (no walk access transit available), and "can walk to transit." Based on the access-to-transit segment of a particular trip, the available transit choices are determined. For example, the "must drive to transit" segment does not have a walk access transit mode available. There is further demographic segmentation applied to HBW and HBO trips. Prior to applying the mode choice model, HBW and HBO trips are segmented based on three vehicle-ownership classes and two income classes. The three vehicle-ownership classes are zero-, one-, and two- or more vehicle households for which separate transit alternative specific constants have been calibrated. The two income categories distinguish households in the lowest income quartile from households in the three higher income quartiles. The income category affects the cost coefficient in the mode choice model.

The model coefficients were originally estimated and calibrated using an estimation dataset blended from home interview survey data and transit on-board survey data, with appropriate model skims appended to each survey. In some cases, parameters have been adjusted based on professional judgment and experience with the model. TABLE J-3 shows the mode choice model coefficients used in the existing model.

TABLE J-3. Existing mode choice model coefficients for Salt Lake City.

Variable	HBW	HBO	NHB	HBC
In-vehicle time (minutes)	-0.0221	-0.0160	-0.0233	-0.0221
Initial wait (minutes)	-0.0442	-0.0320	-0.0466	-0.0442
Transfer wait (minutes)	-0.0500	-0.0480	-0.0663	-0.0500
Drive access time (minutes)	-0.0332	-0.0240	-0.0350	-0.0332
Walk time (1st mile) (minutes)	-0.0442	-0.0320	-0.0466	-0.0442
Walk time (> 1 mile) (minutes)	-0.0663	-0.0480	-0.0699	-0.0663
Cost—low income (cents)	-0.0099	-0.0120	-0.0049	-0.0060
Cost—higher income (cents)	-0.0023	-0.0040	-0.0049	-0.0060
Premium direct walk—bus	0.1105	0.0800	0.1165	0.1105
Premium direct walk—rail	0.2210	0.1600	0.2330	0.2210
Drive access distance divided by auto path distance	-0.3315	-0.24	-0.3495	-0.3315
Transfers	-0.265	-0.192	-0.280	-0.265
1/(transit distance)—walk	-1	-1	-1	0
1/(transit distance)—drive	-3	-3	-3	-1
Urbanization (density) at attraction end	0.0044	0.0032	0.0047	0

For the purpose of this project, the current mode choice model was recalibrated to a more recent transit on-board survey. The transit survey was conducted system-wide (including all the five transit modes) in the spring of 2011. It contained about 7,100 valid records. The calibration involved adjusting the alternative specific constants in the existing model to match boarding counts from the on-board survey by primary and access modes. In addition, boarding counts by transit route were also validated during this process. The calibration results of both the existing model and the new transit path choice model are provided in the comparative results section at the end of this chapter.

Incorporating Transit Amenities and Service Characteristics

The implementation of the methods explored in this research to incorporate non-traditional attributes into a standard practice travel model involved considerations around how to revise the transit path builder, the definition of transit modes, and the mode choice model utility expressions.

As a first step in this model refinement process, an assessment of the availability of non-traditional or premium transit service characteristics for the transit system in the Salt Lake City region was made. Data pertaining to park-and-ride lots, station/stop shelter and seating, and route level on-time performance information were obtained from the local agencies. Other service information about stations/stops such as lighting/safety, security, and proximity to services was not available or was deemed too anecdotal and approximate to be useful. In the Salt Lake City region the on-board amenities were not available at a route level, but the perception among local transit agency staff was that variation in amenities and service characteristics among services was more obvious at the "mode" level (or between service types), than it was at the route level.

Ideally, the path builder should account for all the information on premium transit characteristics at the appropriate level. For example, stop shelter and seating would ideally vary by stop; on-board amenities may vary by route, etc. The way in which Salt Lake City represented their supply system within TRNBUILD does not allow the user to easily apply node- or transit-route-specific penalties or benefits. It is possible to implement stop-specific penalties through careful access link coding leading up to each specific transit stop, but that was not needed for this proof of concept. Further, while route level path-building rules aren't feasible, "similar" routes could be combined into more "modes" to incorporate more variation in path-building rules, parameters, and weights. The parameters that can affect path-building in TRNBUILD are initial/transfer/access/egress time weights, boarding penalties, and in-vehicle time weights. Most of these parameters can be directly applied by mode. Hence, as a work-around for this project, mode-specific composite premium transit characteristic benefits were computed and applied as boarding penalties.

TABLE J-4 shows the asserted premium transit attributes at the mode level based on knowledge of transit system of the region. For each premium transit attribute, the values in terms of IVTT minutes were first obtained by averaging the scaled values from Chicago and Charlotte surveys in Phase 2 for commute trips for both bus and train. The values from the Salt Lake City survey were not used because the survey had changed from Phase 1 to Phase 2, and it was felt that survey data obtained in Phase 2 had better information from a methodological standpoint. Not all the premium transit service attributes measured in the MaxDiff models were available for the existing model. Hence, the values of attributes that were available were scaled by each bundle of premium attributes to reflect the full benefit that could potentially be gained from premium transit characteristics. For example, if only shelter and bench information was available in the "station amenities" bundle, which add up to 1.13 minutes, those values were scaled up to the full value of the bundle (when all other attributes were included), which is 4.33 minutes (see the "Value" and "Scaled Value" columns of TABLE J-4). The benefits were then converted to mode-specific relative penalties that could be applied at each boarding by the path builder. In addition, the estimated value of perceived reduction in the in-vehicle time in a premium mode was used for path-building and mode choice. It was applied to all modes except local bus again based on local knowledge of the transit system.

Transit Mode Definition and Path-Finding

An objective of this research was to explore the switch from mode-specific path-building to service preference related path-building. A separate travel time analysis conducted with the Chicago and Charlotte model networks indicated that there were inaccuracies in comparing reported and network-based travel times and paths. This travel time analysis is documented in Appendix I.

To achieve this objective, mode labels on paths were removed from the existing model. However, access mode distinction (walk/drive) was considered important and retained in path-building. To obtain an optimal set of path-building parameters, an exercise was conducted in which path-building parameters were systematically varied. Two additional parameters to incorporate values of premium transit service attributes were introduced into path-building. One, called "non-premium service boarding penalty factor," was used to weight the relative boarding penalty (shown in TABLE J-4) that is applied based on a specific mode boarding. The other, called "premium service in-vehicle travel time factor," was used to weight the premium service IVTT percent reduction (21% as shown in the table above). The systematic variation of path-building parameters produced 243 paths each for walk and drive access segments. The specific number of paths generated was to keep the run times reasonable. Judgment was used in choosing the parameters to be varied and their values. TABLE J-5 shows the path-building parameters that were varied systematically and their values.

TABLE J-4. Mode level values of premium transit service attributes.

Bundled Attribute	Premium Service Attribute	CRT	LRT	LOCAL	EXP	BRT	Value (min. of IVTT)	Scaled Value (min. of IVTT)
Station amenities	Shelter	√	√	x	√	√	0.75	2.88
	Bench	√	√	x	√	√	0.38	1.45
	Lot count	√	√	x	√	x	0.00	0
On-board amenities	On-board seating availability	√	√	√	x	x	1.81	2.90
	Productivity features	√	x	x	√	x	0.82	1.32
	Vehicle cleanliness	√	x	x	√	√	0.62	0.99

TABLE J-4. (Continued).

Bundled Attribute	Premium Service Attribute	CRT	LRT	LOCAL	EXP	BRT	Value (min. of IVTT)	Scaled Value (min. of IVTT)
Other service features	Reliability	√	√	x	x	√	5.12	7.79
	Mid-day schedule span	√	√	√	x	√	0.32	0.49
	Evening schedule span	√	√	√	x	√	0.32	0.49
	Vehicle ease of boarding	√	√	x	x	√	0.14	0.22
	Fare machines	√	√	x	x	√	0.69	1.06
IVTT with premium (percent reduction in IVT)		21%	21%	0	21%	21%		
Premium Benefit (minutes)		11.0	9.5	2.5	2.6	8.3		
Scaled Premium Benefit (minutes)		19.6	17.3	3.9	6.6	15.4		
Relative Non-premium service boarding penalty		0	2.3	15.7	13	4.2		

TABLE J-5. Path-building parameter ranges for systematic variation.

Path-Building Parameter	Value
Initial/transfer wait time weight	1, 1.5, 2 x IVTT*
Access/egress time weight	1, 1.5, 2 x IVTT
Transfer penalty	0, 5, 10 min.
Non-premium service boarding penalty weight	0.5, 1, 1.5 x boarding penalty
Premium service IVTT weight	0.5, 0.75, 1 x perceived IVTT reduction

*IVTT: in-vehicle travel time

A total of 486 transit paths (243 each for walk access and drive access) were analyzed to obtain a set of paths that matched best with the on-board survey data. A match in the modeled path was said to be found if the modes and routes in sequence involved in the path were the same as those reported in the survey between a specific OD TAZ pair. A combination of three sets of parameters that resulted in the highest match (about 76%) for both walk and drive access was derived by conducting a matching exercise. The choice of three paths was determined by judgment based on the matching analysis. The number of combinations to be analyzed increases exponentially with the number of parameter sets in a particular combination. For obtaining the best combination of three-parameter sets, 114 million combinations (C(486,3) = 114,083,640) were analyzed. TABLE J-6 shows the optimal three-parameter sets obtained for walk and drive access. Based on the weights in the parameter sets, labels on traveler preferences have been assigned. For example, if the weight for access/egress time is high, this may imply that travelers falling under this segment prefer shorter access times. Another example is if the premium service in-vehicle time weight is relatively low (say 0.5), this probably corresponds to a set of travelers who prefer premium transit service for longer trips. The choice of three paths was determined by judgment based on the matching analysis.

TABLE J-6. Path-building parameters for the transit path choice model.

Walk Path	Drive Path	Traveler Preferences	Transfer Penalty	Access/ Egress Time	Wait Time	Non-Premium Service Boarding Penalty	Premium Service In-Vehicle Time
1		Shorter access times, premium service	0	2	1	0.5	1
	1	Shorter access times, premium service for longer trips	0	2	1	1	0.5
2	2	Direct, frequent service	10	1	2	1	1
3	3	Frequent, non-premium service	0	1	2	1.5	1

The nesting structure of the existing mode choice model was changed as shown in FIGURE J-3. Instead of five mode-based paths each under the walk and drive access transit nests, there are now three paths that are more generic and based on traveler preferences (see TABLE J-3) in the new transit path choice model.

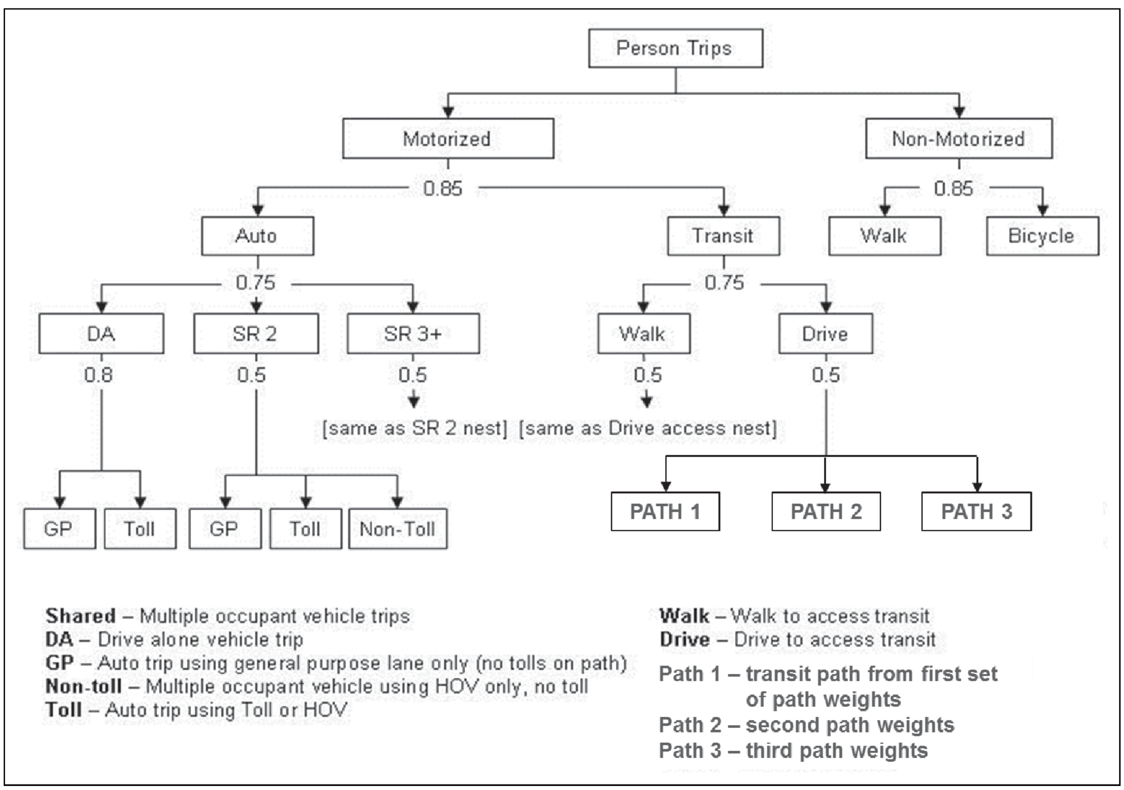


FIGURE J-3. Transit path choice and mode choice model for Salt Lake City.

An issue of interest prior to implementing the transit path and mode choice model was to assess the number of "unique" paths that were being produced as a result of the modified path-generating process. Given that an overlap in paths implies a possible correlation among the attributes of the path choices, this may lead to the violation of the independence of irrelevant alternative (IIA) assumption in multinomial logit models. TABLE J-7 shows the proportion of paths overlapping in the survey dataset based on the paths built. An overlap here is same as the matching criteria specified earlier. Two paths are said to be overlapping/duplicates if the modes and routes involved in one path are the same as the modes involved in another path.

TABLE J-7. Overlapping path choices in the transit path choice model.

	Number of Overlapping paths	Number of Survey Records (%)		Number of Overlapping Paths	Number of Survey Records (%)
Walk Access	3	53 (2%)	Drive Access	3	72 (2%)
	2	1,363 (42%)		2	1,062 (36%)
	0	1,862 (57%)		0	1,826 (62%)
	Total	3,278 (100%)		Total	2,960 (100%)

TABLE J-7 shows that there is an overlap in the path choice alternatives for about 40% of the records. The definition of a duplicate path was revised from matching modes to matching exact transit routes. In other words, two paths would be called overlapping/duplicates only if they both have the same transit routes in the same order of boarding. If two paths involved the same set of modes but different routes, they were to be considered as separate choices. The original method of matching modes was too general and many duplicate paths were identified that were effectively different. This method was not implemented as a result. The process to match transit routes involved modifying the path-building script to print out detailed transit paths (along with the routes involved in the path) in log files for all origin destination pairs. An offline process involving a Python script (originally created by MTC staff) to parse the log files for the transit route information and create files that could be imported back into the TP+ environment was developed. The route information is then processed to check for and remove duplicate paths by additional TP+ scripts before mode choice model is run.

Transit Mode Choice Utility Expressions

After generating a set of unique path choices for each OD pair, the next step was the modification of transit mode choice utility expressions. The existing mode choice model involved calculation of 10 utilities corresponding to the 10 transit paths generated (five paths each for walk access and drive access). The research mode choice model involved calculation of only six utilities (three paths each for walk access and drive access) in comparison to the existing model. Other changes to the utility expressions were to incorporate the effects of boarding non-premium transit modes (non-premium service boarding penalty) and traveling in a premium mode (premium service IVTT), similar to the way they were incorporated in the path-building process. The non-premium service boarding penalties were measured in terms of IVTT minutes and were added to the utility expression after they were factored by the IVTT coefficient. For this part of the utility expression, the number of boardings by mode for each transit path was needed. The number of boardings by mode for each transit path was calculated during the process of identifying and removing duplicate paths. The "direct walk premium" component (see TABLE J-3) was dropped from the utility expression in the transit path choice model. This component adds to the utility of a transit path if it involves direct walk access to a premium service (all modes except local bus are considered as premium). It was felt that this component was no longer necessary in the transit path choice model because the benefits of premium boarding premium services were being incorporated using the non-premium service boarding penalties. The premium service IVTT factor was directly introduced in the utility expression as a part of the IVTT of a transit path. A factor of 0.8 was used to represent the perceived reduction in IVTT as a result of using a premium service.

There was an interest in exploring the influence of sociodemographic characteristics on the choice of transit paths to reflect the differences in the survey of travelers who chose different paths. To this end, an analysis was done to examine path choice behavior along several demographic dimensions, such as income group, age, gender, auto ownership, licensed drivers, etc. Specifically, path choice behavior included critical aspects of walk access and drive access choices, such as access and egress times, transfer times, premium service characteristics, etc. Because the reported path choice components from the survey may not always be accurate, modeled components from transit skims were also used. The average path characteristic values were compared across various categories of each demographic attribute. For example, the average number of transfers was compared across the different income categories available. As a result of this analysis, it was found in the data that younger people have a higher average walk time (combined access and egress). Specifically, the data imply that:

- Persons under 18 years of age are only willing (allowed) to walk up to 1 mile
- Persons ages 18 to 44 years are willing to walk up to 2 miles
- Persons ages 45 to 64 years are willing to walk up to 1¼ miles
- Persons ages 65 and older are only willing to walk up to 0.5 miles

This suggested that an additional demographic segmentation in the mode choice model based on age might help improve the model. The segmentation based on age was added to the existing mode choice model for HBW and HBO trip purposes. The distribution of age segments was obtained from Census 2010 data for the relevant counties. The influence of age on walk times was accounted for by scaling the walk time coefficient up or down based on the age category. The factors for scaling were obtained from mode choice models estimated using Salt Lake City survey data in Phase I of this project. The scaling factor was the ratio between the walk time coefficient in a model with segmentation and one in a model with no age segmentation.

TABLE J-8 shows the walk time coefficients and scaling factors used.

TABLE J-8. Age segmentation in transit path choice model.

Variable	HBW	HBO	NHB	HBC
Walk time (1st mile)—age < 45 years	0.96*-0.0442	0.96*-0.0320	-0.0466	-0.0442
Walk time (> 1 mile)—age < 45 years	0.96*-0.0663	0.96*-0.0480	-0.0699	-0.0663
Walk time (1st mile)—age 45 to 64 years	1.04*-0.0442	1.04*-0.0320	-0.0466	-0.0442
Walk time (> 1 mile)—age 45 to 64 years	1.04*-0.0663	1.04*-0.0480	-0.0699	-0.0663
Walk time (1st mile)—age > 65 years	1.71*-0.0442	1.71*-0.0320	-0.0466	-0.0442
Walk time (> 1 mile)—age > 65 years	1.71*-0.0663	1.71*-0.0480	-0.0699	-0.0663

Addition of age segmentation to the model was found to have a significant impact on transit travel from TAZs with high proportions of people in the higher age categories, as shown in TABLE J-9. For example, it was found that in TAZs which had between 50% and 60% of people over the age of 65 years, there was a reduction of 13% to 29% in the number of walk access transit trips when compared to the model without age segmentation. However, at a more aggregate level, it was found that including age segmentation did not affect the overall model results significantly. This was probably due to the lower proportion of people falling in the higher age categories in most of the TAZs in the region. Due to the insignificant impact of age segmentation on the overall model results and also due to the fact that the age segmented model has a 50% higher runtime, it was decided to drop the age segmentation for calibration purposes. Hence, calibration efforts were focused on a model without age segmentation.

Transit Path Choice Model Calibration

The ultimate goal of the calibration of transit path choice model was to compare the constants with those in the calibrated existing model and analyze the impacts of involving premium service characteristics on the constants. The new transit path choice model (with modified path and mode choice process) used the same demand and supply inputs as the existing model. The calibration targets also were the same and had been obtained from the on-board survey conducted in 2011.

At the beginning of the calibration process, the mode level alternative specific constants in the transit path choice model were set to zero. The motive behind this was to analyze the results from the transit path choice model which incorporated the effects of premium service attributes without any modal biases that were used to calibrate the existing model. Subsequently, there would be modal biases or constants introduced if required. It should be noted that the non-premium service boarding penalties are at a mode level and may themselves be interpreted as modal constants, albeit of a different kind. The difference is that these constants can be explained based on the finding from the maximum difference models. However, the mode level non-premium service boarding penalties will be accounted for while comparing the constants between existing and transit path choice models.

The calibration primarily involved adjusting overall transit constant. The number of transit paths built changed from 10 in the existing model to six in the transit path choice model. As can be expected, this reduced the transit logsum which in turn reduced the overall transit share of trips when the new research mode choice model was run. Appropriate adjustments were made to the overall transit constant to match the total transit trips target. The same adjustments were made to all trip purposes and the two time periods. There was an imbalance found between the walk access versus drive access transit trips in transit path choice model. It was theorized that the non-premium service boarding penalties were quite significant and additional transfer penalties were overkill for walk access transit trips. Hence, transfer penalties were dropped from the utility expression. For drive access transit trips, it is conceivable that transfers in the transit path are still quite onerous due to the burden of driving, parking, and transferring being already involved. Therefore, the transfer disutility for drive access trips was retained in the utility expression. In addition to this, the premium IVTT factor was adjusted from 0.8 to 0.9 to slightly lower the transit trips on premium services. Finally, a few minor adjustments were made to express bus and LRT mode-specific biases to match the mode level targets more closely. TABLE J-10 shows the coefficients used in the research mode choice model.

TABLE J-9. Impact of age segmentation on select trips.

P_TAZ	A_TAZ	% Age 65+	Transit Walk Trips
841	921	66%	-29%
867	921	56%	-13%
938	921	52%	-13%
1352	921	61%	-22%

TABLE J-10. Research mode choice model coefficients for Salt Lake City.

Variable	HBW	HBO	NHB	HBC
In-vehicle time (IVT) (local)	-0.0221	-0.0160	-0.0233	-0.0221
In-vehicle time (IVT) (premium)	0.9×HBW IVT coeff.	0.9×HBO IVT coeff.	0.9×NHB IVT coeff.	0.9×HBC IVT coeff.
Walk time (1st mile)	-0.0442	-0.0320	-0.0466	-0.0442
Walk time (> 1 mile)	-0.0663	-0.0480	-0.0699	-0.0663
Transfers—walk access	0	0	0	0
Transfers—drive access	-0.265	-0.192	-0.280	-0.265
Premium service characteristics—local	16×HBW IVT coeff.	16×HBO IVT coeff.	16×NHB IVT coeff.	16×HBC IVT coeff.
Premium service characteristics—BRT	4×HBW IVT coeff.	4×HBO IVT coeff.	4×NHB IVT coeff.	4×HBC IVT coeff.
Premium service characteristics—express	13×HBW IVT coeff.	13×HBO IVT coeff.	13×NHB IVT coeff.	13×HBC IVT coeff.
Premium service characteristics—LRT	2×HBW IVT coeff.	2×HBO IVT coeff.	2×NHB IVT coeff.	2×HBC IVT coeff.

It should be noted here that because this is a research effort a full-scale recalibration of the model was not attempted. The focus was more on matching transit trips by mode and transit trips by purpose (i.e., marginal distributions) and less on matching transit trips by both mode and purpose (i.e., joint distributions) or boardings by route and mode.

Comparative Results

The transit path choice model was calibrated to approximately the same level of accuracy as the existing model within a reasonable amount of time (approximately 1 week). TABLE J-11 shows a comparison of the number of linked transit trips in the existing and transit path choice models to targets obtained from the on-board survey data by access and primary mode (based on mode hierarchy in the existing model). Linked transit trips represent a trip from the origin to the destination. Boardings represent a trip from the access station to the egress station. The comparison shows that the existing and transit path choice models are more or less equally close to the targets even though it appears that the results from the existing model are "closer." It should be noted again that the existing model had been well calibrated prior to this project, whereas for the transit path choice model significantly less amount of time was spent on calibration.

TABLE J-11. Comparison of linked transit trips by access and primary mode.

Access	Primary Mode	Survey	Existing Model	Transit Path Choice Model
Walk	**CRT**	1,200	900	1,800
	Express	2,900	2,800	3,700
	LRT	25,500	25,000	22,400
	BRT	1,500	1,000	1,000
	Local	34,200	37,200	33,900
Drive	**CRT**	4,700	5,000	4,000
	Express	4,900	4,100	4,100
	LRT	17,700	17,900	18,800
	BRT	100	700	600
	Local	6,200	4,200	3,800

TABLE J-12 shows the comparison of linked transit trips in further detail by separating the primary mode path based on whether or not it involves a local bus boarding. Similar conclusions could be drawn about the existing and transit path choice models as those drawn based on TABLE J-11.

TABLE J-12. Comparison of linked transit trips by access and detailed mode.

Access	Mode	Survey	Existing Model	Transit Path Choice Model
Walk	Local	34,200	37,200	33,900
	BRT	500	300	500
	BRT-local	1,000	700	500
	Express	2,100	2,000	2,200
	Express-local	800	800	1,500
	LRT	12,800	14,900	15,900
	LRT-local	12,700	10,100	6,500
	CRT	400	200	400
	CRT-local	800	700	1,400
Drive	Local	6,200	4,200	3,800
	BRT	100	200	300
	BRT-local	0	500	300
	Express	4,300	3,400	3,600
	Express-local	600	700	500
	LRT	16,000	14,800	15,300
	LRT-local	1,700	3,100	3,500
	CRT	2,800	1,300	2,600
	CRT-local	1,900	3,700	1,400

TABLE J-13 provides a comparison of route boardings from the existing and transit path choice models with observed boarding counts. For conciseness, all the boardings were aggregated to a "route group" level from the individual route level. It appears that the existing and transit path choice models are both close to each other in terms of matching observed route level boarding counts. In some cases, it may happen that the existing model matches the target better on one set of routes (for example 33rd South, WE-SL Express, etc.) and the transit path choice model matches target better on another set of routes (for example Parleys/Millcreek, 17/21, 13th East, etc.). In other cases, the transit path choice model overestimates boardings by the same amount as the existing model underestimates or vice versa (for example, Kearns/WVC, LRT, etc.). Both models are underestimating the total number of transit boardings. Overall, at a higher level, both models are calibrated to more or less an equal extent.

The details of path level benefits as a result of various components of utility expressions in both existing and transit path choice models are presented in TABLE J-14 and TABLE J-15 for the home-based-work trip purpose. The path level benefits are calculated by converting all the relevant coefficients applied in utility expressions of the paths to a common unit (IVTT minutes in this case). It is useful to compare both alternative specific constants and other fixed parameters between existing and transit path choice models because the effects of premium service attributes have been added at mode level in the transit path choice model. The other fixed parameters included were transfer penalty, direct walk benefit, and boarding penalty. The transfer penalty is a penalty applied to the utility of a transit path for each transfer made in the

TABLE J-13. Comparison of transit boardings by route group.

Route Group	Counts	Existing Model	Transit Path Choice Model
Local bus			
13th East	2,983	3,462	2,619
17/21	2,773	3,208	2,819
2 to U	2,323	2,900	1,268
33rd South	1,815	1,617	1,135
45th & 39th	7,836	5,853	4,526
Avenues	2,267	894	742
Kearns/WVC	4,702	5,087	4,590
Magna	1,491	1,046	522
Misc SLC	813	1,888	2,169
Parleys/Millcreek	1,005	1,419	1,013
Redwood	4,434	4,536	3,432
Rose Park	3,378	828	757
S. Davis	316	389	308
Sandy/Midvale	4,215	5,434	5,554
SL 3rd-5th East	3,653	2,127	1,951
State	5,472	3,440	2,080
UT_local	11,617	10,627	10,456
WE/DA intercity	6,388	6,324	5,927
WE/N Davis	8,977	5,781	5,884
West Jordan EW	617	846	689
BRT			
S35MAX	3,358	2,517	4,554
Express/Fast			
SL Fast	2,000	1,941	1,656
Tooele	813	185	125
UT-SL	3,997	3,086	4,984
WE-SL Express	1,342	1,342	975
LRT	47,923	45,205	49,399
CRT	5,300	5,898	5,946
Total	**141,808**	**127,880**	**126,079**

TABLE J-14. Path benefits (IVTT minutes) in existing model for work trips.

	Path Composition	Relative ASC	Transfer Penalty	Direct Walk	Total		Relative ASC	Transfer Penalty	Total
Walk Access	Local	0	0	0	0	Drive Access	0	0	0
	BRT	17	0	5	22		17	0	17
	LRT	33	0	10	43		33	0	33
	Express	33	0	5	38		33	0	33
	CRT	43	0	10	53		43	0	43
	Local-local	0	-12	0	-12		0	-12	-12
	Local-BRT	17	-12	0	5		17	-12	5
	Local-LRT	33	-12	0	21		33	-12	21
	Local-express	33	-12	0	21		33	-12	21
	Local-CRT	43	-12	0	31		43	-12	31
	BRT-local	17	-12	5	10		17	-12	5
	LRT-local	33	-12	10	31		33	-12	21
	Express-local	33	-12	5	26		33	-12	21
	CRT-local	43	-12	10	41		43	-12	31
	Local-express-LRT	33	-24	0	9		33	-24	9

TABLE J-15. Path benefits (IVTT minutes) in transit path choice model for work trips.

	Path Composition	Relative ASC	Transfer Penalty	Boarding Penalty	Total	Total Shifted		Relative ASC	Transfer Penalty	Boarding Penalty	Total	Total Shifted
Walk Access	Local	0	0	-16	-16	0	Drive Access	0	0	-16	-16	0
	BRT	0	0	-4	-4	12		0	0	-4	-4	12
	LRT	14	0	-2	11	27		0	0	-2	-2	14
	Express	0	0	-13	-13	0		9	0	-13	-4	12
	CRT	0	0	0	0	16		0	0	0	0	16
	Local-local	0	0	-31	-31	-15		0	-12	-31	-43	-27
	Local-BRT	0	0	-20	-20	-4		0	-12	-20	-32	-16
	Local-LRT	14	0	-18	-4	12		0	-12	-18	-30	-14
	Local-express	0	0	-29	-29	-13		9	-12	-29	-32	-16
	Local-CRT	0	0	-16	-16	0		0	-12	-16	-28	-12
	BRT-local	0	0	-20	-20	-4		0	-12	-20	-32	-16
	LRT-local	14	0	-18	-4	12		0	-12	-18	-30	-14
	Express-local	0	0	-29	-29	-13		9	-12	-29	-32	-16
	CRT-local	0	0	-16	-16	0		0	-12	-16	-28	-12
	Local-express-LRT	0	0	-31	-31	-15		0	-24	-31	-55	-39

transit path. The coefficient of the transfer penalty has been converted to equivalent IVTT minutes by dividing it by IVTT coefficient. The direct walk benefit is applied to utility of a path if it involves directly walking to one of the four premium transit modes (express bus, LRT, BRT, and CRT). This, too, has been converted to equivalent minutes of IVTT. Finally, the boarding penalty represents the non-premium service boarding penalties (see TABLE J-15) applied to the path utility based on the number of boardings for each mode (only in the transit path choice model).

TABLE J-14 and TABLE J-15 show the total path benefits in terms of IVTT minutes for 15 paths each for walk access and drive access broken down by their contributing components. For the sake of brevity, paths comprising all mode combinations are not presented. In the case of the transit path choice model, the total path benefits were shifted to set the benefit of "Local" path to zero so that all of them can be compared to the path benefits in the existing model.

TABLE J-16 provides a comparison of both the total path benefits and path level biases (which result from alternate/mode-specific constants added to the utilities):

- If only the alternative specific constants (in terms of IVTT minutes) in both models are considered, quite clearly the transit path choice model has far fewer of them both in number and magnitude.

- When total path benefits (total fixed effects) are compared, it can be seen that for simple paths involving one service, the total effects (in terms of IVTT minutes) in the transit path choice model are significantly lower than those in the existing model.

TABLE J-16. Comparison of path benefits (IVTT minutes) by detailed mode for work trips.

		Existing	Research-Shift	Existing	Research		Existing	Research - Shift	Existing	Research
Walk Access	Local	0	0	0	0	Drive Access	0	0	0	0
	BRT	22	12	17	0		17	12	17	0
	LRT	43	27	33	14		33	14	33	0
	Express	38	0	33	0		33	12	33	9
	CRT	53	16	43	0		43	16	43	0
	Local-local	-12	-15	0	0		-12	-27	0	0
	Local-BRT	5	-4	17	0		5	-16	17	0
	Local-LRT	21	12	33	14		21	-14	33	0
	Local-express	21	-13	33	0		21	-16	33	9
	Local-CRT	31	0	43	0		31	-12	43	0
	BRT-local	10	-4	17	0		5	-16	17	0
	LRT-local	31	12	33	14		21	-14	33	0
	Express-local	26	-13	33	0		21	-16	33	9
	CRT-local	41	0	43	0		31	-12	43	0
	Local-express-LRT	9	-15	33	0		9	-39	33	0

- In more complex paths (involving two or more services), the total effects in the existing model are positive because of the hierarchical nature of the transit paths.

- On the other hand, in the case of the transit path choice model, the total effects for complex paths are negative, primarily because of the inclusion of non-premium service boarding penalties wherein boarding a non-premium service is penalized irrespective of the involvement of a premium mode (or a mode higher in the hierarchy). In the existing model, this effect is hidden or subsumed by mode hierarchy.

Overall, the transit path choice model appears to be a more intuitive and realistic representation of transit path choice behavior.

These results are detailed for the HBW trip purpose, but were also compiled for non-work trip purposes. The path benefits calculated for other trip purposes showed similar patterns because all of the calibration adjustments were applied uniformly to all purposes. As a proof of concept, this was sufficient, but additional calibration specific to non-work purposes would be needed to draw further conclusions about the non-work purposes.

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation