TCRP H-37 CHARACTERISTICS OF PREMIUM TRANSIT SERVICES THAT AFFECT MODE CHOICE: KEY FINDINGS AND RESULTS

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ABSTRACT

This research seeks to improve the understanding of the full range of determinants for mode choice behavior and to offer practical solutions to practitioners on representing and distinguishing these characteristics in travel demand forecasting models. The principal findings are that awareness and consideration of transit services is significantly different than the perfect awareness and consideration of all modes which is an underlying assumption of mode choice and forecasting models. Furthermore, inclusion of non-traditional transit attributes and attitudes can maintain or improve the ability of mode choice models to predict the usage of premium transit modes while reducing the weight on modal constants that vary between transit sub-modes. Additional methods and analyses are necessary to bring these results into practice.

This paper focuses on the key findings and results of the research of the value of non-traditional transit service attributes on modal choice, the influence of awareness and consideration of transit service on modal alternatives, and the importance of traveler attitudes on both awareness and consideration of transit and on the choice of transit or auto in mode choice. The models estimated to support these findings are described, but not in detail, due to the space limitations, but are available in the Transit Cooperative Research Program H-37A Final Report. The paper also documents the findings of the implementation testing, which concludes that including path choices and non-traditional transit service attributes in mode choice models can reduce the weight of the modal constants.

1. INTRODUCTION

This research focuses on quantifying the most important attributes of transit service that influence the choice of premium transit services in different urban contexts. Data are collected and analyzed to support findings on these attributes in Chicago and Charlotte; these are combined with data collected in Salt Lake City to better understand traveler responses to these transit service attributes. The research also includes a demonstration of how these attributes could be meaningfully incorporated into travel models to reduce the influence of modal constants and modal labels in mode choice models and improve forecasting capabilities of transit services.

A couple of definitions are in order before proceeding to the rest of the paper. These pertain to "non-traditional transit service attributes" and "premium transit".

- Non-traditional transit service attributes are those attributes other than time and cost that are important to travelers in choosing to ride transit. These include station amenities, onboard amenities and other aspects of transit services, such as reliability, fare machines, ease of boarding, span of service and parking distance.
- In this paper, 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 is not necessarily associated with a particular vehicle technology. For instance, some commuter coach service offering a seat to all customers with WiFi service and a highly reliable schedule may be perceived as superior to a crowded rail rapid transit line with fewer amenities. In this paper, an analytical approach and framework is described to deal with the fact that these services often exist in continuum between premium and non-premium and are not easily represented as separate and discrete modes

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

This research was conducted into two phases. Phase 1 was exploratory and identified the non-traditional attributes that affect travelers' choice of mode and was documented in a previous TRB paper *(1).* Phase 2 quantifies the contribution of the most important attributes to mode choice decisions and sought ways to incorporate the findings into travel models. The Phase 2 modeling and implementation work is the focus of this paper. There are three key research sections described in this paper: 1) non-traditional attributes and 2) awareness and consideration, and 3) attitudes. Following that is documentation for how these findings were put into practice.

2. LITERATURE REVIEW

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. Here are a few excerpts from the previous summary:

- The lack of awareness and familiarity with transit seems to be significant and there is not yet abundant research on this topic *(2) (3).*

- 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. *(4) (5) (6) (7) (8)*
- 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 forecasting models. *(9) (10) (11)*

Further details on the literature review can be found in the earlier TRB paper *(1)* and the Final Report from the first phase of the work.

3. IMPORTANT NON-TRADITIONAL TRANSIT ATTRIBUTES

To support a deeper understanding of what motivates people to choose to ride transit, it is necessary to extend the conventional set of service attributes that are understood by the industry to affect transit ridership. Metropolitan areas with rail lines often require large adjustments to replicate observed ridership on these services. These are either applied by defining rail transit as a separate sub-mode and applying mode-specific constants that are significantly different from bus or by adjusting perceived in-vehicle, boarding, and waiting times for selected modes. The magnitude of these adjustments varies significantly in different parts of the country. Ridership on new transit projects are sometimes underestimated without similar kinds of adjustments. The fact that these adjustments vary in cities where rail transit already exists makes it difficult to apply these factors a priori in cities where these services do not yet exist.

Current practice in transit forecasting and planning processes typically considers the effects of travel times, wait times, frequencies, travel costs and transfers, when evaluating the benefits of transit services. Potentially important transit service attributes that typically are not explicitly considered in transit forecasting or planning include but are not limited to the following:

- 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.
- Onboard features - seating availability, seating comfort, temperature, cleanliness of the transit vehicle, ease of boarding, and productivity features (Wi-Fi, power outlets, etc.).
- Other features - identification of the transit vehicle, schedule reliability, schedule span, and fare machines.

Research Methods

Revealed and stated preference surveys for three cities (Salt Lake City, Chicago and Charlotte) were conducted to explore traveler decision making on modal choices. Maximum Difference Scaling (MaxDiff) and Choice-Based Conjoint Modeling (Choice Modeling) were then used to evaluate the effect of non-traditional transit service attributes on the decision to travel by transit and the nature of the transit path. 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. 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).

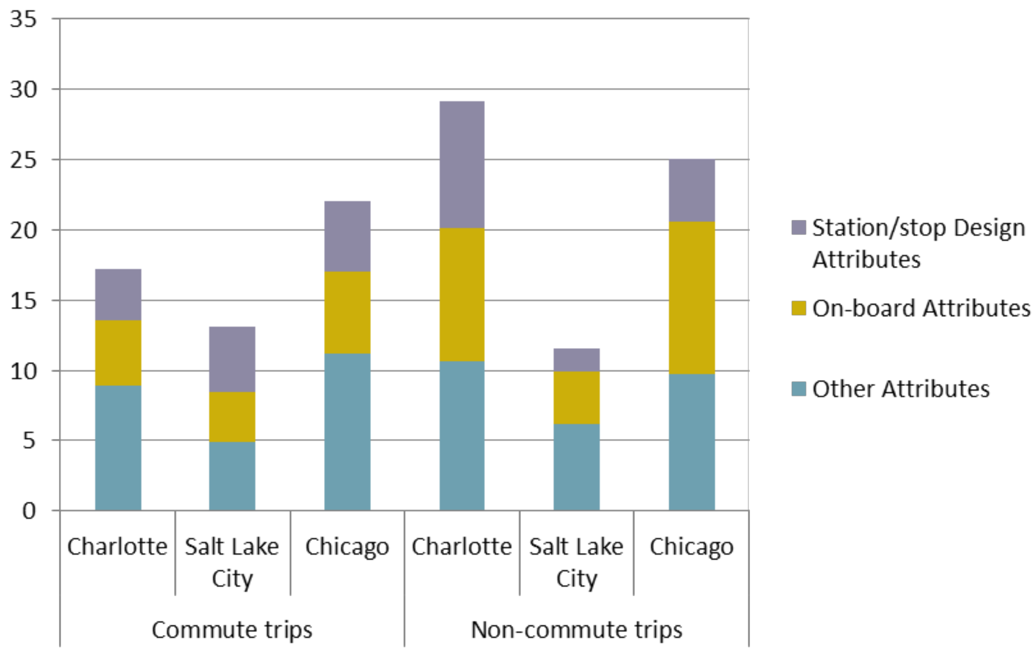
Current practice in transit and mode choice modeling typically results in a model that is sensitive to the effects of travel times, wait times, frequencies, travel costs and transfers. Mode- and sometime transit submode constants are used to adjust the model to match observed ridership volumes and therefore help "correct" other errors in the travel model system. In theory, these constants capture the effect of the unobserved attributes on the choice to use transit and the selection of the optimal transit path. The goal of this project is 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.

Research Results

This research found that non-traditional transit service attributes are important factors in decisions about whether to use transit and which transit service to use. 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 the measurement of the benefits of each transit option. The outcome of the survey and ensuing analytical work resulted in a numeric valuation of the different non-traditional transit service attributes. The numerical value of each transit attribute was compared to in-vehicle travel time (IVTT) and presented as equivalent minutes of IVTT. Many people are familiar with the notion that non-monetary amenities (e.g. time or personal injury) can be expressed in dollar values and used in economic assessments. Using analogous techniques the importance of any transit attribute in this analysis can instead be related to equivalent minutes of IVTT, which is a commonly used approach in travel forecasting. It is then useful to consider the value of a service attribute in relation to the overall time required to complete a trip.

Taken together, the importance of non-traditional transit service attributes was valued as equivalent to 17-29 minutes of IVTT (depending on the city) for commute and non-commute trips. Figure 1 presents the details underlying that finding, for each city and service attribute.

Figure 1. Scaled Equivalent Minutes of In-Vehicle Travel Time for Non-Traditional Transit Service Attributes



While 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. This suggests 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.

4. TRANSIT AWARENESS AND CONSIDERATION

Inclusion of awareness and consideration in mode choice models is a relatively new concept. To date, models typically assume all modes are available and considered by all individuals or simple deterministic rules are applied to determine whether certain modes are available and considered by an individual. Examples of the latter include individuals residing in zero-car households are assumed to not have “drive alone” in their choice set, or individuals residing more than ½ mile from a transit stop are assumed not to have “transit” in their choice set.

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

Separate awareness and consideration models were estimated for Chicago and Charlotte and for bus and rail modes. These were designed to constrain the choice sets in subsequent mode choice models. The surveys demonstrated that awareness of transit modes was a bigger constraint on the choice set than consideration.

Research Methods

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 for mode estimation of awareness and consideration.

Awareness and consideration models were developed using joint bivariate binary probit methods to first identify whether travelers are aware of a transit alternative and then to constrain these choices to identify 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 a two-step decision process:

1. First, an individual can be aware of a transit option if that particular option is available (or feasible) based on the demographic and attitudinal characteristics. .
2. An alternative can be considered only if the individual is aware of that particular alternative., also based on the demographic and attitudinal characteristics

The complete choice set for each individual is formed as a result of awareness and consideration of the transit options (bus and rail). 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.

Research Results

There are three key findings related to the awareness and consideration models:

- Many travelers are not aware of or 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, since awareness and consideration are more a function of demographics, latent variables and traveler attitudes than transit service attributes.
- Travelers are aware of and consider train alternatives more often than bus. This is determined directly from the travel surveys, based upon questions of consideration of bus and rail modes once availability is accounted for.
- Incorporating awareness and consideration of transit into statistical estimation work did improve the statistical fit of the mode choice models. Mode choice models estimated with and without awareness and consideration models constraining the choice sets demonstrated the statistical improvement with the inclusion of these models.

Travelers report fewer modes being available than the modeled representations of choice availability (from the transit network) for a particular trip. Travelers perceive that over 50% of trips have one bus alternative and 40% of trips have one rail alternative when the transit network has less than 10% of trips with one bus or rail alternative. In contrast, travelers perceive that less than 10% of trips have 3 bus or rail alternatives when the transit network has more than 35% of trips with 3 bus or rail alternatives. The model results indicate that there are 2 or 3 transit alternatives available for any specific trip, where travelers consistently underestimate the number of bus and rail alternatives available for any particular trip.

Table 1 reports the survey results for consideration of transit alternatives in Chicago and Charlotte for bus and rail modes. In Charlotte, 88% of travelers having rail as an available mode would consider taking the train while only 62% would consider taking bus. In Chicago those percentages are 86% and 73%, respectively. Even among travelers willing to consider a given mode of transit, the proportion selecting rail is higher than the proportion selecting bus.

Table 1. Consideration of Bus and Rail Modes

		Survey Respondents				Percent of Total			
		Bus		Train		Bus		Train	
Charlotte									
Considered	**Chosen**	513	237	345	174	62%	46%	88%	50%
	Not Chosen		276		171		54%		50%
Not Considered		313		49		38%		12%	
Total		826		394		100%		100%	
Chicago									
Considered	**Chosen**	550	421	601	528	73%	77%	86%	88%
	Not Chosen		129		73		23%		12%
Not Considered		199		97		27%		14%	
Total		749		698		100%		100%	

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 and 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 and was 7250 and 3278 without these constraints.

5. TRAVELER ATTITUDES

Traveler attitudes were evaluated in three different cities using factor analysis and multinomial mode choice models and integrated choice and latent variable models. In each case, the traveler attitudes added explanatory power to the mode choice models and should be considered for future mode choice model development. The traveler attitudes add a distribution to the models that complement the other socioeconomic factors. In all three cities, the attitudes affected the choice of transit vs. auto much more than the choice of bus vs. rail.

Research Methods

The Salt Lake City analysis included fewer attitudinal statements in the survey and these were targeted to specific users (transit and non-transit users and transit choosers), so the Chicago and Charlotte analysis included more attitudinal statements for all survey respondents. This allowed all of the attitudinal factors to be significant in the mode choice models for Chicago and Charlotte where the Salt Lake City attitudinal factors were limited to those for transit users.

The Chicago and Charlotte factor analysis produced five attitudinal factors that were significant in the mode choice models but the complexity around using all five factors diminished the interpretation of these factors. For example, there were three factors that tended to favor auto modes (Pro-Car Attitude, Transit Averse, and Low Transit Comfort Level) and two factors that tended to favor transit modes (Pro-Transit Attitude and Environment, Productivity, and Time Savings) and 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. We recommend that factor analysis for traveler attitudes be limited to fewer, more direct factors to improve interpretation and reduce complexity of the use of these factors in mode choice models.

The integrated choice and latent variable models provided an opportunity to estimate traveler attitudes as a function of socioeconomic variables jointly with mode choice where the multinomial logit models require that traveler attitudes be developed separately the mode choice models. Again we find that even though all five attitudinal factors are significant in the mode choice model estimation, we recommend that fewer factors be used to reduce the complexity and interpretation of these factors in the model. The results of the integrated choice and latent variable models indicate which socioeconomic variables are important for each attitudinal factor. In addition there is a utility associated with the transit modes that indicate some differences between these attitudinal factors and mode choice decisions.

Results

The influence of traveler attitudes on mode choice is interpreted as equivalent minutes of in-vehicle time, so that these attitudes can be compared to the non-traditional transit service attributes and the more traditional attributes of travel time and cost. Table 2 presents the equivalent minutes of in-vehicle travel time for travel attitudinal and latent variables in the multinomial logit mode choice models. Most of the traveler attitudes and latent variables reflect large impacts on the choice of transit vs. auto, but very few differences between the choice of bus and rail.

Table 2. Equivalent In-Vehicle Travel Time (in minutes) for Traveler Attitudes and Latent Variables in Multinomial Logit Mode Choice Models

Explanatory Variables	Commute			Non Commute		
	Auto	Bus	Train	Auto	Bus	Train
Chicago						
Very informed about Transit		8.84				
Pro-Transit Attitude		38.20	38.20		33.32	33.32
Env., Prod., 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
Willing to walk not more than 2 mins		-27.52	-27.52		-41.11	-41.11
Willing to walk 10 or more mins			7.08			8.68
Charlotte						
Very informed about Transit		21.91	12.91		29.16	29.16
Pro-Transit Attitude		14.50	14.50		22.37	23.11
Env., Prod., and Time Savings		15.55	15.55		32.68	34.11
Pro-Car Attitude		-21.82	-21.82		-22.47	-23.32
Transit Averse		-2.00	-2.00		-7.58	-7.95
Low Transit Comfort Level		-14.86	-14.86		-25.00	-26.11
Willing to walk not more than 2 mins		-4.59	-11.55			
Willing to walk 10 or more mins		7.68	7.68		24.63	24.63

The integrated choice and latent variable models produced socioeconomic variables that were significant in model estimation for each of the 7 latent variables (see Table 3). This table shows significant variables with +++ represents positive effects, significant at the 99% confidence level, --- represents negative effects at the same level, and ++/-- represents positive and negative effects at the 95% confidence level, and +/- represents positive and negative effects at the 90% confidence level. Insignificant variables that were tested are also included in this table. This table only reflects the effects of the demographic and the influence of mode on these latent variables. The attitudinal statements included in each model specification were all positive.

Table 3. Demographic and Modal Influence on Latent Variables

Latent Variable	Type*	Lived 5 years in area	Full time student	Employed full time	Retired	Female	Age under 35	Age over 55	Log of Household Income	Vehicles in Household	More Drivers than Vehicles	Reduced mobility	Households with Kids	Utility of Bus	Utility of Train
Chicago Commuters															
Lack of Information about Transit	5 Levels	+++												---	
Willingness to Walk	Continuous	+	+	Insig	Insig	Insig	Insig	Insig	Insig		Insig	Insig	Insig	+++	
Pro-Transit Factor	5 Statements with 5 Levels each		++		Insig	Insig	Insig		++	---	+++	-	Insig	+++	+++
Pro-Car Factor	6 Statements with 5 Levels each				+	Insig			--	+++	---	+++	Insig	---	---
Productivity Factor	2 Statements with 5 Levels each			Insig					Insig					++	+++
Environment Factor	3 Statements with 5 Levels each						++			Insig				+++	
Privacy and Comfort Factor	2 Statements with 5 Levels each					Insig				Insig			Insig	---	+++
Chicago Non-Commuters															
Lack of Information about Transit	5 Levels	+++													
Willingness to Walk	Continuous	Insig	+	Insig	--	Insig	Insig	Insig	Insig		Insig	---	Insig	+++	+++
Pro-Transit Factor	5 Statements with 5 Levels each		+++		---	---	Insig		Insig	---	Insig	Insig	Insig	+++	+++
Pro-Car Factor	6 Statements with 5 Levels each				Insig	Insig			Insig	+++	-	++	Insig	---	---
Productivity Factor	2 Statements with 5 Levels each			++					Insig					+++	+++
Environment Factor	3 Statements with 5 Levels each						+			Insig				++	
Privacy and Comfort Factor	2 Statements with 5 Levels each					++				Insig			Insig	---	+++

6. IMPLEMENTATION IN TRAVEL MODELS

There were quite a few important lessons in the implementation of these research methods into practical travel forecasting models. First, it is important to represent the transit supply accurately. We compared the results of the transit path building process in Salt Lake City to an on-board survey and were able to use these results to improve the path building process relative to the observed results. Second, this particular case study demonstrated that we were able to make real progress towards reducing the influence of alternative specific constants and modal labels in travel models.

The transit path choices were used to define a new multinomial logit mode choice modeling structure, which is based on transit path choices defined by traveler preferences for service characteristics rather than modes or technologies. In this structure, mode of access is retained as the first nest in the transit choice alternative and the second nest replaces technology-based modes with competitive transit path choices. A comparison of the choice alternatives in the existing model structure and those in the new transit path choice model structure revealed that the existing model structure had broader geographic coverage for any mode, but a less accurate representation of actual competitive services because additional viable paths for the same service type (or mode) were not represented and the existing model can overstate competition among different modes by finding uncompetitive paths.

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 4). 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.

Table 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 since the surveys had improved from Phase 1 to Phase 2 and the later surveys had better information from a methodological standpoint.) 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, as a result of the fact that not all the premium transit service attributes were available for the existing model. The benefits were then converted to mode-specific relative penalties that could be applied at each boarding by the path builder. The estimated value of perceived reduction in the in-vehicle time in a premium mode was used for path building and mode choice.

Table 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
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		

Implementation Methods

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

The path choices were systematically defined based on a process of comparing possible paths to observed paths identified in transit onboard survey data. This path-building process included premium transit service characteristics as either constants or scaled to in-vehicle travel or waiting time. The determination of path choice parameters was based on the comparison of possible paths to observed paths and selecting the path choice parameters that provide the best match and align with 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 provided the best match to observed behavior, using a combination of statistics and judgment (see Table 5).

Table 5. 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

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. There are several aspects of constants that are deployed in a mode choice model that are useful to understand in this context:

- **Alternative Specific Constant –** This represents unobserved behavior in the mode choice model. These range from 0 to 43 minutes in the existing model and 0 to 14 minutes in the transit path choice model.
- **Transfer penalty –** This represents additional time spent transferring from one mode to another and range from 12 to 24 minutes in the existing model and 0 to 12 minutes in the transit path choice model, depending on the complexity of the paths.
- **Direct walk time** – This represents additional time to access premium modes directly and ranges from 5-10 minutes for direct access to express bus, bus rapid transit, light rail and commuter rail modes for the existing model. This parameter is zero in the transit path choice model.
- **Boarding penalty** – This represents an evaluation of premium service characteristics from the research and is levied as a boarding penalty by mode because more complex representations of station, on-board and other amenities in the path building software used in Salt Lake City was not possible. These boarding penalties 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. They range from 0 to 31 minutes in the transit path choice model, depending on the specific services included in a path.

It is clear that a strict comparison of the alternative specific constant shows a significant reduction in the transit path choice model compared to the existing model. This was a specific goal of the project and this demonstration confirms that the changes in model structure and path choice parameters, including premium service characteristics have achieved this goal. That said, the combined effects of all fixed parameters mentioned above are a useful comparison as well. In the existing model, the highest combined fixed effects total 53 and 43 minutes for walk and drive access of commuter rail, respectively, relative to local bus. Meaning, the commuter rail path receives a constant "bonus" equivalent to 43-53 minutes of 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. In addition, 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 (i.e. a commuter rail to local bus path is designated a commuter rail mode and given the commuter rail constant, traditionally).

One theory behind these new path choice parameters are that different travelers would choose different paths, based on different market segments. The path choice evaluation process identified age as the most significant demographic characteristic for choosing a walk to transit path. This 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) but did not significantly affect the regional statistics.

7. CONCLUSIONS

There are a number of benefits to accounting for non-traditional factors 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 17-29 minutes of in-vehicle travel time based on maximum difference scaling models.
- 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 reduces the number of choices for transit and improves the representation of competitive services.
- Including these attributes in path and mode choice models and modifying the nesting structure to include path choice does effectively reduce the influence of alternative specific constants in the mode choice models.

There are also benefits to enhancing traveler determinants in mode choice:

- Consideration of transit options do impact modal choices, with 12-14% of bus travelers and 27-38% of rail travelers not considering available transit services. Also, travelers are aware of fewer transit alternatives than we represent in our transit networks.
  - 50% of bus travelers perceive 1 alternative when only 5% of bus travelers actually have only one alternative.
  - 20% of bus travelers perceive 2 alternatives when 60% of bus travelers actually have two alternatives.
  - 40% of rail travelers perceive 1 alternative when only 7% of rail travelers actually have only one alternative.

  – 18% of rail travelers perceive 2 alternatives when 55% of rail travelers actually have two alternatives.

  Awareness and consideration models were estimated and used to constrain mode choice sets, which does statistically improve the goodness of fit for mode choice model estimation.

- Traveler attitudes do influence the choice of transit or auto, but do not consistently or significantly affect the choice of bus or train. Attitudes were estimated from factor analysis. Multinomial logit and integrated choice and latent variable models were estimated with traveler attitudes for commute and non-commute travel in Chicago and Charlotte. Traveler attitudes influenced awareness, consideration and mode choice models.

These benefits are all potential improvements to consider when updating mode choice models for regional travel demand forecasting purposes. Including transit service attributes and incorporating path choice into the mode choice model structure were two benefits that were implemented within the Salt Lake City model to determine the effect on constants in the model.

8. WHAT'S NEXT?

Future research could build from the existing research to integrate the path building with the awareness, consideration, attitude and mode choice models. 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 sub-mode choice sets.

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.

Future implementations of this research in existing or new regional mode choice models would add significantly to the usefulness of the research by comparing model results (reduction in modal constants, calibration results, sensitivity to transit service attributes, etc.) from one place to another. Conducting future scenarios using these updated models could help to explore these travel behaviors. 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.

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