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Assessing Importance and Satisfaction Judgments of Intermodal Work Commuters with Electronic Survey Methodology



MTI Report WP 12-01



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REPORT WP 12-01

**ASSESSING IMPORTANCE AND SATISFACTION
JUDGMENTS OF INTERMODAL WORK COMMUTERS
WITH ELECTRONIC SURVEY METHODOLOGY**

Steven Silver, Ph.D.

September 2013

A publication of

Mineta Transportation Institute

Created by Congress in 1991

College of Business
San José State University
San José, CA 95192-0219

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. CA-MTI-12-1127	2. Government Acession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Assessing Importance and Satisfaction Judgments of Intermodal Work Commuters with Electronic Survey Methodology		5. Report Date September 2013	
		6. Performing Organization Code	
7. Authors Steven Silver, Ph.D.		8. Performing Organization Report MTI Report WP 12-01	
9. Performing Organization Name and Address Mineta Transportation Institute College of Business San José State University San José, CA 95192-0219		10. Work Unit No.	
		11. Contract or Grant No. DTRT12-G-UTC21	
12. Sponsoring Agency Name and Address California Department of Transportation U.S. Department of Transportation Office of Research—MS42 Research & Innovative Technology Admin. P.O. Box 942873 1200 New Jersey Avenue, SE Sacramento, CA 94273-0001 Washington, DC 20590		13. Type of Report and Period Covered Final Report	
		14. Sponsoring Agency Code	
15. Supplemental Notes			
16. Abstract Recent advances in multivariate methodology provide an opportunity to further the assessment of service offerings in public transportation for work commuting. We offer methodologies that are alternative to direct rating scale and have advantages in the quality and precision of measurement. The alternative of methodology for adaptive conjoint analysis for the measurement of the <i>importance</i> of attributes in service offering is implemented. Rasch scaling methodology is used for the measurement of <i>satisfaction</i> with these attributes. Advantages that these methodologies introduce for assessment of the respective constructs and use of the assessment are discussed. In a first study, the conjoint derived weights were shown to have predictive capabilities in applications to respondent distributions of a fixed total budget to improve overall service offerings. Results with the Rasch model indicate that the attribute measures are reliable and can adequately constitute a composite measure of satisfaction. The Rasch items were also shown to provide a basis to discriminate between privately owned vehicles (POVs) and public transport commuters. Dissatisfaction with uncertainty in travel time and income level of respondents were the best predictors of POV commuting.			
17. Key Words Urban transportation; Work commuting; Intermodal transportation; Conjoint measurement; Measures of satisfaction		18. Distribution Statement No restrictions. This document is available to the public through The National Technical Information Service, Springfield, VA 22161	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 38	22. Price \$15.00

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Library of Congress Catalog Card Number:
2013942602

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ACKNOWLEDGMENTS

I am grateful to MTI Deputy Executive Director and Research Director Karen Philbrick, Ph.D. for her interest and facilitation of the research. Akshay Jagtap and Mangesh Dhumne provided competent research assistance.

The authors also thank MTI staff, including Director of Communications and Technology Transfer Donna Maurillo; Research Support Manager Joseph Mercado; and Webmaster Frances Cherman who also provided additional editorial and publication support.

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EXECUTIVE SUMMARY

To further the objectives of increasing the use of public transportation in work commuting, this study directly examines traveler judgments of the importance of attributes of public transportation service offerings and satisfaction with these attributes. Methodology was introduced to further the quality of measurement of these judgments. Additionally, a useful beginning point is to recognize that there are bases to expect that the objectives of valid and useful assessment differ between importance and satisfaction. While satisfaction with attributes may be modeled as defining a unidimensional construct, the same cannot be said for ratings of importance. The objective in assessing importance ratings is, in fact, to discriminate between attributes. These differences in objectives can be reflected in the assessment methodology.

Traveler judgments of importance and satisfaction with service offerings have typically been assessed with multipoint rating scales. However, respondents with low involvement tend to reduce cognitive work they do not find “interesting” by using limited ratings of direct rating scales. To the extent that intercorrelations between direct ratings of both importance and satisfaction result from response sets (e.g., the tendency of raters to use limited ranges in the tables), this reduces the quality of measurement and the ability to offer statistical inference.

Recent multivariate methodology in the assessment of respondent ratings of service offerings provides an opportunity to advance the study of public transportation usage in work commuting. The methodologies offered here are an alternative to direct rating scale and provide advantages in the quality and precision of measurement. The orientation here is not that rating scale methods are inherently faulty but that there are superior methods for assessing importance. This report offers an alternative methodology of adaptive conjoint analysis for the measurement of the *importance* of attributes in service offerings. It also introduces Rasch scaling methodology for the measurement of *satisfaction* with these attributes. The advantages these methodologies offer for assessment of the respective constructs and use of the assessment are discussed.

Two questionnaire studies of the rated importance of attributes of the service offerings by public transportation and the satisfaction with the current offerings by work commuters are reported. Both commuters who are regular users of public transportation and those who use privately owned vehicles (POVs) are studied. The studies use samples of work commuters in Santa Clara County, California. In these corridors, high-technology firms are the predominant employers. Both of the studies exclusively use electronic data collection from the commuter samples.

A highly significant correlation between the set of derived importance ratings of attributes and results of an exercise in which the monetary allocation to improve these attributes was obtained in Study 1. Respondents distributed a fixed total budget to improve the overall service offering. This suggests that in addition to their measurement qualities, the conjoint derived weights have predictive capabilities in applications to the assessment of public transportation offerings.

The contribution of Rasch modeling of subjective judgment are reviewed and implemented in Study 2. Results with the Rasch model indicate that the attribute measures are reliable and can jointly constitute an adequate composite measure of satisfaction. The Rasch items were also shown to provide a basis upon which to discriminate between POV and public transport commuters. Finally, a hierarchical decomposition of the predictor variables indicated that dissatisfaction with uncertainty in travel time and income level of a respondent best predicted POV commuters.

The increased comprehensiveness and accuracy introduced by these methods can provide further insight into designs for increased use of public transportation in work commuting.

Conjoint and Rasch methodology can be particularly useful for detailed segmentation of commuter markets. Commuters can be segmented on the basis of their attribute importance and satisfaction scores with different attributes as cross-classified by their sociodemographic profiles. The methods allow scores across the set of attributes.

RESEARCH OBJECTIVE

The primary objective of the reported studies is to increase the understanding and measurement of decision variables in the choice of a public transportation mode in work commuting. Focus groups and the results of a literature search are used to define a relevant set of attributes in service offerings for work commuting. The methodology follows from the differentiation of objectives in assessing importance and satisfaction and differs from the direct rating scales of importance and/or satisfaction that typify most studies. Both of the reported studies exclusively use electronic data collection from the commuter samples. The objective is supported in reports of metrics that demonstrate the quality of measurement for the methodologies and the contribution to empirical studies in transportations methodologies can offer. The research also shows that they have suitable concurrent and predictive validity in exploratory implementations.

A longer-term objective is to implement these measurement capabilities and use results to further the segmentation of the commuter market. This includes definition of the segments and the offerings that would be most likely to induce them to try or continue to use public transportation for their commuting. Concurrent with this objective, the methodologies must be compact and efficient to use. Part of this involves direct contact with, and training of, managers and designers in higher-technology travel corridors.

I. INTRODUCTION

A frequently referenced public policy goal of state and federal transportation agencies is to reduce or limit the growth of single-passenger private vehicle use for routine trips (Siggerud 2006, United States Government Accountability Office, 2010, Weiner 2008). This policy goal continues to have limited success in the densely populated travel corridors of California. Studies of travel in urban corridors most often have been conducted among commuters with multiple purposes (e.g., commuting to work, shopping, and visits to relatives or friends). However, there are bases for focusing on travelers with different purposes. For example, regular work commuters can be expected to judge the importance of attributes in intermodal travel by public transportation very differently from those who have more casual travel purposes. While work commuting is about 20 percent of total travel in the U.S., its importance is increased by the regularity and predictability of travel times. This facilitates understanding of the time distribution of peak loads in transit planning.

The use of privately owned vehicles (POVs) in routine trips has well-documented negative externalities (e.g., Manaugh, 2009, Shirgaokar 2012, Short and Kopp, 2005). As has been often observed, congestion, infrastructure wear and maintenance, and air quality are externalities of using privately owned vehicles for work commuting that have long-run public costs. Although placing restrictions on mode choice—through increased bridge tolls or parking costs, for example—is one means of reducing POV commuting, it is commonly viewed as coercive, and thereby aversive, to travelers. A more suitable alternative may be to increase the use of public transportation through designs of service offerings that better match the preferences of travelers.

One of the reasons for POV work commuting in technology corridors, in general, is structural. Many households are employed by companies that are located outside of, but in close proximity to, urban centers. As such, a large percentage of these households do not have access to a single transportation mode to their work location. Typically, wait time, total travel time, and uncertainty about them are increased when travel is intermodal, since it involves coordination between two transport vehicles in work commuting. That there has not been more coordination between commuters and employees is somewhat surprising. Although there is an extensive background on integrating land use and public transportation offerings (e.g., Bennett 1999; Metropolitan Transportation Commission, 2003), it is common for private companies to most heavily weight the factors of cost and proximity to suppliers and other producers when deciding on a location. In contrast, decisions about residence location most heavily weight the size and price of a residence, neighborhood quality, and amenities, such as the quality of schooling and location of cultural and ethnic facilities (Manaugh, Miranda-Moreno, El-Geneidy 2010). A consequence of this is that many work commuters reside at distances from their work locations, making it impractical to walk or cycle to work.

If the structure of work and residence is in place, the definition of policy variables and means to implement them increases in importance. This, in turn, increases the importance of understanding the decision variables that enter into choice of mode in work commuting. While there are a number of studies of attitudinal variables that are related to mode choice, the studies reported here assess attributes of the service offering in public transportation

for work commuting. More than two-thirds of the sample of work commuters in these studies report that public transit would require at least one connection. The increased complexity that intermodal commuting introduces is likely to make the study sample much more sensitive to decision variables in service offerings.

Two questionnaire studies of the importance of attributes of the service offerings by public transportation and the satisfaction with the current offerings by work commuters are reported. Both commuters who are regular users of public transportation and those who use POVs are studied. The studies use samples of work commuters in Santa Clara County, California, in corridors where high-technology firms are the predominant employers. Both of the studies that are reported exclusively use electronic data collection from the commuter samples. Additionally, the methodology used differs from the direct rating scales of importance and/or satisfaction that typify most studies. The basis for the contribution of these methods to the study of urban and suburban work commuters will be discussed in the next section.

ASSESSING SERVICE OFFERINGS IN WORK COMMUTING

There are bases for expecting that the objectives of valid and useful assessment differ between importance and satisfaction. While satisfaction with attributes may be modeled as defining a unidimensional construct, the same cannot be said for ratings of importance. The objective of importance ratings is, in fact, to discriminate between attributes.

Travelers' assessments of the importance of, and satisfaction with, service offerings typically have been measured with multipoint, Likert-type rating scales. Among the limitations of these rating scales for importance and satisfaction are the high intercorrelations of attribute ratings. Respondents with low involvement tend to minimize cognitive effort on subjects they do not find "interesting." They may do so by using limited ranges of direct rating scales. To the extent that intercorrelations between direct ratings of both importance and satisfaction result from response sets (e.g., the tendency of raters to use limited ranges in the scales), this reduces the quality of measurement and the ability to offer statistical inference. When multiple items are directly rated by the same individual, the ratings typically evidence systematic bias across the items. For example, individuals often have biases toward high or low ratings that carry across items. Intercorrelations between ratings of the importance of different attributes that do not reflect dimensionality of the measurement reduce the capability to discriminate the differences in judgments of travelers on attributes.

Given the divergence in measurement objectives for importance and satisfaction, it is useful to consider different measurement assessment models for these constructs. The contention here is not that Likert-type rating scale methods are inherently flawed but that better methodology for objectives in the assessment of importance can be implemented. The next section considers the alternative of conjoint analysis for the measurement of the *importance* of attributes in service offerings. The Rasch scaling methodology for the measurement of *satisfaction* is then introduced. This methodology has been shown to have both conceptual and empirical advantages for the measurement of affective constructs.

ESTIMATING THE IMPORTANCE OF ATTRIBUTES IN SERVICE OFFERINGS FOR WORK COMMUTING

Conjoint Analysis. Choice-based conjoint measurement of importance weights has psychometric origins as a theory to decompose ordinal scales of holistic judgment (e.g., full profiles of attributes in a service offering) into interval scales for each component attribute. Conjoint methods also have the general advantage of seeming more similar to the mental process a buyer goes through when deciding which product to purchase. As such, they can be expected to result in better discrimination of differences in importance. While conjoint designs can be in direct pairwise trade-offs between attribute levels or judgments of full attribute profiles of service offerings, choice tasks that are full-profile are generally easier for respondents to work through than pairwise trade-off tasks.

In summary, the advantages of conjoint analyses are that:

- they estimate psychological trade-offs that consumers make when simultaneously evaluating several attributes together
- they uncover real or hidden drivers which may not be apparent to the respondent themselves
- they present realistic choices
- model interactions between attributes can be used to develop needs-based segmentation

In recent years, investigators have become aware of potential problems with the way respondents typically process information in the methods of choice-based conjoint tasks. The number and complexity of profiles offered respondents is a principal problem. As frequently reported (e.g. Orme 2009), when respondents rate a large number of choice profiles they are unlikely to be weighing all the variations in factor levels. When they simplify their procedures for making choices, their responses become less accurate as a representation of how they would behave when buying a real product. Additionally, early conjoint designs also assumed strictly linear combinations of attributes to define a respondent's utility. Respondents commonly violate this assumption.

Gilbride and Allenby (2004) and Hauser, Dahan, Yee (2006) have shown that for most respondents they studied, choice involves nonlinear processing, such as cutoff points, below or above which the attribute will not be processed. If a respondent is strongly focused on a particular level of a critical attribute (a "must have"), standard choice tasks can result in their limiting processing to a few "must have" levels of attributes. Finally, when a large number of similar choice tasks are presented to the respondent, the experience is often seen as repetitive and boring, and respondents may be less engaged in the process than the investigator is assuming.

Adaptive Choice Conjoint (ACBC). Methodology of ACBC models (e.g., Orne 2007) is designed to reduce the number and complexity of choice profiles presented to respondents

and thereby reduces or eliminates problems in early choice-level methods. ACBC uses early judgments of ratings or ranking of full profiles to select the profiles that the respondent is subsequently shown for rating or ranking. This methodology generally reduces the number of profile judgments a respondent is asked to make. Additionally, ACBC allows nonlinear combinations of attributes that, in the respondent's judgment, more realistically represent processing on attribute levels.

In the initial stage of ACBC, "must have" questions directly follow "unacceptable level" questions. Once the respondent has completed the initial stage of screening questions, a transition is made to the second stage of the choice task. In this stage, the respondent is shown a series of choice tasks that present only attributes that were indicated to be actively processed on the first stage. ACBC methodology has been found to (1) increase efficiency by initially screening a wide variety of factors but then focusing on a subset of attribute levels that are indicated to be of greatest interest to the respondent, (2) better mimic actual usage experiences that involve both non-compensatory and compensatory processing and (3) provide an experience that encourages more engagement in the task than conventional CBC or direct rating tasks.

External validity (i.e., the extent to which a measurement procedure predicts or corresponds to behavior of the respondent in an independent, "real-world" situation) for ACBC designs has been reported by several investigators. Gaskin, Evgeniou, Bailiff and Hauser (2007) tested ACBC against a traditional CBC design choices of Global Positioning Systems (GPS). Using five-point scales, the two-stage task was seen as significantly more interesting (48.8% vs. 35.8%, $p=0.012$), and more enjoyable (26.8% vs. 23.4%, $p=0.29$, n.s.) than the traditional CBC task.

In two studies reported by Orme (2007), respondents were randomly assigned to ACBC and CBC designs. In each design, the results of the ACBC samples were used to predict the selection of attribute profiles of a prior or "hold-out" sample. ACBC was found to have outperformed CBC by counts of 61 to 50 and 44 to 37, respectively, in the number of correct classifications. Testing the ACBC against a model based on the directly rated (i.e., self-explicated) importances, ACBC evidenced better correspondence than the CBC design.

ACBC questionnaires generally do take longer than the CBC questionnaires to complete. Orme (2007) reports three studies in which ACBC took at least 50 percent longer than CBC versions. Even though ACBC respondents completed a longer task, they rated it as more interesting and engaging than respondents taking traditional CBC surveys.

The above are reasons to operationalize the assessment of attribute *importance* in work commuting in ACBC. What follows is the basis for the methodology that will be implemented in the assessment of *satisfaction* with the offerings of public transportation in work.

RASCH MEASUREMENT OF SATISFACTION IN WORK COMMUTING

Rasch Measures of Satisfaction. Rasch measurement of affective judgments, such as satisfaction, has a number of well-described and documented advantages over direct scale ratings. Rasch models have the objective of requiring data to meet fixed standards

of the model (Andrich 2004; Wright 1999). In a Rasch model, a specified response to scale rating points is modeled as a function of both the person and item parameters. Assessing person consistency jointly with scale properties gives more guidance to how to improve the assessment instruments. There are now a number of accounts by measurement theorists across a range of applications that document the advantages of Rasch measurement models in assessing a construct such as satisfaction (e.g. Andrich 2005; Ludlow 2010).

Rasch models begin with the assumption that the study construct is unidimensional and scale points are appropriately distributed across an ordered continuum in the intensity or strength of the construct. Rater judgments of the distance between scale points should be close to equivalent. Measured development in Rasch modeling involves developing a clear definition of the study construct and constructing specific items to represent it. For the construct of satisfaction with the service offerings of public transportation in work commuting, it was hypothesized that overall satisfaction as measured by multiple items for each of the five attributes identified is unidimensional and can be hierarchically ordered in the intensity with which items define overall satisfaction, (i.e., exists along a continuum in which the ordered items define the intensity of the judgment of satisfaction).

It can be expected that the ordering of attributes in the intensity or strength of overall satisfaction will correspond to the weights of the respective attributes obtained in the conjoint estimation of importance. Although few applications have been made of Rasch scaling in the assessment of satisfaction in public transportation, the range of other applications indicate that the methodology can be implemented with the advantages cited above. This repeats a recent observation made by Gallo (2011).

II. EMPIRICAL STUDIES

Next are two studies of work commuting by employees in high-tech industries that implement the conjoint and Rasch methods for the assessment of the importance of, and satisfaction with, respectively, trip attributes in service offerings. In the first study, a conjoint measurement model was applied to estimate the *importance* of factors in the choice of travel mode by work commuters. In this study, an initial version of a Rasch scale for satisfaction judgments was implemented. In this study, three items were used for each attribute identified. In the second study, the Rasch modeling was refined for the measurement of *satisfaction* with current service offerings in public transportation. Statistics for the quality of the Rasch model in this study are summarized. Respondents sampled for both studies were drawn from individuals who worked in high-tech industries and agreed to complete a 20-minute online survey. The list of candidates was drawn from graduate students enrolled in two courses.

DEMOGRAPHICS OF STUDY POPULATIONS

Table 1 summarizes demographic descriptors for the state of California, the county of Santa Clara and the samples used for this study. Clearly, the county and study samples are above the average levels of education and income in the state. In such a case, work commuters can be expected to have the ability to actively discriminate the importance of factors in mode choice and their satisfaction with current service offerings. It is also likely that they can afford POV commuting more than most commuters in the state. The respondents were generally earlier in their careers in comparison to the county and state samples.

As noted, there is some incentive for them to use POVs for commuting since, as in many technology centers, work commuting is intermodal, i.e., it involves at least two transport modes. The above increases the necessity to understand the importance of attributes in respondents' mode choice and satisfaction with these attributes in the service offering. Such an understanding can provide a basis to design offerings that better serve the needs of relevant work commuters and increase public transport net revenue.

Table 1. County, State and Sample Demographics

Descriptor	Santa Clara County (2009)	State of California (2009)	Technology Study Samples (2013)
Percent of Residents with Bachelor's Degree or Higher	40.5	26.6	45.4
Median Household Income ^a	\$88,525	\$61,017	\$50,000 – 75,000
Mean Travel Time to Work (minutes)	26.1	27.7	PUB=40.2, POV=20.0
Persons Per Square Mile	1,303	217	–

Source: U.S. Census Bureau 2010 (<http://www.census.gov/>) for county and state.

^a Household income in the technology sample is the sample's median category.

III. METHODOLOGY AND RESULTS

ATTRIBUTES OF SERVICE OFFERINGS IN PUBLIC TRANSPORTATION FOR WORK COMMUTING

The attributes that investigated in both studies were identified from previous focus groups of both public transportation users and POV users in work commuting. The discussions of the focus groups were directed to the “most burdensome,” “least burdensome” and “most important to improve” attributes in work commuting. The transcribed text of the discussion groups was then hierarchically decomposed into constituent attributes that were affirmed in a study with closed-end ratings and are used in the studies reported here.

ASSESSING IMPORTANCE AND SATISFACTION

In part, the reported studies assess the feasibility of the methodology introduced for the measurement of importance and satisfaction. Given the requirements of establishing reliability and validity for both the ACBC design procedure introduced for the assessment of the importance of attributes in public transportation offerings and the Rasch measurement procedure that will be implemented to assess satisfaction with the attributes, two studies were initiated. The first study implemented initial procedures for the assessment of importance with ACBD methodology and an initial study of the assessment of satisfaction with Rasch methodology. The second study used a modification of the Rasch scaling and showed statistics that supported the quality of the assessment in the Likert study. The usefulness of the scaling tradition was also demonstrated.

Both studies used closed-end ratings that operationalized attributes of service offerings as identified in previous studies. The samples in each study included those who regularly use an intermodal public option in commuting to work and those who regularly use their POVs in commuting to work. The POV commuters who participated are limited to those who indicated they also had experience in the use of public transportation, even if they do not regularly commute to work this way.

QUESTIONNAIRE DESIGN

The electronic questionnaires in both studies were similarly sequenced. The introductory statement indicated the general importance of the transportation modes used by regular work commuters. A first section elicited information on dimensions of the respondents' regular work commuting, including commuting distance from their residence to their work location, the frequencies of the modes used in the past month, and the range of waiting and traveling times for the trips. A second section then elicited measures of the importance of, and satisfaction with, attributes in their regular traveling. This section introduced conjoint methodology for assessment of importance and Rasch measurement for the assessment of satisfaction. In the second study, items in the Rasch scale were modified from results of the first study. The third and final section of both studies requested demographic information. Categories of age, education, income and gender and marital status were included in this section.

PROCEDURE

Respondents

Members of graduate classes were asked to provide the names and electronic addresses of three other contacts that were in professional careers with high-technology employers in Santa Clara county and were willing to complete an electronic questionnaire about their work commuting. For each study, samples were drawn from the list of contacts. Although there was no remuneration for participation, having the learning experience with multivariate assessment procedures in an online format was a motivating factor for participation. The electronic questionnaire was maintained on the site of a company whose primary business was electronic hosting and the sale of specialized software.

STUDY 1: CONJOINT-EXPLICATED IMPORTANCE WEIGHTS FOR ATTRIBUTES OF WORK COMMUTING

The conjoint measurement design that was implemented used ratings of full profiles of attributes in work commuting in an adaptive choice-based (ACBC) design. In the procedure, respondents first configure factors or attribute combinations that are their preferred service or product offerings through *Build-Your-Own* (BYO) questions. Answers were used to determine if the respondent had absolute requirements (“Must Have”) in levels of attributes and other cutoff rules. Finally, respondents were asked to rate profiles built from attributes following the exclusion rules uncovered in the screening procedure in a *Choice Tasks* section. An exemplary screen in the full profiles of the choice task is shown in Figure 1.

Next could you please rate how well the following profile of features in a public service offering for work commuting meets your personal needs?



Figure 1. Exemplary Screen in Full-Profile Choice Task

A subsequent section introduced a constant-sum allocation task in which respondents were asked to allocate a fixed budget to the improvement of service attributes in work commuting. The task provided a putative measure of the importance of attributes closer to behavioral intention. The screen for this task is shown in Figure 2.

Figure 2. Allocation to Improve Attributes of Service Offerings for Work Commuting by Public Transportation

If you had **\$100 to spend on improvements in the service offering you face in commuting to work by public transportation**, how would you spend it? You can spend it on one attribute or spread it around on multiple attributes. Be sure your total equals \$100.

- Cost
- Comfort
- Distance
- Uncertainty in total travel time
- Total travel time
- Wait time
- Total

RESULTS

Table 2 presents descriptive statistics for the ACBC-generated importance weights and the allocation task in which respondents allocated a fixed total-dollar amount to the improvement of different attributes in their work commuting with canonical correlation. Conjoint-derived importance weights for the set of attributes are expected to predict allocation to these attributes.

Table 2. Means and Standard Deviations of Importance Weights of Attributes and Allocation to the Attributes

	Importance Weights ^a	
	Mean	Std. Deviation
Importance Cost	22.6519	9.45873
Importance Comfort	6.0905	5.24222
Importance Distance	17.5206	9.61921
Importance Uncertainty	12.9783	7.72659
Importance Total Travel Time	15.9743	7.58860
Importance Wait Time	14.6120	7.17127
Importance Security	10.1724	7.75780
	Constant Sum to Improve Attributes of Service Offerings ^b	
	Mean	Std. Deviation
Money Spent Cost	18.7213	20.55130
Money Spent Comfort	9.9617	9.84962
Money Spent Distance	12.3661	12.55854
Money Spent Uncertainty	15.5574	15.42389
Money Spent Total Travel Time	17.5082	15.53580
Money Spent Wait Time	14.1093	12.93301
Money Spent Security	11.7760	13.54598

^a Monotone Regression: n – 186.

^b n=183.

The mean correlation between the seven items was -0.160. In a principal component analysis (PCA), three factors explained .572 of the item variance, with the first factor explaining .206 of the item variance. A previous study with a nine-point Likert-type rating scale found an average correlation of .381. The PCA in that study yielded a two-factor solution that explained .712 of the total variation in the ratings. Next, the relationship between conjoint explicated importance weights for attributes and the allocation of a fixed budget to improve these attributes in service office offerings was assessed. Here, the importance weights were expected to predict allocations even though assessment methods differ. Canonical correlation was used to assess this relationship.

Canonical Correlation Analysis

Canonical correlation (CCA: González, Déjean, Martin, Baccini 2008 and Muller 1982) is a generalization of bivariate correlation. It is a method for estimating relationships between two vectors of variables in contrast to the scalars in bivariate correlations. Given two sets of variables, x_1, \dots, x_n and y_1, \dots, y_m , canonical correlation analysis assesses linear combinations of the x and the y vectors that have maximum correlation with each other. Despite the advantages of CCA in analyzing multidimensional relationships, no background studies that have applied it in transportation research were found.

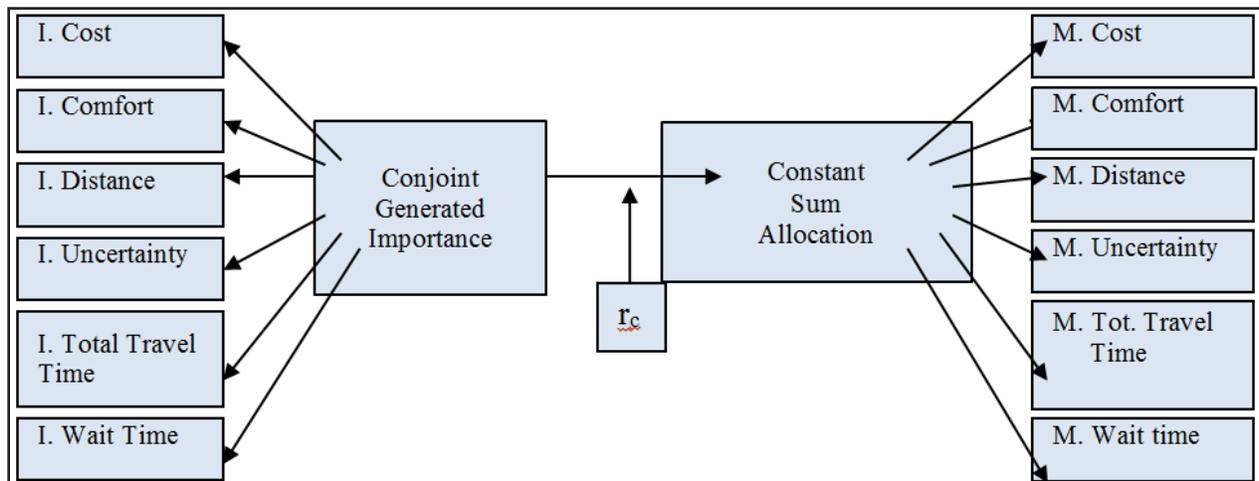
First, to summarize the information in the results, CCA reduces the numerous original variables to a few dimensions or canonical variates. More exactly, CCA yields a succession of mutually independent canonical variates, which are pairs of linear combinations

of variables from each of the two sets that are uncorrelated within a set but maximally correlated between sets. Wilk's Lambda was used to test the significance of the canonical variates in determining how many dimensions were necessary to represent the relationship between conjoint explicated importance weights and constant sum allocation to improve attributes of the offering.

CCA reports the relationship between the two sets of variables through canonical loadings (i.e., the correlations between original variables and canonical variates). Thus, canonical loadings are analogous to factor loadings and indicate the contribution made by each original variable to the explanatory power of the relevant canonical variate.

To confirm the statistical power of the entire model, the CCA assesses the adequacy of prediction—i.e., how strongly the independent canonical variates explain the dependent variable of allocation. The relevant redundancy coefficients indicate the percentages of total variance of the original dependent variables accounted for by each independent canonical variate. Figure 3 graphically illustrates the model.

Summary statistics for the CCA application to conjoint explicated importance rates and constant sum allocation of money to improve attributes are presented in Table 3. As shown in the table, the relationships between the two sets of variables were reducible to two dimensions that explain more than half of the variation in the measures ($p < 0.05$, Wilk's Lambda). The first pair of canonical variates (i.e., the combination of weighted items in the independent variables that maximizes their relationship to a combination of weighted items in the dependent variables) showed a canonical correlation of 0.414.



Notes:

- I. Cost ... I. Wait time here are the conjoint derived importance weights.
- M. Cost ... M. Weight time here are allocations from the constant sum exercise in which a fixed budget was allocated to each attribute to improve the overall service offering.
- r_c is the canonical correlation coefficient.

Figure 3. First Canonical Function Between Conjoint-Generated Importance for Trip Attributes and Allocations to Improve Attributes of their Work Trip Variables^a

Table 3. Summary Statistic for Canonical Variates^a

Canonical Variates	Canonical Correlation	Test that Remaining Correlations are Zero			Redundancy Coefficient
		Wilk's Lambda	DF	Sig.	
1	0.410	0.668	36	0.002	0.507
2	0.351	0.829	25	0.137	0.354
3	0.178	0.946	16	0.888	0.082
4	0.124	0.978	9	0.920	0.039
5	0.080	0.993	4	0.891	0.016
6	0.001	1.00	1	0.989	0.0

^a Redundancy coefficients are percentages of total variation in the dependent and independent variables that the model explains.

Table 4. Canonical Solution for Conjoint-Explicated Importance Weights Predicting Constant Sum Allocations to Improving Trip Attributes

Variable	Function I			Function II			h ² (%)
	Coef	r _s	r _s ² (%)	Coef	r _s	r _s ² (%)	
Moneyspent Cost	0.600	-0.247	0.061	1.486	0.594	0.352	0.413
Moneyspent Comfort	0.129	-0.395	0.156	0.625	-0.026	0.001	0.156
Moneyspent Distance	0.356	-0.124	0.015	0.951	0.374	0.139	0.155
Moneyspent Uncertainty	1.132	0.822	0.675	0.465	-0.370	0.136	0.812
Moneyspent Tot. Travel Time	0.718	0.422	0.178	0.776	-0.124	0.015	0.193
Moneyspent Wait Time	0.363	0.029	0.001	0.802	0.057	0.003	0.004
R _c ²			50.753			35.413	86.166
Importance Cost	0.762	0.031	0.001	1.023	0.584	0.341	0.342
Importance Comfort	0.316	0.148	0.021	0.241	0.208	0.043	0.065
Importance Distance	0.821	0.009	0.001	0.701	0.107	0.011	0.011
Importance Uncertainty	1.298	0.768	0.589	0.029	0.597	0.356	0.946
Importance Total Travel Time	0.513	0.226	0.051	0.462	0.083	0.006	0.057
Importance Wait Time	0.700	0.111	0.012	0.846	0.380	0.144	0.156

Notes: Coef is the standardized canonical function coefficient;

r_s = structure coefficient; r_s² = squared structure coefficient; h² = communality coefficient.

As shown in Table 4, the relationships between the two sets of variables were reducible to a single significant dimension ($p < .05$) by test of a Wilk's Lambda statistic. The first pair of canonical variates showed a canonical correlation of .414, whereas dimensions 2 and 3 had slowly decreasing canonical correlations not greater than .157.

For each pair of canonical variates, original variables with the highest canonical loadings compose an importance profile and an allocation profile that are maximally correlated.

As shown in Table 3, the first dependent canonical variate is strongly associated with the importance of uncertainty, distance, wait time, and cost. According to the first independent canonical variate, travelers with these importance weights allocate their budgets primarily to reduce wait time and total travel time. The redundancy coefficient indicates that the first independent canonical variate explained 50.7% of the total variance in the original dependent variables.

Designing Segmentation Studies

With larger sample sizes, canonical correlation can be used to designate segments of the commute market. In such an application, sociodemographic variables would be added to the predictors, and segments would be defined from the loadings in the best-fitting vector of predictor variables. That is, segments can be defined in terms of the combination of sociodemographic variables that differentiate the preferred set of attributes preferred in a commuter service offering. If the sociodemographic variables are defined as nominal categories rather than intervals, then correspondence analysis (Murtagh, 2010) could be an appropriate model that yields information similar to CCA.

STUDY 2: REFINED RASCH MEASUREMENT OF SATISFACTION

Study 2 replicated conjoint results of Study 1 and refined the Rasch scale for satisfaction with attributes of public transportation in work commuting. The electronic questionnaires used in this study had the same sections as in the first study. Results with the initial instrument of fifteen items in Study 1 were used to define a ten-item instrument with appropriate measurement properties. Table 5 shows conjoint explicated importance weights similar to those reported in the first study. Travel time, wait time and cost were judged to be the most important attributes in service offerings for commuters.

Table 5. Conjoint Estimated Importance Weights:^a Study 2

	Mean	Std. Deviation
Cost HB	25.817113277	9.6768549668
Comfort HB	10.4983792945	6.89583137337
Uncertainty in total travel time HB	15.146270406	9.7138898818
Total travel time HB	24.760797778	7.7958608206
Wait time HB	23.777439339	9.7759995887

^a Hierarchical Bayes: n=88

Results

After establishing the measurement properties with criteria for a Rasch scale, significant differences were found between own-vehicle and public transportation commuters in the judgments of attributes in the service offerings they face in public transportation. Finally, an exploratory study is reported that implements a hierarchical decomposition of items of the satisfaction scale and demographics of respondents to identify variables that discriminate own-vehicle and public transportation commuters.

Testing of Scale Point (Category) Usage

Evaluating how respondents use the rating points on the scale is considered to be a first step in conducting a rating scale analysis (e.g., Linacre 2002; Lopez 1996). This usually involves an analysis of extent to which the full range of points on the scale is used in a uniform way by respondents. In Study 1 with a nine-point agree-disagree scale, the analysis indicated that the full range of the scale was not uniformly used. In Study 2, a five-point scale was pretested and used. In a Rasch analysis, a useful diagnostic for evaluating scale point (category) usage is the average measure and thresholds of each category. The average measure across scale point or categories should increase monotonically. Correspondingly, the thresholds should increase monotonically. The so-called “threshold” indicates the ordering of the scale at which ratings on scale points are equally likely. For the five-point scaling of the ten-item satisfaction scale, the average measure was found to increase with scale (or category) points. Threshold estimates are in logits, and also are appropriately ordered. Figure 3 graphically shows the probability curves for the five-point scales. The interior points are comparable in magnitude and slope parameters and consequently support a claim that the scale points of (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree) as used by respondents are an adequate scaling of satisfaction. This suggests that the five-point scale measures the construct of satisfaction adequately. When the distributions of a certain scale points are empty or markedly different, the scale may have too many scale points for the dimension being judged.

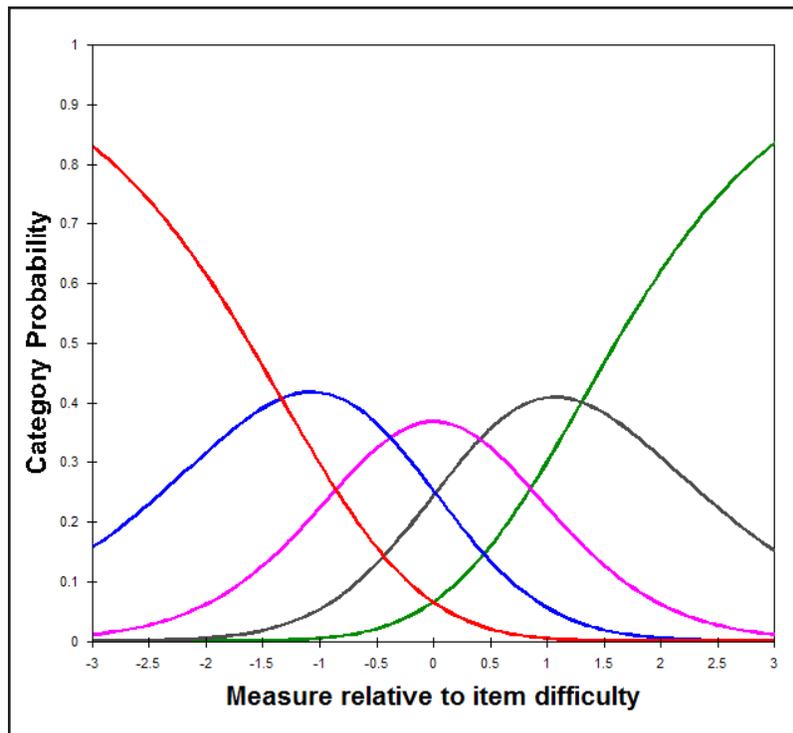


Figure 4. Response Function for Five-point Rasch Scale

Dimensionality

Dimensionality assesses the extent to which satisfaction with each of the set of attributes of public transportation in work commuting can be represented in an overall satisfaction measure. In Rasch analysis, an item mean square (MNSQ) of approximately 1.0 indicates unidimensionality. An item MNSQ of less than 0.8 or greater than 1.2 is inconsistent with a single uniform measure for the construct of satisfaction. $MNSQ > 1.2$ indicates an absence of construct homogeneity across items, whereas $MNSQ < .80$ indicates excessive redundancy with other items in the scale. Two MNSQ statistics (*Infit* and *Outfit*) are generally used for this assessment. Infit is a weighted statistic; outfit is an unweighted statistic. Most interpretations are in the weighted statistic of infit. As shown in Table 6, most of the items show reasonable fit to the hypothesized dimensionality of a single satisfaction construct. Thus the multi-item measures of satisfaction can be used as an overall index as well as in the assessment of different attributes.

Table 6. Parameters for Ten-Item Scale of Satisfaction with Public Transportation Offerings^a

		INFIT MNSQ	OUTFIT MNSQ	Difficulty Level
1	Waiting time for my connections seems reasonable to me.	.83	.85	-1.1
2	I do not feel that I can reliably plan for the variation in wait times that I face. (Reversed)	1.38	1.47	2.2
3	Total travel time including wait time is not a burden to my schedule.	1.16	1.12	1.0
5	Generally public transportation is not managed to provide adequate comfort for travelers. (Reversed)	1.31	1.31	1.9
7	Variation in wait time does not interfere with my planning a schedule.	1.04	1.07	.3
8	All considered, total travel time including wait time is reasonable for the distance I travel and the time of day.	.81	.82	-1.2
9	Comfort is reasonable on the public transportation that I use.	.85	.84	-1.0
10	Increases in the cost of public transportation generally do not exceed cost of living increases.	1.15	1.18	1.0
11	I do not generally find waiting time for my connections to be excessive.	.84	.84	-1.1
15	The cost of public transportation is excessive for what it offers. (Cost reversed)	.69	.69	-2.2
	Overall Ten-Item Scale	1.00	1.02	.0

^a MNSQ = mean square. Difficulty Level is scaling of item distances in logits.

The term “item difficulty” in the table and elsewhere arises from the early use of Rasch scaling to test ability levels. In these applications difficulty was defined in terms of the correctness of a response to an item. In this application, difficulty level refers to the extent to which there is agreement with the statement in the item and is scaled in logits following the derivation of a Rasch model (e.g., Bond and Fox 2007). A logit is the log of the likelihood of selecting a particular rating point on a scale relative to all other rating points (i.e., the log odds ratio).

Assessment of the Scale Difficulty Level for the Sample

As indicated in previous discussion, Rasch scaling models person and item “difficulty” parameters on a common metric (i.e., logits). This allows an assessment of whether the ten-item scale is appropriate for the study sample of respondents. If the instrument is appropriate to the study sample, there should be clear correspondence (or overlap) between the range of the person “trait” (i.e., overall satisfaction) levels and the range of item difficulty levels. A distribution of the person trait levels and item difficulty levels on the five-point scale used for scaling satisfaction is shown in Figure 5. The left side of the continuum in the figure is the person “trait” level; the right side of the scale is the item difficulty level.

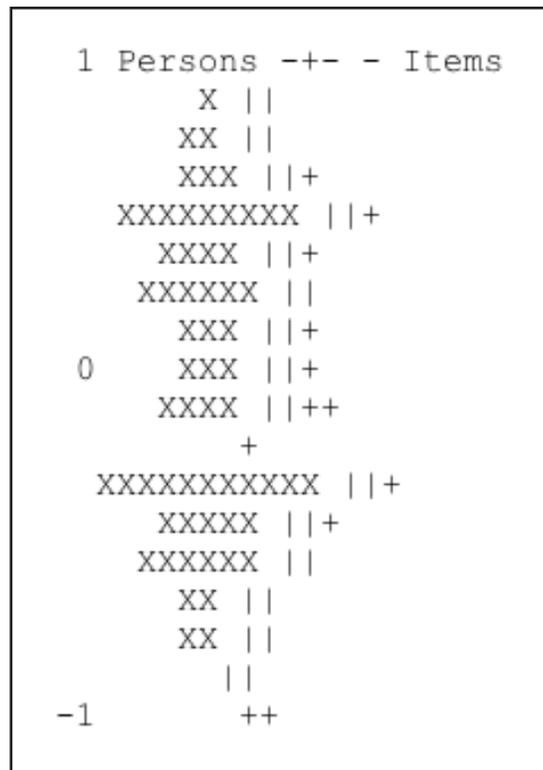


Figure 5. Distribution of Person Trait Level and Item Difficulty Level for Ten-Item Satisfaction Scale

As indicated in the figure, there is considerable correspondence on both sides of the scale. Zero is the scale midpoint. The symmetry on both sides of the midpoint indicates that the scale has approximately corresponding ranges for “easier” and “more difficult” items. This correspondence indicates that the set of items for the multi-attribute measure of the satisfaction construct is appropriately scaled for the target sample. A further refinement of the Rasch scale might seek to increase item range on both of the extreme sides of the scale—i.e., include the low and high intensity of satisfaction items.

SUMMARY OF RASCH SATISFACTION ASSESSMENT

The Rasch Satisfaction scale was designed to assess satisfaction with available service offerings for public transportation commuting to work. A set of constituent attributes was identified for the service offerings from focus group and Likert scaling studies. In Studies 1 and 2, Rasch-based methods were used to assess psychometric properties (reliability and construct validity) of the scale. Results with the initial fifteen-item scale having three items for each attribute in Study 1 was reduced to a ten-item scale with two items for each attribute in Study 2. The items that were removed were indicated to not fit the overall measure of satisfaction on defined criteria of the Rasch model. Either these items did not adequately contribute to construct homogeneity or they were too redundant with other items. Results of Study 1 also indicated that the nine-point scale did not evidence approximately equal spacing of the interior points. Consequently, the nine-point scales in Study 1 were reduced to five-point scales in Study 2.

A final step in the Rasch assessment of the scaling of satisfaction in Study 2 was to examine the person-item map. The map indicated that when both the “difficulty” level of items and respondent “trait” levels were defined in logits, the difficulty level of items in the scale adequately functioned to represent the full range of respondents’ trait abilities. This suggests that the scale is adequate to assess various levels of satisfaction. As indicated, it remains important to assess both high and low levels of satisfaction. This appears to be adequately accomplished here in contrast to the Likert scaling of a number of previous studies.

This was followed by an examination the differences between POV and public transportation work commuters on the ten items of the Rasch scale of satisfaction. Table 7 reports the result of this comparison.

Table 7. Comparison Between Own-Vehicle and Public Transit Commuters on Rasch Measure of Satisfaction with Constituent Attributes of the Service Offering

	Note	N	Mean	Standard Deviation	t
Rasc r1 Wait 1	1	40	2.60	1.008	.000
	2	25	2.60	1.323	
Rasc r2 Uncertainty 1 Reversed	1	40	2.80	.966	-.138
	2	25	2.84	1.375	
Rasc r3 Total Travel Time 1	1	40	3.68	1.207	1.683*
	2	25	3.12	1.424	
Rasc r5 Comfort 1 Reversed	1	40	2.68	1.095	-.433
	2	25	2.80	1.190	
Rasc r7 Uncertainty 2	1	40	3.65	1.051	1.848*
	2	25	3.12	1.236	
Rasc r8 Travel Time 2	1	40	2.98	1.121	2.766***
	2	25	2.68	1.215	
Rasc r9 Comfort 2	1	40	3.08	1.071	1.000
	2	25	2.32	1.069	
Rasc r10 Cost2	1	40	2.95	1.061	.575
	2	25	2.80	.957	

Table 7, Continued

	Note	N	Mean	Standard Deviation	t
Rasc r11 Weight 2	1	40	2.83	.958	.394
	2	25	2.72	1.173	
Rasc r15 Cost Reversed	1	40	2.80	.823	-2.631**
	2	25	3.40	1.000	

Note: 1 = POV commuters, 2 = public transportation commuters; *p<.10; **p<.05; ***p<.01.

The largest differences between POV and public transportation commuters are in means for total travel time (Rasc r3), uncertainty in travel time (Rasc r7) and cost (Rasc r15). The differences between POV commuters and public transportation commuters on these items are statistically significant (p<.10), even in the small sample comparisons.

PREDICTING PUBLIC TRANSPORT USE FROM RASCH SATISFACTION AND COMMUTER DEMOGRAPHICS

Finally, a classification and regression algorithm was used to predict differences between respondents who use own-vehicle or public transportation in work commuting. These algorithms find the split in the scaling of independent variables (i.e., satisfaction with attributes of the service offering and demographics) that explain the most variance in the dependent variable (i.e., whether commuters use POV or public transportation). The CHAID algorithm available in SPSS analytics was used for this application. Because of the sample size of the studies, results designated only two splits to differentiate POV and public transit users. The first split was on dissatisfaction in the uncertainty of total travel time. Commuters who were highly dissatisfied with uncertainty of travel time in the public service offering further split on income. Those with high incomes were more likely to be POV users while lower income travelers were more likely to use public transit. While this difference may be intuitive, it does suggest that the methodology can meaningfully recover significant relationships in the data. Applications of the CHAID algorithm with larger numbers of observations can be expected to recover more complex relationships. These results do support the discrimination between work commuters allowed by the Rasch scaling of satisfaction and encourage further application to facilitate understanding of attributes to target in policy design.

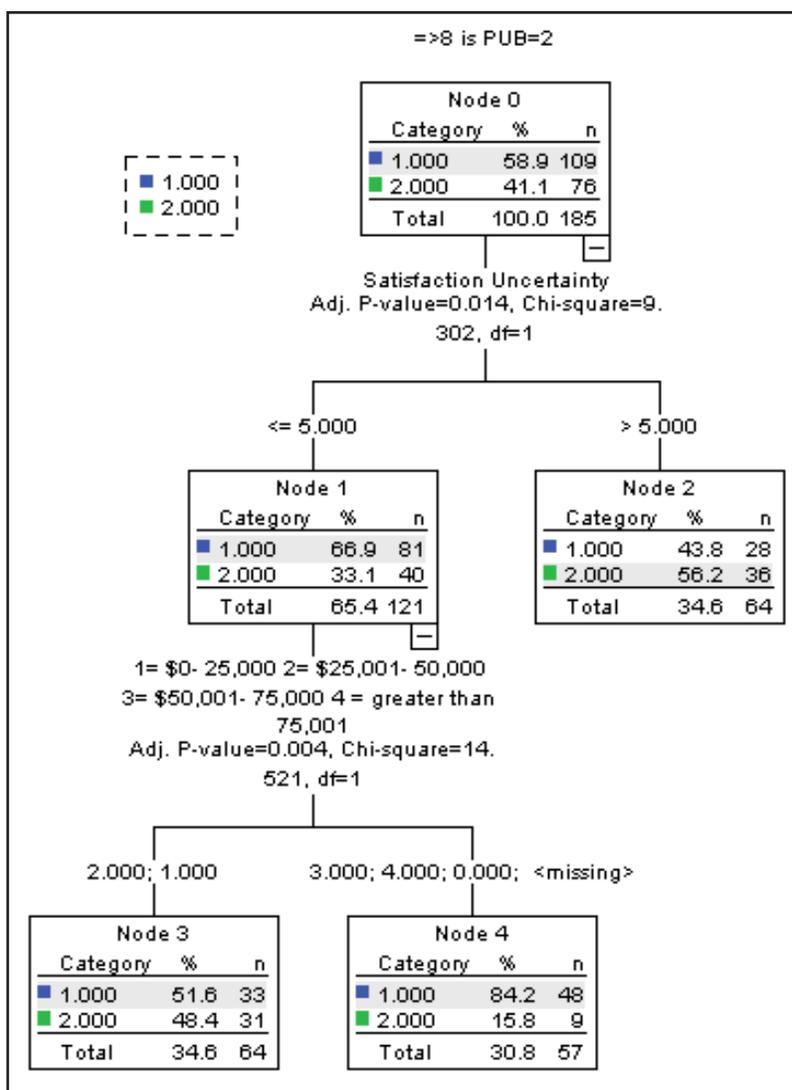


Figure 6. Predicting Public Transportation Users in Work Commuting: Hierarchical Decomposition of Satisfaction and Demographics

In terms of directions for subsequent study, generalizability of the importance and satisfaction measures developed in these studies is required for applications. This is best accomplished with larger sample studies that at least include one geographically diverse replication across travel corridors. It is important that larger sample studies would support using the scalings of importance and satisfaction to segment the commuter market. In such an application, clustering and hierarchical decomposition methods could identify the segments in terms of the attributes that they consider important but are most dissatisfied with the public transportation offerings they face as well as the sociodemographics of the travelers on different segments. These differences between segments could be used to modify offerings (as in increased frequency of service at an increased cost to the traveler) that best fit the preferences of commuters on different routes in a corridor.

For example, bus routes that are used by a large number of professionals in technology companies may be able to attract greater ridership by offering more frequent service

at common commuter times and more company stops at the work destination. This is likely to require a higher fare, but the increased cost may be justified by this segment of the commuter market. In contrast, bus routes that serve government offices or are more frequented by support personnel may clearly have the highest priority in low fares. The service offering to this segment would not be well served by any service augmentation that raised the fare. Conjoint analysis can be used to verify the trade-offs that different segments make. As a trade-off methodology that can operate under resource constraints, it has important advantages in comparison to direct ratings of service attributes.

An additional objective in subsequent studies would be to make the implementation of the methodologies compact and efficient for designers and managers. It is hoped that these methodologies can further the general objective of facilitating service designs that increase the use of public transportation in work commuting.

IV. SUMMARY AND DISCUSSION

As initially noted, the common goal of achieving increased use of public transportation for routine trips has been difficult for county, state and federal transportation agencies to accomplish. Work commuting is among the routine travel that policy can readily address because of its regularity in schedule. As typified in the high-technology corridors studied in this report, the commuting trip often requires at least one transfer and possibly more than one transit mode (e.g., travel that involves light rail and a bus), and this further complicates the task. It also increases the importance of understanding fundamental factors in the mode choice of commuters in these travel corridors.

Previous studies have often emphasized attitudes and demographics as discriminants of mode use. This research suggests that direct study of constituent trip attributes of service offerings as judged by commuters remains the most informative source for policy design. Available studies have also predominantly used Likert-type rating scales (e.g., direct judgments of importance and/or satisfaction on a five- or seven-point scale). These scaling methods have a number of limitations. For importance, the high intercorrelations of attribute ratings may obscure differences in judgments of trip attributes when in fact they reflect response sets in the face of multiple attribute rating tasks. For satisfaction, Likert-type scales do not assess both person and item goodness-of-fit on a common scale. This has been shown to be important to the quality of measurement.

Two studies of work commuters that elicit judgments of the importance of and satisfaction with a set of attributes in the service offerings were reported here. The specific attributes examined were defined in focus group and closed-end questionnaire studies of work commuter in multiple travel corridors. A methodology for the measurement of importance and satisfaction that can better represent users differences between own vehicle and public transportation commuters was used. Exploratory studies show that these methods can be implemented in even small samples and support inferences for design.

Both studies utilize online hosted procedures for assessment of attributes of public transportation offerings to commuters. Initially, differences were noted in the objectives of assessing importance and satisfaction in work commuting. To be informative, importance ratings need to differentiate between attributes rather than constitute a unidimensional construct. As recognized, a composite in overall importance has no useful interpretation. In contrast, overall satisfaction is an interpretable construct, and the weighting or intensity of different attributes to overall satisfaction remains a meaningful assessment. Given these different objectives in assessing importance and satisfaction in the application to attributes of work consumption, different methodologies were introduced for the assessment of importance and satisfaction.

The first study introduced conjoint measurement of the importance of these attributes. The online procedure used full profile designs presenting respondents with levels of all the attributes or factors in each rating screen. Full profiles have shown to be more realistic than pairwise trade-offs and to thereby increase the quality of results. As indicated, adaptive conjoint methodology has a number of advantages over both direct ratings of importance and the choice-based conjoint methodology that had previously predominated in earlier

conjoint assessment studies. This methodology uses early choices of a respondent to filter subsequent profiles shown to the respondent. It thereby reduces the total number of profiles that the respondent is asked to rate and generally increases involvement in the task. Additionally, early conjoint choice designs were linear and compensatory. The adaptive choice designs that implemented in this study relax this condition to allow non-linearity as in “must have” levels of attributes.

To further assess the validity of the importance weights for attributes generated by the conjoint design; the relationship between the derived importance ratings of attributes and importance weights from an exercise in which respondents allocated a constant monetary sum to the improvement of each attribute was investigated. Respondents were allowed to designate any amount to each attribute as long as the total allocation did not exceed the total dollar budget. The latter is considered to approximate a measure of behavioral intention.

The relationship between the set of conjoint explicated importance ratings and the set of allocations to most improve service offerings was assessed with canonical correlation. A highly significant canonical correlation between the set of derived importance ratings of attributes and the monetary allocation to improve these attributes was indicated. This suggests that in addition to the greater independence of importance weights, the conjoint derived weights have predictive capabilities in applications to the assessment of public transportation offerings.

As has been indicated, Rasch methodology for the measurement of satisfaction has a number of advantages over direct ratings on Likert-type scales. In keeping with the requirements of Rasch methodology, the research began with a predefined measurement model and requisite standards for goodness-of-fit to the model. Multiple items in agree-disagree ratings were developed to assess each of the attributes of public transportation. The first study was used to assess the reliability of agree-disagree questions and the number of scale points respondents used for Rasch scaling of satisfaction. The second study applied a final set of items for the Rasch model of satisfaction.

Results with the Rasch model in Study 2 indicate that the attribute measures are reliable and, jointly, can constitute an adequate composite measure of satisfaction. The Rasch items also were shown to provide a basis to discriminate between POV and public transport commuters. In a hierarchical decomposition of the predictor variables, it was found that dissatisfaction with uncertainty in travel time and income level best predict POV commuters. Among the commuters who report high dissatisfaction with uncertainty, those with higher incomes are most likely to be POV commuters. This result confirms the attributes in service offerings whose modification is most likely to increase usage of public transportation and the demographics of a traveler population to target. The reported results remain exploratory because of sample size. Larger samples are likely to provide more detailed discrimination between POV and public transportation commuters and allow segmentation of the commuter. The task of introducing methodologies to practitioners would be a priority in further study.

V. CONCLUSIONS

Increases in population density in urban areas increase the importance of using public transportation for routine trips. It is important to differentiate types of routine trips. For example, in work commuting attributes such as waiting time, total travel time and uncertainty in travel times can be expected to become increasingly differentiated from attributes such as cost and comfort. Recent advances in multivariate methodology for the assessment of respondent ratings of service offerings provide an opportunity to advance the study of public transportation usage in work commuting. The increased comprehensiveness and accuracy that these methods can offer can provide further insight into bases for greater usage in studies of public transportation.

While the contributions of conjoint methodologies are well recognized in a range of applications, no recent studies were located in which the methodology of adaptive conjoint analysis has been applied to public transportation usage. Correspondingly, while Rasch models of ability and affect are extensively in evidence, there are few direct implementations in the study of work commuting. Conjoint methodology is particularly used for when the goal is to find trade-offs between service characteristics that users make when there is a constraint on resources that can be allocated.

Conjoint and Rasch results can be particularly useful for detailed segmentation of commuter markets. Consumers can be segmented on the basis of their attribute importance and satisfaction scores as cross-classified with their demographics. The importance weights from conjoint estimation can be combined with satisfaction judgments. The basis to implement assessment in Rasch models has been discussed and applied. The implementation of conjoint designs does require the presentation of multiple independent screens and as such is not readily administered in paper questionnaires. This study shows that assessment procedures using electronic data collection can be readily implemented. Undoubtedly this will require new sampling procedures and incentives for respondent participation. However, the increases in the quality of results make a strong case for the development of online procedures despite the challenges presented.

Finally, direction is given for applying the results. As noted, the most important of these is likely to be in market segmentation. It is now well recognized that disaggregation of markets including travel markets can accommodate differences in the price sensitivity of segments and result in more effective designs in service offerings. With appropriate sample sizes, studies with the methods introduced can demonstrate differences in sensitivities to service offerings in public transportation that are implementable in designs.

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