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Structural Equation Model of Customer Satisfaction for the New York City Subway System

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A more complex model in content and design than previously applied to the measurement of customer satisfaction within the transportation industry is used in this study. Drawing from the results of previous studies that had a narrower focus, a network of 10 potentially important factors that affect customer satisfaction within the New York City subway system was postulated and tested using data collected from a cross section of adult residents. Results indicate that several factors have a direct influence on satisfaction, whereas others have an effect through intermediary variables. Path coefficients for the posited model are statistically significant, although several factors have notably more impact than others. Using model diagnostics, minor revisions and improvements to the initial model have been made while adhering closely to the principles of the original theory. Future developments are discussed, as is the model's application for planning and resource allocation.

As public-transit organizations become more customer oriented, there is increasing focus on the measurement of customer satisfaction in addition to using more traditional internal-service measures (e.g., on-time performance and mean distance between failures of equipment). Organizations that incorporate external evaluation of their performance often turn to quantitative surveys of current and potential customers as part of the assessment. This provides the opportunity to collect data on customer satisfaction with overall performance as well as with specific aspects of the public-transit experience (e.g., service performance and service environment). Moreover, this allows transit management to develop a better understanding of what drives customer satisfaction to better meet customer needs.

TRADITIONAL STATISTICAL ANALYSIS

The methods employed for assessing customer satisfaction vary considerably in complexity and may be as simple as looking at a single measure to help evaluate performance. An organization can monitor progress over time by tracking this measure over successive time periods. This univariate approach, however, does not permit the analysis of causal factors that drive customer satisfaction; for this, multivariate techniques are necessary. To help explain relationships, a *bivariate model* (i.e., a pair of variables, such as the impact of service frequency upon customer satisfaction) is often used. This type of model is depicted in Figure 1.

A positive aspect of the bivariate approach is that some insight into the strength of the relationship may be obtained. Its weakness, though, is that it can provide an overly simplistic, even erroneous, view of causality—an issue that statisticians have been grappling with since Galton (*1*) first published the concept of a single correlation coefficient. This approach, by definition, does not allow the impact of more than one variable in the model to be considered at a time.

Multiple-regression analysis provides the potential for improvement when the impact of different variables is assessed. This technique extends simple correlation and was pioneered by Edgeworth (*2*), Pearson (*3*), and Yule (*4*) to permit more than one variable to have direct association with another. Figure 2 shows an example of such a model.

This technique may be used either strictly for prediction purposes or as an attempt to explain relationships between variables. One aspect of multiple-regression analysis is that the relationships of variables to the outcome measure can be assessed simultaneously. This facilitates analysis of their relative strengths and often is used to provide insight into the importance of drivers of satisfaction.

There is still a significant weakness in the approach, however. It forces each variable under consideration to be either dependent or independent in nature; thus, no variables can be both dependent and independent in nature. The real world of customer satisfaction is more likely to be a complex set of relationships in which some variables influence others, which in turn can affect still other measures.

STRUCTURAL EQUATION MODELING

An extension of regression analysis is the path analytic model, pioneered by Wright (*5*), in which a causal ordering of variables is postulated. In contrast to regression, each relationship between variables in the path (or structural) model represents a causal link rather than a mere empirical association. This method can be used to examine a network of interrelated variables. Direct and indirect influences may be studied, with some variables being both dependent and independent in nature. The model can be represented by a system of interrelated regression equations. Figure 3 is an example of a structural model in which some variables are *exogenous* (no prior causation) and others are *endogenous* (variables have prior influence). Additionally, one of the variables is postulated to be both dependent and independent. Finally, customer satisfaction is a function of the direct impact of certain variables and, at the same time, the indirect impact of others.

There is an important extension of path analysis that incorporates multiple indicators of key attributes. Path analysis necessitates the statistical assumption that observed measures correlate with their respective underlying constructs without error. Although combining several indicators into an index can ameliorate this issue, as would

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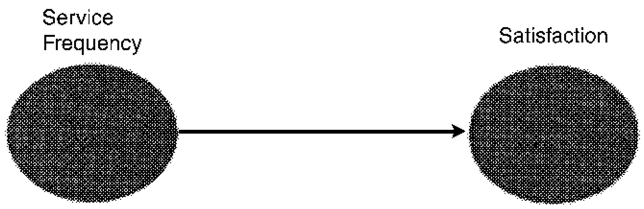

FIGURE 1 Hypothetical two-variable model of customer satisfaction.

having a particularly good single indicator, "latent" constructs with multiple observable variables can be a statistical improvement.

Joreskog (*6, 7*) helped pioneer this advance by developing a viable computer algorithm to solve the resulting complex set of simultaneous equations. Stuart (*8*) first applied this technique in the field of public transportation with a study of bus operators and their work environment. Golob (*9–11*) has examined travel demand and activities extensively, and Mokhtarian and Salomon (*12*) began to incorporate attitudinal data into demand models. These efforts, among others, have expanded the understanding of travel demand and have policy implications. However, they have not looked specifically at customer satisfaction with transit service.

STUDY OBJECTIVES AND SCOPE

The objectives of this study are as follows:

- To develop a more complete model than heretofore used to describe causal factors leading to customer satisfaction within a key element of the transportation industry;
- To establish quantitative values for the relationships that are hypothesized to exist for variables leading to customer satisfaction; and
- To describe potential uses for the model in strategic planning and resource allocation.

The study focuses on the subway system of New York City. There are a myriad of possible influences on satisfaction. For purposes of

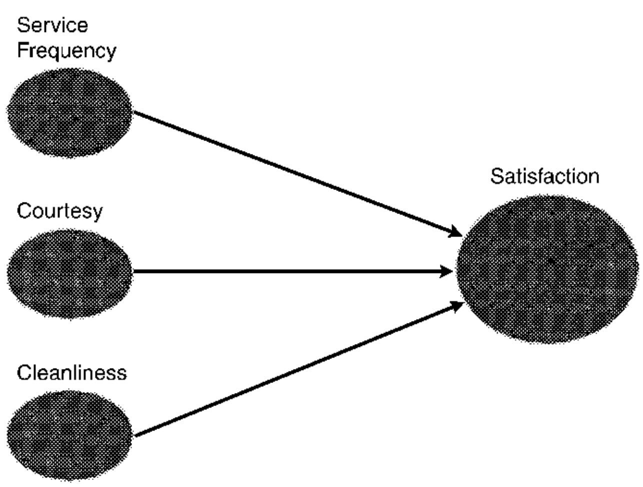

FIGURE 2 Hypothetical regression model of customer satisfaction.

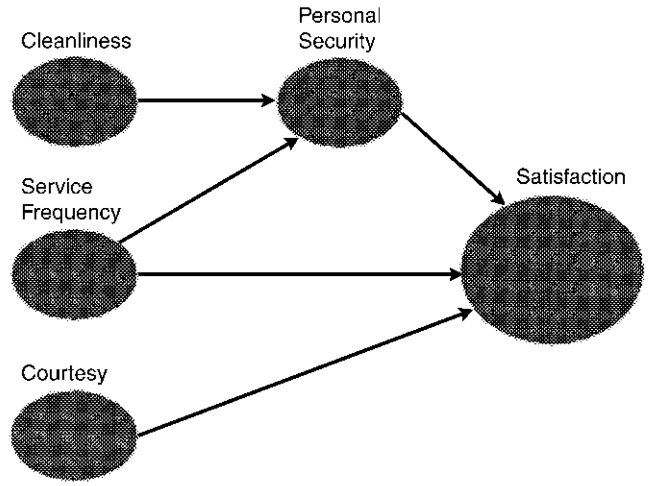

FIGURE 3 Hypothetical structural equation model of customer satisfaction.

this modeling effort, the potential major factors of service, service environment, safety, and personal security are included.

STUDY METHODOLOGY

Sample

Data were compiled from the Transportation Panel of the Metropolitan Transit Authority's (MTA's) New York City Transit. This panel is composed of 1,500 individuals who represent a cross section of adult residents of the city. They are interviewed quarterly (500 per month) via telephone regarding their general travel behavior, detailed travel behavior for the most recent 2 days, and attitudes toward various transportation modes, including subway, bus, taxi, and automobile. Attitude questions include overall satisfaction as well as specific aspects of the transportation experience.

Data used were those that were gathered during the first quarter of 1999. Those residents who answered all of the questions (variables) that are in the model are included in the sample. A total of 1,075 people met this criterion.

Variables Under Consideration

The following variables from the Transportation Panel are used in the model. Each is measured on a 0-to-10 scale, with 0 being worst and 10 being best:

- Overall satisfaction—the overall satisfaction that one has with the NYC subway system.
- Value for money—a customer's perceived value of a ride on the subway given the fare.
- Speed of service—the overall speed of the ride, including waiting and travel time.
- Personal security—the sense of personal security one has in the system after 8:00 p.m.
- Safety—perceived safety from accidents while in the system.
- Courtesy—the courtesy of NYCT employees.
- Cleanliness—cleanliness of the system (including subway stations and train cars).

- Panhandlers—presence of panhandlers within the system.
- Frequency of service—perceived frequency of overall subway service.
- Predictability of service—perceived reliability of subway service.
- Crowding—crowding on station platforms and in subway cars.

Technique and Postulated Model

Structural equation modeling was chosen, without latent traits, for this analysis. This decision stems in part from a desire initially to develop management tools that are considered more concrete, easily understood, and, in turn, actionable. The 11 variables described in the previous section all were incorporated and are theorized to have a particular set of relationships—some are causal, whereas others are not. A similar model was described by Stuart and Schaller (*13*). The exogenous variables are not deemed to be causally related, although it is recognized that they have a nonzero correlation with each other. The statistical software AMOS, from the Statistical Package for the Social Sciences (SPSS), was used for this analysis, although other credible software programs exist, such as LISREL (Linear Structural Relationships). The proposed structural model is based on theoretical underpinnings.

The causal links stipulated below generally stem from prior research on the New York City subway system. They are depicted in Figure 4, in which straight lines represent causal links, and curved lines represent the noncausal relationships. The *e* represents error that exists in estimation. The causal links are as follows:

- Safety to value for the money,
- Courtesy to value for the money,
- Cleanliness to value for the money,
- Cleanliness to personal security,
- Panhandlers to personal security,
- Frequency of service to personal security,
- Frequency of service to speed of service,
- Predictability of service to speed of service,
- Crowding to overall satisfaction,
- Speed of service to value for the money,
- Speed of service to overall satisfaction,
- Personal security to value for the money,
- Personal security to overall satisfaction, and
- Value for the money to overall satisfaction.

FINDINGS

The overall model fits the data set, and each of the individual hypothesized paths between variables is statistically significant. All variables were measured on the same metric (using a scale of 0 to 10), and Table 1 shows the unstandardized coefficient (beta weight) for each path. The corresponding critical ratio (a measure of the level of statistical significance) for each path is also shown. This critical ratio provides a measure of statistical significance of the path coefficient—1.96 indicates significance at the 95 percent level of confidence.

Several key findings emerge. One is that all of the hypothesized paths are statistically significant, although the strength of the relationships can vary dramatically. Another finding is that the impact of predictability of service on perceived speed of the trip is as important (even more so) than is frequency of service. This was thought to be a possibility from earlier research but was never quantified before.

Model Revisions

One of the important pieces of output besides the coefficients and their level of significance is model diagnostics. This tool can help refine a model, although caution should be given to summarily changing the theory to fit the data.

Diagnostics indicated other paths to consider, and two were chosen. One is a new link between predictability of service and overall satisfaction. This makes intuitive sense because predictability usually provides a greater sense of comfort to customers. Another is the link between safety from accidents and speed of service. There was some initial skepticism of this possible causal association, but after discussion, it was decided that a customer's comfort level in this area could make that person less anxious. One who is anxious often overestimates the passage of time, so this link was introduced.

The model was rerun with only these two changes and is shown in Figure 5 with the new path coefficients.

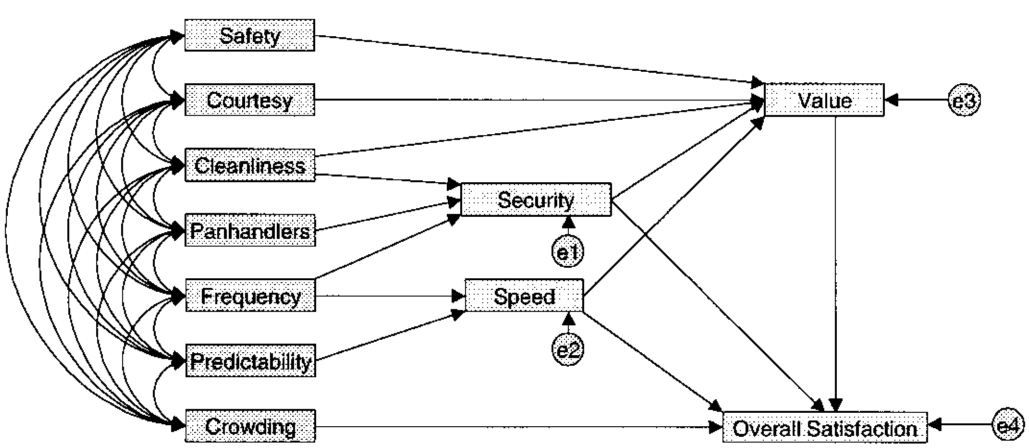

FIGURE 4 Initial model of customer satisfaction.

TABLE 1 Path Coefficients and Critical Ratios for Initial Model

Variables		Path Coefficient	Standard Error	Critical Ratio
Frequency	→ Speed	0.27	0.04	7.55
Predictability	→ Speed	0.32	0.03	9.42
Panhandlers	→ Personal security	0.12	0.03	4.05
Frequency	→ Personal security	0.21	0.03	6.50
Cleanliness	→ Personal security	0.40	0.04	11.18
Speed	→ Value	0.32	0.03	10.29
Safety	→ Value	0.22	0.03	6.62
Personal security	→ Value	0.11	0.03	3.93
Courtesy	→ Value	0.07	0.03	2.60
Cleanliness	→ Value	0.12	0.03	3.56
Value	→ Overall satisfaction	0.19	0.03	8.36
Speed	→ Overall satisfaction	0.33	0.02	12.69
Personal security	→ Overall satisfaction	0.18	0.02	8.50
Crowding	→ Overall satisfaction	0.13	0.02	7.46

Findings for the Revised Model

The addition of the two paths improved the overall model fit. However, the specific link between predictability and overall satisfaction reduced the strength of the link between speed and satisfaction. This is understandable, given that predictability can now exercise influence directly, not only indirectly. The impact of crowding on satisfaction dropped but is still significant. Other paths changed relatively little, and all remained significant. Table 2 shows the coefficients and ratios.

DISCUSSION OF RESULTS

One overarching finding is that although customer satisfaction is a complex and sometimes elusive concept in which customer expectations and evaluations change, the components of what drives customer satisfaction can be isolated and examined. Moreover, the strength of the relationships can be quantified and compared with one another in terms of both direct and indirect effects. Clearly, there are applications for planning and resource allocation. Because the relative weights of the path coefficients provide an indication of importance in their effect on customer satisfaction, this can assist planners in determining what efforts should be placed if enhancements to satisfaction are desired. Furthermore, by associating a cost with a given improvement and estimating the "ripple" impact it has on corresponding customer perception in the model, it is possible to produce cost estimates for improving customer satisfaction under several different scenarios. The same impact on customer satisfaction may be made in a more cost-effective manner.

THE FUTURE

The year 2000 draws us not only to the start of a new millenium, but also to a greater understanding of customers and the keys to increasing their satisfaction with transportation alternatives. The future for structural equation models in helping to study customer satisfaction has many possibilities:

- Developing more complex and realistic models to assess the drivers of satisfaction. These could incorporate additional items of importance (e.g., communication within and outside the system);
- Linking mode choice among transportation alternatives with customer satisfaction; and
- Expanding use of actionable structural models in cost-benefit analysis to help establish priorities for capital expenditures.

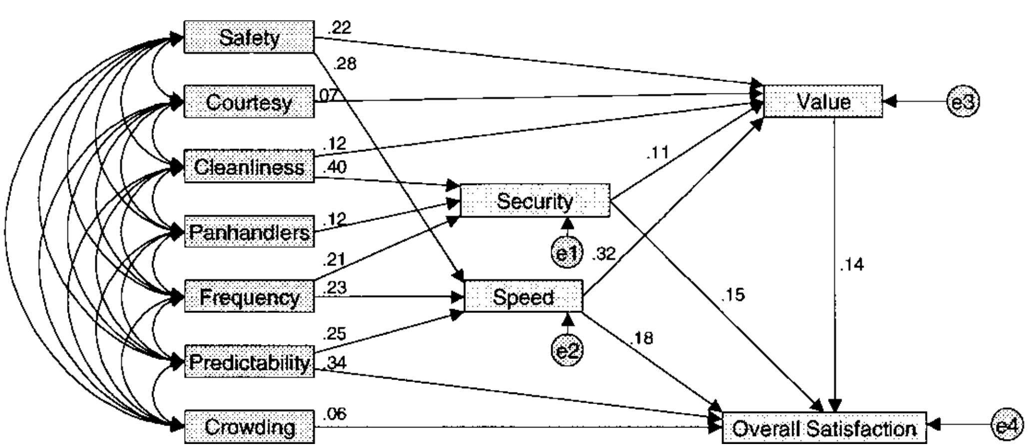

FIGURE 5 Revised model of customer satisfaction.

TABLE 2 Path Coefficients and Critical Ratios for Revised Model

Variables		Path Coefficient	Standard Error	Critical Ratio
Frequency	→ Speed	0.23	0.03	6.64
Predictability	→ Speed	0.25	0.03	7.43
Safety	→ Speed	0.28	0.03	10.95
Panhandlers	→ Personal security	0.12	0.03	4.05
Frequency	→ Personal security	0.21	0.03	6.50
Cleanliness	→ Personal security	0.40	0.04	11.18
Speed	→ Value	0.32	0.04	9.37
Safety	→ Value	0.22	0.04	6.14
Personal security	→ Value	0.11	0.03	3.94
Courtesy	→ Value	0.07	0.03	2.60
Cleanliness	→ Value	0.12	0.03	3.57
Value	→ Overall satisfaction	0.14	0.02	6.41
Speed	→ Overall satisfaction	0.18	0.03	6.32
Personal security	→ Overall satisfaction	0.15	0.02	7.56
Crowding	→ Overall satisfaction	0.06	0.02	3.40
Predictability	→ Overall satisfaction	0.34	0.03	13.26

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