**American Journal of Engineering Research (AJER)**
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-7, Issue-4, pp-54-60
www.ajer.org
Research Paper Open Access

# Analysis of Transit User Satisfaction using Structural Equation Models

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***ABSTRACT :*** *This study aims to understand the relationships among various transit system and service variabl es and transit user satisfaction. The dataset is utilized to test the hypothesis postulated in this study using Struct ural Equation Models. According to results of models, transit information service is the most valuable service ef fecting on satisfaction. Also, transfer service and staff/human service are also very crucial factors effecting on user satisfaction, which are somewhat different to information service because transfer service is significantly d ependent on transport facility plans and design and staff/human service is related to human resources. In order to implement the transit system successfully, the system is viewed from user perspective, which is revealed by us er satisfaction. Hence, system and service components effecting on user satisfaction should be identified, into w hich resources should be put in order to enhance the satisfaction effectively..*

***Keywords*** *-Transit, Satisfaction Structural Equation Models*

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Date of Submission: 23-03-2018 Date of acceptance: 07-04-2018

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## I. INTRODUCTION

Eco-friendly transportation systems play an important role in the construction of a sustainable city. Especially transit systems such as buses and subways are attractive transportation modes in metropolitan areas from this perspective because, when effectively utilized, they not only produce fewer emissions, but they also efficiently provide a high level of rider mobility. Major cities around the world have aggressively adopted transit-oriented policies to provide efficient and sustainable transportation systems to users. Since the effectiveness of transit-oriented service can be varied by user's satisfaction for the service, awareness of satisfaction of transit-user is a crucial component to policy-makers. This study aims to understand the relationships among various transit system and service variables and transit user satisfaction. Understanding of relationships can be a milestone to make and implement effective transit-oriented policies.

According to previous studies, transit user satisfaction is highly related to various service factors such as service reliability including travel time and waiting time, station and terminal facility, transfer and connection service. However, magnitudes influenced of factors can be different by persons, regions, service types and so forth. Hence, relationships between factors and satisfaction should be understood by policy makers to implement transit service effectively and successfully.

In this study, a large sample data for user satisfaction for transit service collected for nationwide in Korea, which is collected in 2012 by Korean Transportation Safety Authority. The dataset is utilized to test the hypotheses postulated in this study using Structural Equation Models. This paper is organized as follows. Firstly, selected previous studies related to transit user satisfaction are reviewed. Secondly, SEM is briefly introduced and the data used is described. Thirdly, model estimation results and its interpretation are provided. Finally, conclusions are drawn in this paper.

## II. LITERATURE REVIEW

Lee (2008) proposed the user evaluation models for implementation of transit-related policies, which adopted GAP, IPA and SEM. GAP measures the gap between expectation prior to buy a commodity and satisfaction after using the commodity. GAPs of facilities for handicap persons and bus information service (BIS) show high numbers, which indicates unsatisfactory of users for the service given. IPA investigates the importance of factors and compares importance of factors and level of satisfaction of user simultaneously. It shows that BIS, complementary facility, facility for handicap persons should be improved for the better service. In addition, results of SEM can be interpreted with a similar manner that BIS, complementary facility, facility for handicap persons highly effects on user satisfaction. Kim (2008) evaluated quality of service for local bus system in Daejon metropolitan area using various measures such as responsiveness, assurance, tangibility, conformity, reliability, efficiency and accessibility. Regression analysis showed that conformity is the most important component effecting on user satisfaction followed by accessibility, assurance, efficiency and tangibility.

GITHUI John Ngatia (2008) developed "User satisfaction models for Innercity transit service" using SEM, which employed quality of transit service, transit fare, safety as explanatory variables. Fare-collection system plays an important role in user satisfaction mechanism. At the same time, fare for bus, subway and taxi is also important to the users using the specific modes. It is somewhat different results compare to those in our cases because transit fare in Korea is relatively cheaper than other developed countries. Laura Eboli (2007) also employed SEM to make relationships between user satisfaction and several components of bus service systems, which are service headway, service routes, service reliability, management of service for facilities, courtesy of working crews, fare, and safety. Study showed that management of facility is the most important factor effecting on satisfaction followed by service routes, courtesy of working crews, fare, and safety.

Review of previous studies shows that several works for evaluation of transit service on a specific mode (e.g., bus or subway) can be found, limited studies has been conducted for a overall satisfaction measure for a nationwide transit service. Similarly, some studies in oversea countries have focused on basic service. However various service components such as information service, transfer service and so forth should be taken into account in measuring user satisfaction, which also be incoperated in developing and implementing policies.

## III. METHODOLOGY

### 3.1Structure Equation Model

SEM is a technique that can handle a large number of endogenous and exogenous observed variables simultaneously. Since SEM consists of a set of equations that are specified by direct links between variables, it can be called “the simultaneous equations” from the perspective. However, in SEM, we can introduce ‘latent variables’ which are the unobserved variables and represent unidimensional concepts in their purest form. Other terms for these are unobserved or unmeasured variables and factors. The observed variables of a latent variable contain random or systematic measurement errors, but the latent variable is free of these. Since all latent variables corresponding to concepts, they are hypothetical variables. Latent variables specified as linear combinations of the observed variables. The linear combinations are weighted averages. Hence, regression, path analysis, factor analysis and canonical correlation analysis are all special cases of SEM. In SEM we can separate errors in measurement from errors in equations (Golob, 2003).

### 3.2Elements of SEM

A SEM with latent variables has at most three components as shown in Fig 1: (a) a measurement model for the endogenous variables (Y measurement model), (b) a measurement model for the exogenous variable (X measurement model), and (c) a structural model. The structural parameters are the elements of the three matrices. B is the matrix (m×m) of direct effects among endogenous latent variables and Γ is the matrix (m×n) of regression effects for exogenous latent variables to endogenous latent variables. Λ is linking matrix between the latent and observed variables. The elements of SEM are explained in Table 1.

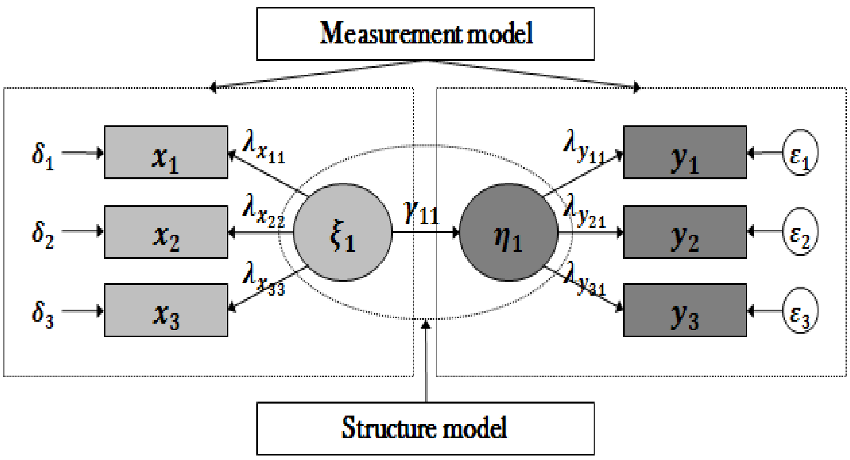

**Fig 1** An example of structural equation model

**Table 1 Elements of Structural Equation Model.**

| | | |
|---|---|---|
| Measurement submodel | X | q×1 column vector of observed exogenous variables |
| | Y | p ×1 column vector of observed endogenous variables |
| | ξ | n×1 column vector of latent exogenous variables |
| | η | m×1 column vector of latent endogenous variables |
| | δ | q×1 column vector of measurement error terms for observed variables |
| | ε | p×1 column vector of measurement error terms for observed variables |
| | $\Lambda_x$ | the matrix (q×n) of structural coefficients for latent exogenous variables to their observed indicator variables |
| | $\Lambda_y$ | the matrix (p×m) of structural coefficients for latent endogenous variables to their observed indicator variables |
| Structural submodel | Γ | the matrix (m×n) of regression effects for exogenous latent variables to endogenous latent variables |
| | B | the matrix (m×m) of direct effects between endogenous latent variables |
| | ζ | m × 1 column vector of the error terms |

### 3.3Multiple Indicators Multiple Causes (MIMIC) Model

Joreskog and Goldberger define two general types of these observable variables: (a) indicator variables, which are imperfect measures of a latent variable, or measures of the effect the latent variable has on observable quantities, and (b) cause variables, which are exogenous factors that are believed to determine the latent variable value. The MIMIC model is a special case within the general class of structural latent variable models that can consist of many indicators of an unobservable variable, and many causes. Fig 2 shows the general structure of the MIMIC model.

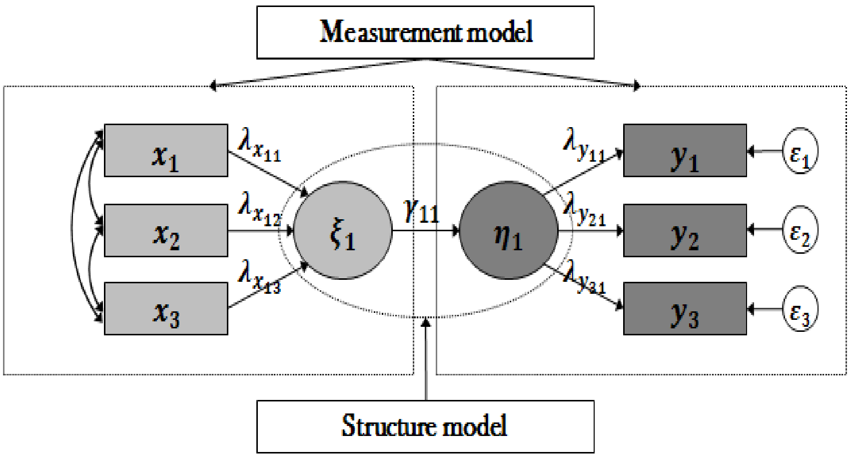


**Fig 2 An example of MIMIC model**

The MIMIC model explains the relationship between observable variables and an unobservable variable by minimizing the distance between the sample covariance matrix and the covariance matrix predicted by the model. The observable variables are divided into causes of the latent variable and its indicators. Formally, the MIMIC model consists of two parts: the structural equation model and the measurement model. The structural equation (Equation 1) and measurement equation (Equation 2) in the latent variable model can be expressed as

$$\eta = B\eta + \Gamma X + \zeta \qquad (1)$$

$$y = \Lambda\eta + \varepsilon \qquad (2)$$

where

$\eta = (M \times 1)$ vector of latent variables,

$X = (K \times 1)$vector of observed exogenous variables,

$y = (P \times 1)$vector of observable indicators of η, and

$\Lambda = (P \times M)$matrix of factor loadings.

The (M × M) matrix B and the (M × K) matrix Γ contain unknown regression coefficients. The (M × 1) vector ζ and the (P × 1) vector ε are measurement errors that are independently, identically distributed multivariate normal.

## IV. DATA USED

Data in use were collected on Tuesday, Wednesday and Thursday from October to December in 2012 using on-line survey method. Respondents should be over 15 years old and use transit at least 4 times a week to participate the survey. Total sample size is 49,000 and 7 points likert scale is adopted to measure level of user satisfaction for transit service. A seven pointlikert scale was used to rate the questions by using "disagree absolutely" "disagree strongly," "disagree somewhat," "neutral," "agree somewhat," and "agree absolutely." Questionnarie was designed to survey overall user satisfaction and level of service for basic, supplementary, internal/external environments, staff/human information. The overall user satisfaction is composed of three aspects such as satisfaction for mode itself, expectation, transport facility. Detail items for each service are summarized in Table 3. Characteristics of respondents in survey are summarized in Table 4.

**Table 3 Service categories and their detail items in the survey**

| Main Question Category | Detail Items |
|---|---|
| Overall satisfaction | Satisfaction for mode, Satisfaction to expectation, Satisfaction to facility |
| Basic Service | Appropriacy of connection, service time, station location, travel time, fare, reliability, etc. |
| Supplementary Service | operating system in general, Safety, information, public relations for polcies |
| External Service | amenity at stations, cleanness at station, convenience of amenity, convenience of purchasing transport ticket and charging transport card, |
| Internal Service | number of seats, temperature, load factor, interior management, cleanness of interior, interior and facility for handicap people |
| Staff/Human Service | Safe Driving , Courtesy, readiness to customers demand |
| Information Service | Level of completion of Bus Information System, Reliability of Bus Information, Availability of Information |
| Transfer Service | Connectivity System, Transfer distance and waiting time, Transfer information, Transfer fare |

**Table 4 Descriptive Statistics of Respondents in the survey**

| Characteristics of Respondents | | Number of Respondents | Percentage (%) |
|---|---|---|---|
| Gender | Male | 21,569 | 44.0 |
| | Female | 27,431 | 56.0 |
| Age | 10 | 9,322 | 19.0 |
| | 20 | 15,306 | 31.2 |
| | 30 | 9,710 | 19.8 |
| | 40 | 7,619 | 15.5 |
| | Over 50 | 7,043 | 14.4 |
| Occupancy | White-Collar | 25,034 | 51.1 |
| | Blue-collar | 2,020 | 4.1 |
| | Farmer/Fisherman | 38 | .1 |
| | Housewife | 2,987 | 6.1 |
| | Student | 15,305 | 31.2 |
| | Non-worker/others | 3,616 | 7.4 |
| Education | Middle School | 1,598 | 3.3 |
| | High School | 12,118 | 24.7 |
| | Community College/University | 31,016 | 63.3 |
| | Graduate School | 4,268 | 8.7 |
| Monthly Income | Below 10 Thousand Won | 2,911 | 5.9 |
| | Between 10 and 20 thousand Won | 6,969 | 14.2 |
| | Between 20 and 30 thousand Won | 10,033 | 20.5 |
| | Between 30 and 40 thousand Won | 9,511 | 19.4 |
| | Between 40 and 50 thousand Won | 8,526 | 17.4 |
| | Between 50 and 60 thousand Won | 5,000 | 10.2 |
| | Over thousand Won | 6,050 | 12.3 |

## V. EMPIRICAL MODELS

AMOS (Analysis of Moment Structure) software is utilized to develop a "User Satisfaction Model for Transit Service", in which basic service, supplementary service, internal environment service, external environment service, staff/human service, transfer service are employed as exogenous latent variables and overall user satisfaction as a endogenous latent variable, respectively.

Various goodness-of-fit measures are tested for developed models, which are summarized in Table 5. As shown in Table 5, values calculated of Chi-squares, GFI, AGFI, CFI, RMR, and RMSEA are above the critical values (the values in parenthesis in the table indicate the recommended value for acceptance). Hence goodness-of-fit of models developed in this study is statistically accepted .

**Table 5 Goodness-of-fit Measures for Models**

| Measures | Chi-square | GFI | AGFI | CFI | RMR | RMSEA |
|---|---|---|---|---|---|---|
| Value | 2435.358<br>(P=0.00) | 0.997<br>(greater than 0.9) | 0.968<br>(greater than 0.9) | 0.997<br>(greater than0.9) | 0.007<br>(less than 0.05) | 0.030<br>(less than 0.05) |

Table 6 and Fig 2 show that parameters estimated in the models, t-statistics, and p-values. According to parameters estimated, information service has the highest value of parameter as 0.221 followed by transfer service, staff/human service, supplementary service, external service and internal service. Higher value of coefficient represents greater influence on user satisfaction. Detail items for transit service can be ranked by importance from user's perspective, which can be done by estimated coefficients in the models. Firstly, exogenous variables of connectivity, headway, location of station, travel time, fare, arrival time, schedule reliability are statistically significant at confidence level of 95% in the model. The estimated coefficient of headway has the highest value. However, location of station has a negative sign, which is not intuitively correct but cannot be explained at this moment. It should be scrutinized in future studies.

Among components for supplementary service, operating system, safety, schedules, public relation significantly effect on user satisfaction. Public relation the second highest value of 0.292 is followed to Operating system the highest value of 0.502. While facility for handicap persons in internal environmental service is not statically significant at 0.05 confidence level, number of seats, inside temperature, loading factor, management of interior, cleanness of interior are statistically significantly effecting on user satisfaction. Among significant components, cleanness of interior has the highest normalized coefficient representing the strongest impact on user satisfaction. Other services such as external environment service, staff/human service and so forth can be interpreted as the same manner above.

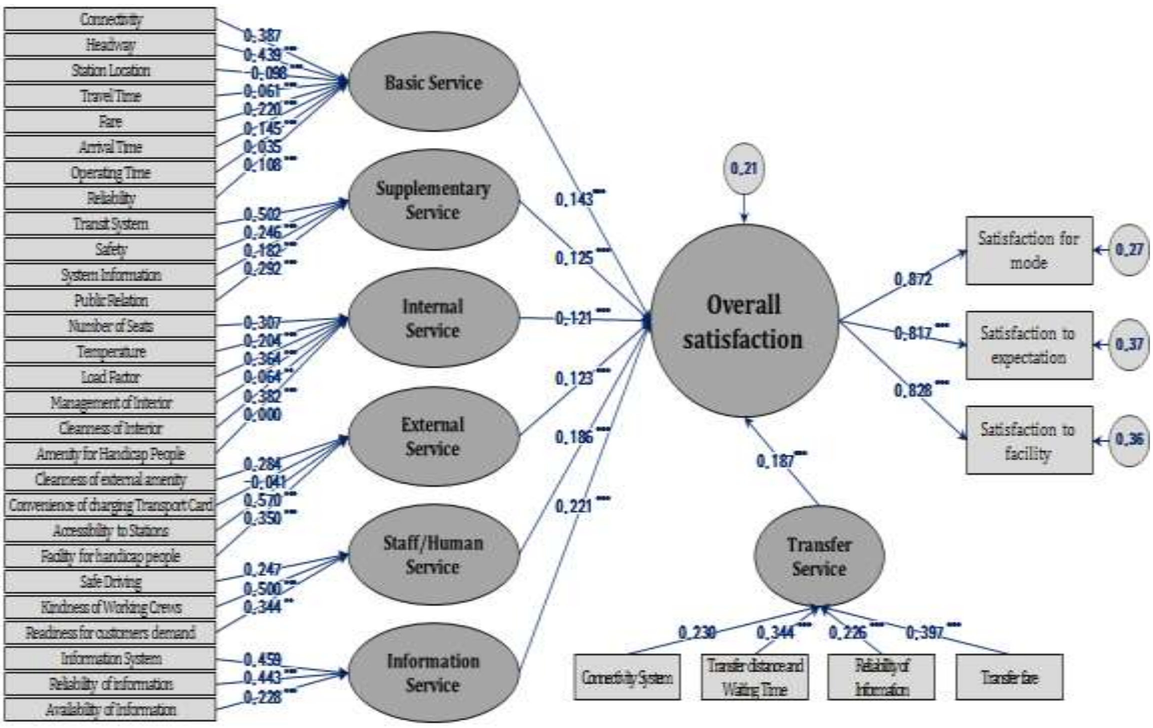


**Fig 2 SEM for User Satisfaction for Transit Service**

**Table 6 Parameters estimated in SEM for User Satisfaction for Transit Service**

| Latent Variables | Measurement Variables | Estimate | S.E. | t-value | P | Standardized Estimate |
|---|---|---|---|---|---|---|
| Basic Service | Connectivity | 1.000 | - | - | - | 0.387 |
| | Headway | 1.059 | 0.115 | 9.229 | 0.000 | 0.439 |
| | Station Location | -0.270 | 0.082 | -3.277 | 0.001 | -0.098 |
| | Travel Time | 0.153 | 0.076 | 2.009 | 0.045 | 0.061 |
| | Fare | 0.475 | 0.071 | 6.649 | 0.000 | 0.220 |
| | Arrival Time | 0.335 | 0.075 | 4.474 | 0.000 | 0.145 |
| | Operating Time | 0.082 | 0.061 | 1.330 | 0.183 | 0.035 |
| | Reliability | 0.258 | 0.074 | 3.467 | 0.000 | 0.108 |
| Supplementary Service | Transit System | 1.000 | - | - | - | 0.502 |
| | Safety | 0.459 | 0.077 | 5.942 | 0.000 | 0.246 |
| | System Information | 0.354 | 0.073 | 4.864 | 0.000 | 0.182 |
| | Public Relation | 0.551 | 0.073 | 7.496 | 0.000 | 0.292 |
| Internal Service | Number of Seats | 1.000 | - | - | - | 0.307 |
| | Temperature | 0.644 | 0.137 | 4.685 | 0.000 | 0.204 |
| | Load Factor | 0.960 | 0.139 | 6.909 | 0.000 | 0.364 |
| | Management of Interior | 0.212 | 0.120 | 1.765 | 0.077 | 0.064 |
| | Cleanness of Interior | 1.155 | 0.168 | 6.869 | 0.000 | 0.382 |
| | Amenity for Handicap People | 0.000 | 0.100 | -0.005 | 0.996 | 0.000 |
| External Service | Cleanness of external amenity | 1.000 | - | - | - | 0.284 |
| | Convenience of charging Transport Card | -0.143 | 0.116 | -1.237 | 0.216 | -0.041 |
| | Accessibility to Stations | 2.270 | 0.347 | 6.548 | 0.000 | 0.570 |
| | Facility for handicap people | 1.152 | 0.199 | 5.792 | 0.000 | 0.350 |
| Staff/Human Service | Safe Driving | 1.000 | - | - | - | 0.247 |
| | Kindness of Working Crews | 2.151 | 0.290 | 7.420 | 0.000 | 0.500 |
| | Readiness for customers demand | 1.518 | 0.215 | 7.053 | 0.000 | 0.344 |
| Information Service | Information System | 1.000 | - | - | - | 0.459 |
| | Reliability of information | 0.933 | 0.068 | 13.678 | 0.000 | 0.443 |
| | Availability of Information | 0.502 | 0.056 | 8.945 | 0.000 | 0.228 |
| Transfer Service | Connectivity System | 1.000 | - | - | - | 0.230 |
| | Transfer distance and Waiting Time | 1.530 | 0.239 | 6.396 | 0.000 | 0.344 |
| | Reliability of Information | 1.029 | 0.172 | 5.984 | 0.000 | 0.226 |
| | Transfer fare | 1.526 | 0.190 | 8.009 | 0.000 | 0.397 |

## VI. CONCLUSIONS

This study purports to indentify causal relationships from various components of transit service to user satisfaction, which can help us develop and implement transit-oriented policies. It can be a small stride for sustainable transportation systems. SEM with the large size of sample data collected in this study gives us a valuable insight for selecting important factors influencing on user satisfaction.

According to results of models, transit information service is the most valuable service effecting on satisfaction because users living in modernized high-techno cities heavily rely on reliable information through internet, smart-phone, and other sources. Accurate and reliable information for transit service easily and efficiently enhances the level of user satisfaction. Smart investment must be encouraged to improve the reliability and accessibility of transit information. For example, arrival/departure time, route choice, transfer service, fare information, waiting time, etc. are very useful information prior to making trip because user can plan their schedule. Furthermore feeling disutility (e.g., waiting time, travel time) can be diminished if the user can expect or know it.

In addition, transfer service and staff/human service are also very crucial factors effecting on user satisfaction, which are somewhat different to information service because transfer service is significantly dependent on transport facility plans and design and staff/human service is related to human resources. Hence in order to tackle the problems emerging from the services different approaches should be applied. For instance, transfer service should be carefully considered in planning stage and higher quality of human service can be achieved by consistent and continuous education programs for human resource. Although the two services are important factors, they need adequate time and investment.

In order to implement the transit system successfully, the system is viewed from user perspective, which is revealed by user satisfaction. Hence, system and service components effecting on user satisfaction should be identified, into which resources should be put in order to enhance the satisfaction effectively.

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