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# **A Confirmatory Factor Analysis of the End-User Computing Satisfaction Instrument**

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User satisfaction is considered one of the most important measures of information systems success (DeLone and McLean, 1992; Ives and Olson, 1984). The structure and dimensionality of the user satisfaction construct are important theoretical issues that have received considerable attention (Doll and Torkzadeh, 1988; Ives, et al., 1983; Larcher and Lessig, 1980; Swanson, 1982; Zmud, 1978). These issues have not been fully resolved. Most of this literature focuses on explaining what user satisfaction is by identifying its components, but the discussion usually suggests that user satisfaction may be a single construct. Substantive research studies use a total score obtained by summing items (i.e., implying that user satisfaction is a single first-order construct).

The importance of developing standardized instruments for measuring user satisfaction has been stressed by several researchers (DeLone and McLean, 1992; Ives and Olson, 1984; Straub, 1989). The research cycle (Mackenzie and House, 1979; McGrath, 1979) for developing a standardized instrument has two steps: (1) exploratory studies that develop hypothesized measurement model(s) via the analysis of empirical data from a referent population; and (2) confirmatory studies that test hypothesized measurement model(s) against new data gathered from the same referent population.

Only a few researchers have devoted serious attention to the measurement of user satisfaction (e.g., Bailey and Pearson, 1983; Baroudi and Orlikowski, 1988; Doll and Torkzadeh, 1988; Goodhue, 1988; Ives, et al., 1983; Jenkins and Ricketts, 1979). These instrument development efforts have been exploratory studies or replications using exploratory techniques. Confirmatory factor analysis is needed to complete the research cycle; it provides a more rigorous and systematic test of alternative factor structures than is possible within the framework of exploratory factor analysis (Bollen, 1989; Joreskog and Sorbom, 1989).

Doll and Torkzadeh (1988) propose a second-order factor model of end-user computing satisfaction (EUCS) that consists of five first-order factors (content, format, accuracy, ease of use, timeliness) measured by 12 items. The second-order factor is interpreted as EUCS. The first-order factors provide a framework for explaining

the EUCS construct by identifying underlying components that permit more precision in formulating and testing research hypotheses. The acceptance of the Doll and Torkzadeh model as a standardized instrument requires confirmation that it explains and measures the user satisfaction construct. This research completes one instrument development research cycle by gathering new data to test the validity and reliability of the end-user computing satisfaction instrument.

## Research Methods

Confirmatory factor analysis involves the specification and estimation of one or more putative models of factor structure, each of which proposes a set of latent variables (factors) to account for covariances among a set of observed variables (Bagozzi, 1980; Bollen, 1989; Joreskog and Sorbom, 1989). It requires a priori designation of plausible factor patterns from previous theoretical or empirical work; these plausible alternative models are then explicitly tested statistically against sample data. Confirmatory factor analysis has been used extensively in psychology, marketing, and counseling for validating instruments by testing alternative models (e.g., Byrne, 1989; Harvey, et al., 1985; Kumar and Sashi, 1989; Marsh, 1985; Marsh and Hocevar, 1985; Thacker, et al., 1989).

This study uses LISREL VII (Joreskog and Sorbom, 1989) to describe alternative models and test the fit of each hypothesized model against the sample data. First, based on logic, theory, and previous studies, four plausible alternative models of factor structure are proposed (see Figure 1). Without respecifying the models, model-data fit and evidence of a higher-order factor are assessed using several goodness-of-fit indexes. One model is selected as representing the underlying factor structure in the sample data. Second, confirmatory factor analysis is used to assess the reliability and validity of the factors and items in the selected model.

### *Alternative models*

Model 1 hypothesizes one first-order factor (EUCS), accounting for all the common variance among the 12 items. Theory as well as substantive research studies using user satisfaction in-

struments, including EUCS, typically assume that user satisfaction is a single first-order construct. This assumption is implicit in the typical practice of scaling the satisfaction construct by adding individual items to obtain a total score. Doll and Torkzadeh (1988) scale EUCS by using such a total score, implying that one first-order factor is a plausible model of underlying data structure.

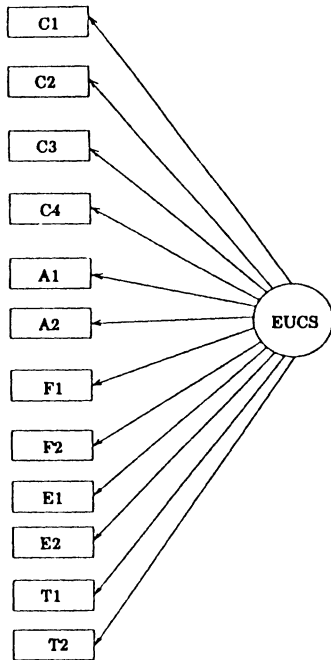
Model 2 hypothesizes that the 12 items form into five uncorrelated or orthogonal first-order factors (content, accuracy, format, ease of use, timeliness). Doll and Torkzadeh's use of varimax (orthogonal) rotation should have resulted in five uncorrelated factors; thus, Model 2 is considered a plausible alternative model of underlying data structure. Examining this model also provides a test of the necessity of incorporating correlated factors by enabling a comparison of the increase in fit between uncorrelated and correlated models.

Model 3 hypothesizes that the five first-order factors are correlated with each other. Doll and Torkzadeh (1988) clearly lay a foundation for this model in their discussion of the large common variance among the 12 items (see page 265). The original study used corrected-item total correlations and correlations with an overall criterion (a global user satisfaction measure) to eliminate items. This elimination method resulted in 12 items that had substantial common variance. The factor scores from a varimax rotation are orthogonal, but the subscales are not necessarily orthogonal (uncorrelated). If the items have a large amount of common variance, scales based on these items may be correlated. This model was not explicitly proposed by Doll and Torkzadeh, yet it is plausible because of common variance among the 12 items.

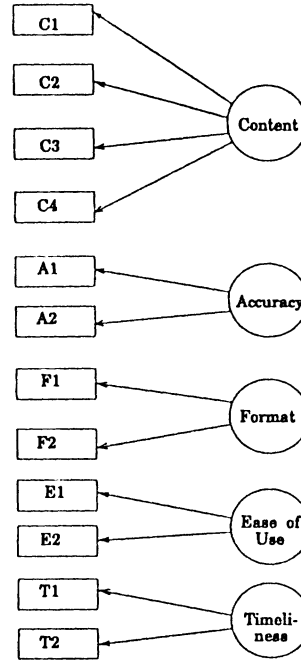
Model 4 hypothesizes five first-order factors and one second-order factor (EUCS). This model was tested because it was proposed by Doll and Torkzadeh (see Figure 3 on page 268 of their 1988 article). If first-order factors are correlated, it is possible that the correlations between first-order factors is statistically "caused" by a single second-order factor (Tanaka and Huba, 1984).

### *Criteria for comparing model-data fit*

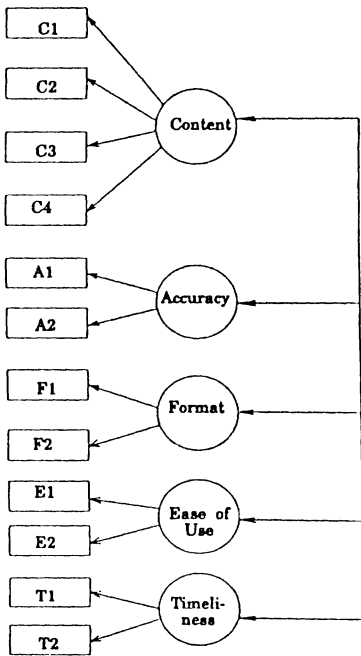
Because no one statistic is universally accepted as an index of model adequacy, our interpretation of results emphasizes substantive issues, practical considerations, and several measures



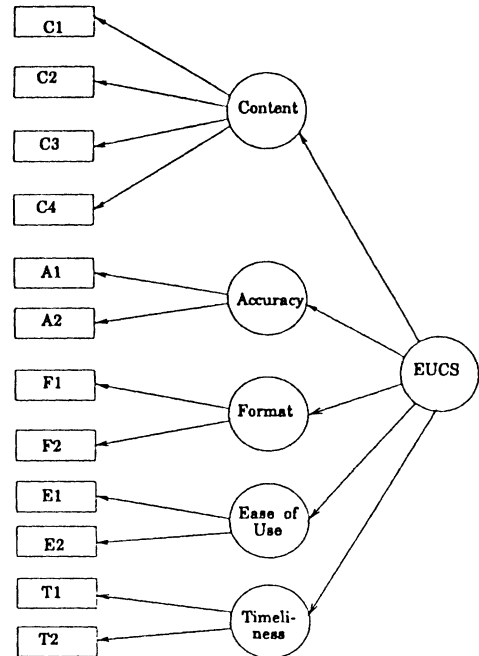
Model 1. One First-order Factor



Model 2. Five First-order Factors (Uncorrelated)



Model 3. Five First-order Factors (Correlated)



Model 4. Five First-order Factors One Second-order Factor

Figure 1. Alternative Models for the EUCS Instrument

of fit. In this study, relative or incremental fit indexes reflecting the improvement in fit of one model over an alternative (i.e., ratio of chi-square to degrees of freedom, normed fit index (NFI), and target coefficient) are used to compare models. Absolute indexes of goodness-of-fit such as chi-square, goodness-of-fit index (GFI), adjusted goodness-of-fit index (AGFI), and root mean square residual (RMSR) are used to evaluate individual models.

Although the chi-square statistic is a global test of a model's ability to reproduce the sample variance/covariance matrix, it is sensitive to sample size and departures for multivariate normality (Bollen, 1989). Thus, the chi-square statistic must be interpreted with caution in most applications (Joreskog and Sorbom, 1989). Many researchers interpret GFI or AGFI scores in the .80 to .89 range as representing reasonable fit; scores of .90 or higher are considered evidence of good fit. Smaller values of the RMSR are associated with better fitting models with scores below .05 considered as evidence of good fit (Byrne, 1989; Joreskog and Sorbom, 1984).

The *ratio* of chi-square to the degrees of freedom provides information on the relative efficiency of competing models in accounting for the data. Researchers have recommended using ratios as low as 2 or as high as 5 to indicate a reasonable fit (Marsh and Hocevar, 1985). The NFI assesses the fit of a model relative to the fit of a null model by scaling the chi-square value from 0 to 1, with larger values indicating better models (Bentler and Bonett, 1980). Well-fitting models generally yield normed fit indexes of at least .90, i.e., only a relatively small amount of variance remains unexplained by the model (Harvey, et al., 1985). The target coefficient index (the ratio of chi-square of the first-order model to the chi-square of the higher-order model) is an index used to provide evidence of the existence of a higher-order construct (Marsh and Hocevar, 1985). It reflects the extent to which the higher-order factor model accounts for covariation among the first-order factors and can be interpreted as the percent of variation in the first-order factors that can be explained by the second-order construct.

### *Evaluating validity and reliability*

In confirmatory factor analysis, factor loadings can be viewed as regression coefficients in the

regression of observed variables on latent variables. On the first-order level of measurement models, the standard factor loadings of observed variables (items) on latent variables (factors) are estimates of the validity of the observed variables. For second or higher levels, the standard structural coefficients of factors on higher-order constructs are estimates of the validity of the factors. The larger the factor loadings or coefficients—as compared with their standard errors and expressed by the corresponding *t* values—the stronger the evidence that the measured variables or factors represent the underlying constructs (Bollen, 1989; Mueller, 1994).

Confirmatory factor analysis enables us to estimate the reliability of individual items, factors, and the overall instrument. On the first-order level of measurement models, the proportion of variance (R-square) in the observed variables that is accounted for by the latent variables influencing them can be used to estimate the reliability of the observed variables (items). For second or higher levels, the proportion of variance (R-square) in the latent variables (factors) that is accounted for by the higher-order construct influencing them can be used to estimate the reliability of the latent factors (Bollen, 1989; Mueller, 1994). The total coefficient of determination for observed variables is an estimate of the reliability of the overall instrument.

### *Confirmatory sample*

The data gathering methods were identical to those used in the exploratory study (Doll and Torkzadeh, 1988). The sample investigated in this study consists of 409 computer end users from 18 organizations, including eight manufacturing firms, one retail firm, two government agencies, two utilities, two hospitals, two educational institutions, and one "other." The sample represents 139 different applications including accounts payable, accounts receivable, budgeting, CAD, CAD-CAM, customer service, service dispatching, engineering analysis, process control, work order control, general ledger, manpower planning, financial planning, inventory, order entry, payroll, personnel, production planning, purchasing, quality, sales analysis, student data, and profit planning. The large number of organizations and the variety of applications support the generalizability of the findings.

Respondents were asked to identify their position within the organization; they responded as follows: 20 top-level managers, 80 middle managers, 76 first-level supervisors, 143 professional employees without supervisory responsibility, and 90 operating personnel. Forty-seven percent of the respondents stated they used a personal computer (micro) application. Thirty-six percent of the computer applications were developed primarily by end users, but only 12 percent of the respondents personally developed the applications themselves. Fifty percent of the applications provided data analysis capabilities (spreadsheet, modeling, simulation, optimization, or statistical routines). Forty-six percent of the applications provided a database with flexible inquiry capabilities.

## Results<sup>1</sup>

The goodness-of-fit indexes for the alternative models (Figure 1) and the null model are summarized in Table 1. The primary purpose of the null model is to establish the zero-point for the NFI. As expected, the null model provides a poor fit to the data, as evidenced by a ratio of chi-square to degrees of freedom of 49.24. Model 1 provides a substantially better fit relative to the null model for all indexes of goodness-of-fit. Model 2 again substantially improves all indexes of goodness-of-fit relative to Model 1. By normal standards, neither Model 1 nor Model 2 are even close to being considered a good fit with the sample data.

Model 3 shows good model-data fit, as indicated by absolute indexes (GFI, AGFI, and RMSR), and provides substantial improvement over Model 2, as evidenced by the changes in the NFI index (from .826 to .957) and the ratio of chi-square to degrees of freedom (from 10.45 to 3.14). From an empirical perspective, this model provides a more than satisfactory solution.

Model 4 shows reasonable model-data fit, as indicated by absolute indexes (GFI, AGFI, and RMSR). As expected for a second-order model, Model 4's GFI and AGFI scores are slightly lower than its first-order counterpart (Model 3). Like

Model 3, it provides substantial improvement over Model 2, as evidenced by the changes in the NFI index (from .826 to .940) and the ratio of chi-square to degrees of freedom (from 10.45 to 3.72). Thus, the results suggest that both Model 3 and Model 4 are satisfactory and competing representations of the underlying structure of the instrument.

The target coefficient was used to test for the existence of a higher-order user satisfaction construct. Using Model 3 as the target model, the target coefficient is the ratio of the chi-square of Model 3 to the chi-square of Model 4. In this case, a target coefficient of .74 provides reasonable evidence of a second-order user satisfaction construct. Seventy-four percent of the variation in the five first-order factors in Model 3 is explained by Model 4's user satisfaction construct.

In comparing first-order and second-order models, it is important to realize that the higher-order factors are merely trying to explain the covariation among the first-order factors in a more parsimonious way (i.e., one that requires fewer degrees of freedom). Consequently, even when the higher-order model is able to explain effectively the factor covariations, the goodness-of-fit of the higher-order model can never be better than the corresponding first-order model.

Since theory in this field suggests the existence of a single overall user satisfaction construct, Model 4 is of greater theoretical interest than Model 3. Also, in this study, there is reasonable evidence of a single second-order construct. Both Model 3 and Model 4 enable us to examine the validity and reliability of individual items. Estimates of item validity and reliability are not sensitive to the addition of a second-order factor; thus, conclusions concerning the validity and reliability of the 12 items would be the same regardless of which model was selected. Model 4 has the additional advantage of providing estimates of the validity and reliability of the latent factors (content, accuracy, format, ease of use, and timeliness). For these reasons, the researchers recommend Model 4 and proceed with the analysis of the validity and reliability of factors and items assuming this second-order model.

LISREL'S maximum likelihood estimates of Model 4's standardized parameter estimates are

<sup>1</sup>The correlation matrix used as input for the confirmatory analyses as well as the item and 12-item scale means and standard deviations are available from the authors upon request.

**Table 1. Goodness-of-Fit Indexes for Alternative Models (n = 409)**

Model	Chi-sqr (df)	Chi-sqr/df	NFI	GFI	AGFI	RMSR
0. Null model	3250.34 (66)	49.24	—	.241	.103	.411
1. 5 First-order factors (Uncorrelated)	1323.85 (54)	24.51	.593	.597	.418	.356
2. 1 First-order factor	564.43 (54)	10.45	.826	.805	.718	.064
3. 5 First-order factors (Correlated)	138.16 (44)	3.14	.957	.946	.904	.027
4. 5 First-order factors 1 Second-order factor	185.81 (50)	3.72	.940	.929	.889	.035

NFI - Normed Fit Index.

GFI - Goodness of Fit Index.

AGFI - Adjusted Goodness of Fit Index.

RMSR - Root Mean Squared Residual.

presented in Table 2 for both latent variables and observed variables. For the observed variables, Table 2 shows factor loadings, their corresponding *t* values, and R-square values. With *t* values above 2.0 being considered significant, factor loadings can be interpreted as indicators of validity for the 12 items. All items have large (greater than .72) and significant loadings on their corresponding factors, indicating evidence of good construct validity. The proportion of the variances, or R-square, in the observed variables that is accounted for by its corresponding latent variable is used as an indicator of each item's common factor reliability. R-square values range from .52 to .79, indicating acceptable reliability for all items. The total coefficient of determination for the first-order model is .998, indicating excellent overall reliability of the 12 items combined.

For the latent variables, Table 2 presents the standard structural coefficients, their corresponding *t* values, and R-square values. Standard structural coefficients can be interpreted as indicators of validity of the latent factors as components of the EUCS construct. With *t* values above 2.0 being considered significant, all factors have large (greater than .72) and significant structural coefficients, indicating good construct validity. R-square values for each of the five latent factors range from .55 to .98, indicating acceptable reliability for all factors. The total coefficient of determination for the structural equations of the second-order EUCS factor is .998, indicating excellent overall reliability of the five first-order factors combined.

## Discussion and Conclusions

Confirmatory factor analysis results should always be interpreted with caution. The criteria for comparing models and judging goodness-of-fit are relative rather than absolute. There are no standard cutoff values for evaluating model-data fit or the existence of higher-order constructs. Also, the fact that a model fits one sample does not imply that it is the ultimate solution. Models can often be respecified to improve model-data fit. Future research might focus on using confirmatory factor analysis to revise and improve the instrument (e.g., analyze the correlation between the error terms of items, change the wording of items, or respecify the model).

This study completes one exploratory-confirmatory research cycle by more rigorously validating the EUCS instrument developed by Doll and Torzadeh. Initial instrument development efforts often contain some ambiguity concerning the appropriate model of underlying data structure. Completing the research cycle is important because, as we have seen, it requires more precision in model specification. Inadequate measures confound the interpretation of research results and prevent the development of an additive body of knowledge that can serve as a basis for information systems practice. Researchers should be cautious in using user satisfaction instruments that have not been cross-validated in confirmatory studies.

The results enhance the utility of the EUCS instrument by providing confirmation that it ex-

**Table 2. Standardized Parameter Estimates and t-values for Model Four (n = 409)  
(5 First-Order Factors, 1 Second-Order Factor)**

Item	Observed Variables		Latent Variables		
	Factor Loading	R-Square (Reliability)	Factor	Std. Structure Coefficient	R-Square (Reliability)
C1	.826*	.68	Content	.912 (17.67)	.83
C2	.852 (20.36)	.73			
C3	.725 (16.23)	.53			
C4	.822 (19.32)	.68			
A1	.868*	.76	Accuracy	.822 (16.04)	.68
A2	.890 (20.47)	.79			
F1	.780*	.61	Format	.993 (18.19)	.98
F2	.829 (17.89)	.69			
E1	.848*	.72	Ease of Use	.719 (13.09)	.52
E2	.880 (16.71)	.78			
T1	.720*	.52	Timeliness	.883 (13.78)	.78
T2	.759 (13.10)	.58			

**Note:** \*indicates a parameter fixed at 1.0 in the original solution.  
t-values for item factor loadings and factor structural coefficients are indicated in parentheses.

plains and measures the user satisfaction construct. The EUCS instrument can now be used as a standardized measure of user satisfaction with a specific application. This cross validation study provides evidence that EUCS is a multifaceted construct consisting of five subscales (content, accuracy, format, ease of use and timeliness) and that researchers and managers can use these subscales with confidence (i.e., the items have adequate validity and reliability). This study also provides evidence that EUCS is a single second-order construct.

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