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RESEARCH NOTE

Confirmatory Factor Analysis of the End-User Computing Satisfaction Instrument: Replication within an ERP Domain*

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ABSTRACT

Over the past decade, organizations have made significant investments in enterprise resource planning (ERP) systems. The realization of benefits from these investments depends on supporting effective use of information technology (IT) and satisfying IT users. User satisfaction with information systems is one of the most important determinants of the success of those systems. Drawing upon a sample of 407 end users of ERP systems and working within the framework of confirmatory factor analysis (CFA), this study examines the structure and dimensionality, and reliability and validity of the end-user computing satisfaction (EUCS) instrument posited by Doll and Torkzadeh (1988). In response to Klenke's (1992) motion to cross-validate management information system (MIS) instruments and to retest the end user computing satisfaction instrument using new data, this study's results, consistent with previous findings, confirm that the EUCS instrument maintains its psychometric stability when applied to users of enterprise resource planning application software. Implications of these results for practice and research are provided.

Subject Areas: End-User Computing, IS Implementation, Management Information System, Structural Equation Models, and Survey Research/ Design.

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INTRODUCTION

Shortcomings of manufacturing resource planning (MRPII) such as managing a production facility's orders, production plans, and inventories led to the development of an integrated solution called enterprise resource planning (ERP) (Chung & Snyder, 1999). Enterprise resource planning systems, also referred to as enterprise-wide systems or enterprise systems, offer the "seamless integration of all the information flowing through a company—financial and accounting information, human resource information, supply chain information, and customer information" (Davenport, 1998, p. 121) and present a holistic view of the business from a single information and information technology (IT) architecture (Gable, 1998). Enterprise resource planning systems were one of the largest IT investments in the last decade (Chung & Snyder, 1999), and remain the largest segment of the applications budget (34%). In general, ERP penetration is 67%, and 15% of companies that do not have ERP today plan to implement it within the next 12 months (Scott & Shepherd, 2002). Total revenues for companies selling ERP applications are projected to reach $31 billion by 2006, up from $21 billion in 2002. The majority of growth is expected to result from strategic extensions such as supply chain, customer resource management, and product life-cycle management (AMR Research, 2002).

Enterprise resource planning systems can provide a wide array of benefits that are both tangible (e.g., reduced personnel, inventory, IT and procurement, transportation, and logistic costs; improved cash flow management, revenue, and profits) and intangible (e.g., increased visibility of corporate data, speed of decision making, and control over global business operations; improved customer responsiveness and business processes) (Callaway, 1999; Deloitte Consulting, 2000). While some companies, such as Chevron, IBM, and McKesson HBOC have seen performance gains, many ERP installations achieve only partial implementation. Nearly one in five are scrapped as total failures (Soh, Tien, & Tay-Yap, 2000; Trunick, 1999). Prior research has found that only 10% of new information systems failures can be attributed to technological problems (Bikson & Gutek, 1984). Many ERP projects fail to achieve anticipated benefits because managers underestimate the efforts involved in managing change (Appleton, 1997). Thus the human element has become the critical determinant of information system (IS) success (Martinsons & Chong, 1999). Users play a pivotal role in achieving ERP system success and affecting the perceived benefits arising from its use (Mahmood, Burn, Gemoets, & Jacquez, 2000). Assessing the degree to which key organizational members and all potential users agree on how the technology is to be applied in their particular situation within the organization (Sarker & Lee, 2000) is critical for organizations to achieve success with ERP systems.

One important issue that to date has remained largely unexplored is the nature of end-user computing satisfaction with ERP (Esteves & Pastor, 2001). Enterprise resource planning systems were designed to solve the problem of fragmentation of information in large organizations by consolidating all business operations into a uniform system environment to improve delivery of critical information to users and to improve data consistency. Given these goals, the attributes measured by end-user computing satisfaction (EUCS) such as content, accuracy, and so on, appear to be relevant to an evaluation of ERP systems. Some users, for example, may perceive ERP as a means to enhance efficiency by providing information that is accurate and timely. Accurate data is an absolute requirement for an ERP system to function properly, as inaccurate data can lead to errors in market planning, production planning, material procurement, capacity acquisition, and the like. Yet while EUCS has been validated and found generalizable across several applications (Doll & Torkzadeh, 1988), it has not been validated with users of ERP systems.

This paper reports the results of a study that further examines the theoretical meaning, structure and dimensionality, and reliability and validity of EUCS when used to measure end-user satisfaction with ERP software applications. This study also addresses previous limitations of other EUCS validation studies by using multiple informants from the same organization and a diverse range of industries, and examining systems that are used for one or more functional areas, and in one or more locations (single or multisite).

USER INFORMATION SATISFACTION

User information satisfaction (UIS) refers to the extent to which users perceive that the IS available to them meets their information requirements. As a surrogate measure of IS success in computing environments, UIS measures the success or failure of an IS (Galletta & Lederer, 1989) and has been a heavily researched topic (see Au, Ngai, & Cheng, 2002, for a critical review of research in UIS). DeLone and McLean (1992) identified three reasons why user satisfaction has been widely used as a measure of IS success: high degree of face validity, development of reliable tools for measure, and conceptual weakness and unavailability of other measures. Cyert and March (1963), who were the first to propose the concept of UIS as a surrogate of system success, suggested that an IS that meets the needs of the users reinforces their satisfaction with the system. User information satisfaction is often used as an indicator of user perception of the effectiveness of an MIS (Bailey & Pearson, 1983; Doll & Torkzadeh, 1988), and is related to other important constructs in systems analysis and design. Instruments that assess both general UIS (e.g., Ives, Olson, & Baroudi, 1983, based on the previous work of Bailey and Pearson, 1983), and application-specific UIS, or end-user computing satisfaction (Doll & Torkzedah, 1988), are widely used by researchers.

END-USER COMPUTING SATISFACTION

Many IS researchers have assessed the success of an application through the measurement of user satisfaction (for example, Bailey & Pearson, 1983; DeLone & McLean, 1992; Doll & Torkzadeh, 1988; Ives & Olson, 1984; Ives et al., 1983). End-user satisfaction is "the affective attitude towards a specific computer application by someone who interacts with the application directly" (Doll & Torkzadeh, 1988, p. 261). To measure end-user computing satisfaction, Doll and Torkzadeh (1988) developed a 12-item survey instrument that was a synthesis of the Ives et al. (1983) measure of UIS, and which is a widely used, validated, and generalizable instrument (e.g., Gelderman, 1998; Igbaria, 1990; Rahman & Abdul-Gader, 1993). Specifically, EUCS is a multifaceted construct that requires subjective self-reports of five subscales that measure end-user satisfaction with the content, accuracy, format, timeliness, and ease of use of a computer application and a single overall second-order construct called EUCS. The first four scales evaluate product usefulness, while ease of use evaluates the user friendliness of the application. The second-level structure is composed of the original factor structure of content, accuracy, format, ease of use, and timeliness (Chin & Newsted, 1995; Doll, Xia, & Torkzadeh, 1994). Past research has demonstrated instrument validity (content validity, construct validity, and reliability [Straub, 1989]) as well as internal validity and statistical validity (Doll & Xia, 1997; Doll et al., 1994; Hendrickson, Glorfeld, & Cronan, 1994; Hendrickson, Massey, & Cronan, 1993; McHaney & Cronan, 1998; McHaney, Hightower, & White, 1999).

Klenke (1992) highlighted the importance of cross-validation of measurement models and stressed the need to retest EUCS with different samples. Since the instrument was established, a number of researchers have applied it to various advanced information technologies. Adams, Nelson, and Todd (1992) used it to assess user satisfaction with voice mail and e-mail applications at 10 different companies. In a test-retest of the instrument, Hendrickson et al. (1994) engaged a sample from a large public organization using applications on either a mainframe or PC/desktop. Simon, Grover, Teng, and Whitcomb (1996) used it in a study of techniques that could be used in computer-related training. More recently, applicability of the EUCS instrument has been shown in conjunction with computer simulation models (decision support systems applications) (McHaney & Cronan, 1998), and in cross-cultural settings with Taiwanese end users of business software applications (McHaney, Hightower, & Pearson, 2002). Dowing (1999) used the EUCS measure with end users of telephone interactive voice response systems. Part of the instrument has also been used to assess the quality of user-developed applications in a study that explored the determinants of information center success (Essex, Magal, & Masteller, 1998), small business user satisfaction with information technology (Palvia, 1996), and end user satisfaction with data warehouses (Chen, Soliman, Mao, & Frolick, 2000). The past applications of EUCS by researchers are promising, but had limitations. For example, some studies involved only student groups, or groups of users within a single organization, or particular groups of users, such as decision support system users.

Over a decade ago, Davis, Bagozzi, & Warshaw argued that a set of theoretically and psychometrically justified measures would "provide a common frame of reference within which to integrate various research streams" (1989, p. 983). Yet, there is an alarming lack of effort in validating instruments (Boudreau, Gefen, & Straub, 2001; Doll & Xia, 1997; Jarvenpaa, Dickson, & DeSanctis, 1985; Klenke, 1992; Straub, 1989) and a relative paucity of replication in MIS, which needs to be ameliorated (BerthonPitt, Ewing, & Carr, 2002). Responding to the call for "reinstating replication as a critical component of research" (Berthon et al. 2002), we believe EUCS as developed by Doll and Torkzadeh (1988) should be reinvestigated in light of emerging technologies with new data to demonstrate robustness of the measurement model. Enterprise resource planning systems represent some of the largest and most complex applications of IT that offer many challenges and often fail (Scott & Vessey, 2000). It is this complexity that may contribute to the nature of user satisfaction being different within the ERP domain. Several factors contribute to ERP system complexity: (1) the implementation scope or number of sites (locations, geographies) with which systems can, or need to, interconnect; (2) the range or number of functions/modules that were implemented; (3) enterprise resource planning system diversity or the number of independent or heterogeneous ERP systems that are linked by means of some kind of messaging services (Hasselbring, 2000); and (4) the business process reengineering efforts associated with the implementation.

DATA COLLECTION

Data used in this study were collected via a nationwide mail survey of users of ERP systems. End users were asked to indicate the ERP module(s) they were using and to answer questions about their specific application(s). The sample was drawn from the *Directory of Top Computer Executives* (2000) and included only companies with ERP systems. We gathered data from a wide variety of industry sectors to make the results generalizable. For content validation purposes, the questionnaire was pretested with a group of 25 end users prior to mailing, who were not used in subsequent analyses. Using a snowballing technique (Simon & Burstein, 1985), introductory letters along with three questionnaires were sent to the chief information officer (CIO) or other top-level executive at 1,162 firms in the United States who identified the major end users and applications.

The mailing, with one follow-up, resulted in 407 usable questionnaires representing a 12.19% response rate from the population of 1,162 firms (1,162 × 3 surveys = 3,486 – 148 = 3,338; 407/3,338 = .1219), which is fairly typical of mail surveys (e.g., Rai, Lang, & Welker, 2002). Approximately 148 surveys were returned incomplete for various reasons. Data came from 214 organizations with the number of respondents per organization ranging from a minimum of one to a maximum of three ($n = 70$ for one end user from an organization, $n = 190$ for two end users from the same organization, $n = 147$ for three end users from the same organization). This approach ensured that one or more end users provided their experiences with the ERP system, thus minimizing the extent of common method variance bias and maximizing assessment of convergent or discriminant validity.

Nonresponse Analysis

Whereas 12% was a reasonable response for an unsolicited survey, we examined the sample data for evidence of nonresponse bias using two analyses. First, consistent with the procedure suggested by Armstrong and Overton (1977), we tested for statistically significant differences in the responses of late (130 end users) versus early respondents (277 end users) using industry type and revenue. The chi-square tests comparing the categories across the two groups revealed no significant differences for industry type ($\chi^2 = 12.346$; $\chi^2_{.05,8df} = 15.5073$) or revenue ($\chi^2 = 9.021$; $\chi^2_{.05,5df} = 11.0705$). Second, we compared the industry distribution of returned questionnaires to the population industry distribution and found no significant differences ($\chi^2 = 13.573$; $\chi^2_{.05,8df} = 15.5073$).

End User Characteristics

Table 1 shows characteristics of the end users' organizations. Seventy-nine percent had revenues of $500 million or more, and almost half (48%) had revenues exceeding $1 billion. Approximately 32% were manufacturing organizations, 18% were financial services organizations, and 13% were utility organizations. The

Table 1: Profile of end users' organizations (number of organizations = 214).

Number of End Users	407	
Revenue ($Millions)		
Over 1,000	195	(48%)
501 to 1,000	128	(31%)
251 to 500	54	(13%)
101 to 250	12	(3%)
25 to 50	11	(3%)
Less than 25	5	(1%)
Unknown	2	(>1%)
Industry Type		
Manufacturing	129	(32%)
Financial Services	72	(18%)
Utilities	54	(13%)
High Technology	37	(9%)
Insurance	36	(9%)
Retail	28	(7%)
Government	27	(7%)
Health Care	13	(3%)
Education	11	(3%)
Scope of Organization's ERP System		
Regional	220	(54%)
National	132	(32%)
Global	55	(14%)
Organization's ERP Software[a]		
PeopleSoft	198	(39%)
SAP	132	(26%)
J. D. Edwards	33	(6%)
Oracle	33	(6%)
Baan	22	(4%)
Mapics	12	(2%)
JBA Intl.	11	(2%)
Glovia Intl.	1	(0%)
Symix	1	(0%)
Other	66	(13%)

[a]Organizations had one or more ERP systems implemented.

remaining 37% came from a variety of sectors, including education, insurance, retail, high tech, health care, or government. Approximately 86% of the organizations implemented ERP systems regionally or nationally, and 14% reported global implementations. The majority of organizations implemented commercial off-the-shelf systems from vendors such as Baan, J. D. Edwards, Oracle, PeopleSoft, and SAP, and many organizations reported implementing ERP systems from more than one vendor.

Table 2 shows that end users were college educated with approximately 92% possessing bachelor's or master's degrees. End users typically used the following ERP modules: finance, production, receiving, inventory, human resources, purchasing, and shipping and distribution. End users received an average of 6.5 weeks

Table 2: Profile of end users.

Number of End Users		407	
Education			
High School		10	(2.5%)
Associate's Degree		10	(2.5%)
Bachelor's Degree		220	(54.0%)
Master's Degree		155	(38.0%)
Doctoral Degree		12	(3.0%)
ERP Modules Used by End Users			
Finance		352	(86.5%)
Production		308	(75.5%)
Receiving		264	(64.9%)
Inventory		253	(62.2%)
Human Resource Management		198	(48.6%)
Shipping/Distribution		154	(37.8%)
Purchasing		154	(37.7%)
Customer Order Management		132	(32.4%)
Business to Business Commerce		99	(24.3%)
Plant Maintenance		66	(16.2%)
Estimating and Quoting		55	(13.5%)
Other		55	(13.5%)
Quality Management		44	(10.8%)
Internet		33	(8.1%)
	Mean		Standard Deviation
End Users' Training Characteristics			
Number of weeks of in-house training	6.49		14.01
Number of weeks of external training	7.63		16.97
General End User Demographics			
Number of years in present position	4.99		4.40
Number of years with the organization	11.97		8.00
Number of years using the ERP system	2.97		1.96

of in-house and 7.5 weeks of external training. On average, end users had been with their organization for 12 years, and within their present position for 5 years. Typically, end users had used ERP systems for approximately 3 years.

RESULTS

Doll and Torkzadeh's (1988) 12-item instrument to measure EUCS along with descriptive statistics is shown in Table 3. The item means indicate that end users considered their ERP systems to be highly accurate, were satisfied with the systems' accuracy, and gave high ratings to the timeliness dimension. Ease of use and the ERP system's user friendliness received the lowest ratings by the end users in our sample, which was not surprising given that ERP systems are profoundly complex pieces of software that require large investments of money, time, and expertise (Davenport, 1998).

Table 3: Sample descriptive statistics for end user computing satisfaction.

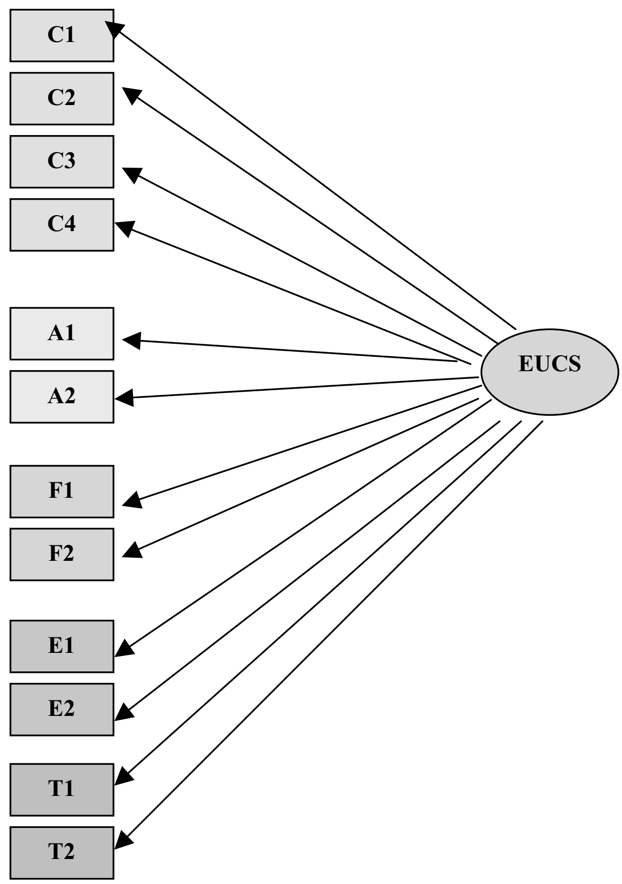
Item Code	Question[a]	Mean	Standard Deviation
C1	Does the system provide precise information you need?	3.44	.72
C2	Does the information content meet your needs?	3.49	.74
C3	Does the system provide reports that seem to be just about exactly what you need?	3.63	.76
C4	Does the system provide sufficient information?	3.35	.78
A1	Is the system accurate?	4.33	.82
A2	Are you satisfied with the accuracy of the system?	4.28	.78
F1	Do you think the output is presented in a useful format?	3.88	.81
F2	Is the information clear?	3.91	.77
E1	Is the system user friendly?	2.49	.73
E2	Is the system easy to use?	2.61	.77
T1	Do you get the information you need in time?	4.11	.75
T2	Does the system provide up-to-date information?	4.15	.73

[a]Five point scale: 1 = almost never; 2 = some of the time; 3 = about half of the time; 4 = most of the time; 5 = almost always.

The EQS 5.6 (Bentler, 1995) program with maximum likelihood estimation was used to estimate the confirmatory and structural equation models in this study. Multivariate normality and model determinacy (or identification) are important assumptions of confirmatory factory analysis (CFA). We tested for multivariate normality of the observed variables to ensure observations were independently and identically distributed (Schumacker & Lomax, 1996, pp. 102–103). First, the variables were examined for outliers and other departures from nonnormality. No significant outliers were detected. Skewness for scale items ranged between –0.27 and 1.21, kurtosis ranged between −.22 and 3.93, and standardized residuals among scale items ranging from −.11 to .13 were well within the robustness thresholds for normality (West, Finch, & Curran, 1995). Second, Mardia's coefficient (Mardia, 1970) provided an indication that the data were free from multivariate kurtosis (Mardia's coefficient = 6.87; normalized estimate = 3.02). Third, an examination of moments around the mean of each variate's distribution suggested no serious departures in univariate normality. A simple test for identification problems (Hair, Anderson, Tatham, & Black, 1998) was conducted using multiple estimation of the structural models with varying starting values. The solutions converged at the same point each time, indicative of model identification.

Doll et al. (1994) proposed four plausible alternative models of factor structure that are shown in Figures 1 to 4. We tested the fit of each hypothesized model to determine its consistency and applicability with the sample data of end users of ERP applications. Comparison studies examined in this paper have assumed that a second-order factor structure applies, consisting of a single factor called EUCS. Model 1 (Figure 1) hypothesized one first-order factor (EUCS) accounting for all the common variance among the 12 items. Previous studies (Simon, 2000) have scaled the satisfaction construct by summing individual items to obtain a

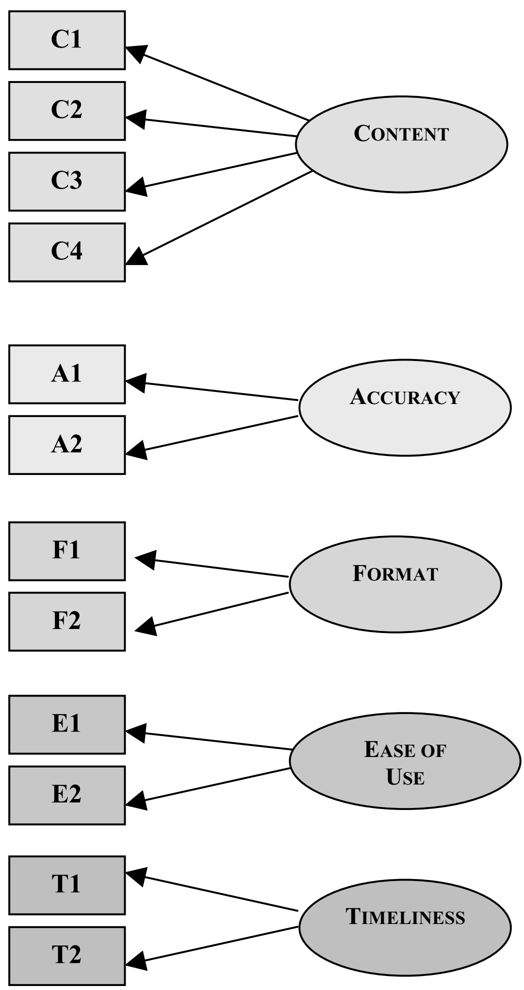
Figure 1: Model 1: One first-order factor.



total score, assuming a first-order factor is a plausible model. Model 2 (Figure 2) hypothesized that the 12 items form into 5 uncorrelated or orthogonal first-order factors defined as content, accuracy, format, ease of use, and timeliness. Model 3 (Figure 3) hypothesized that the five first-order factors are correlated with each other. Model 4 (Figure 4) hypothesized five first-order factors and one second-order factor (EUCS). In model 4, the intercorrelations among first-order factors form a system of interdependence that is itself important in measuring the construct. Conceptually, each factor and second-order factor is necessary in capturing the nature of the construct domain. The second-order factor EUCS exists but cannot be directly measured by indicator variables. It can only be inferred from the first-order factors, which in turn are measured by their respective indicator variables.

Model 4 is the only model that has been tested in previous studies over the past decade (Doll & Xia, 1997; Doll et al., 1994; McHaney & Cronan, 1998; McHaney et al., 2002; McHaney et al., 1999). Characteristics of the previous validation studies with EUCS are summarized in Table 4. These studies are subsequently

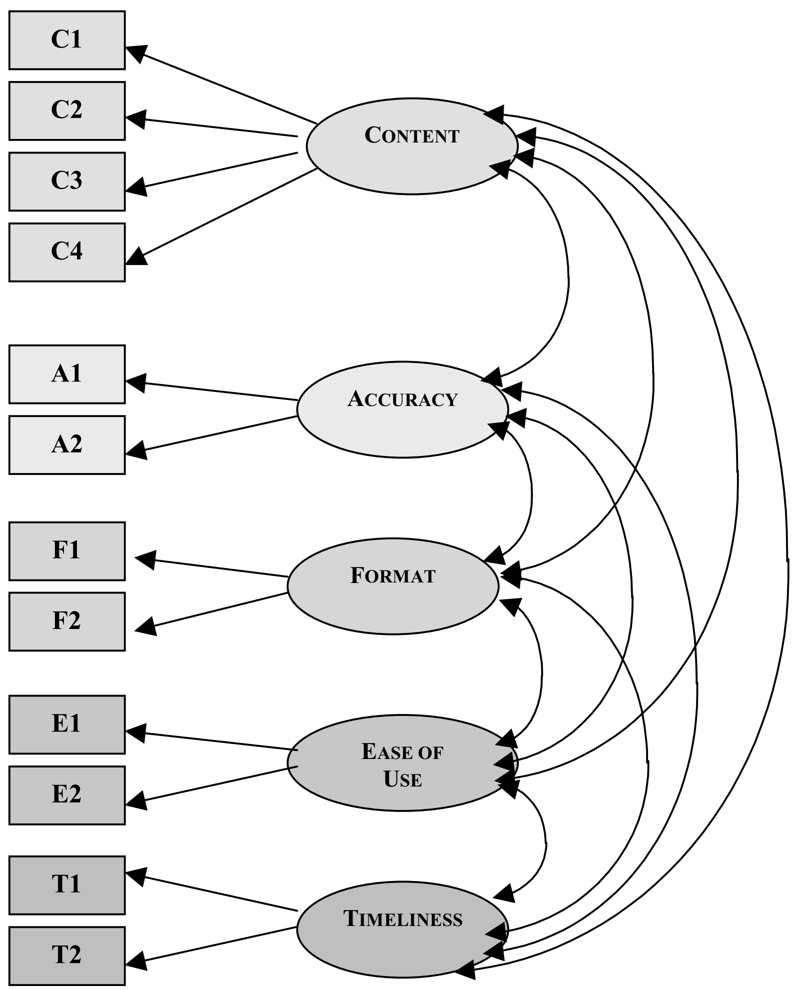
Figure 2: Model 2: Five first-order factors (uncorrelated).



used for comparisons of results over time and applications with the study reported here. We excluded two validation studies of EUCS (Torkzadeh & Doll, 1991; Hendrickson et al., 1994) whose focus was limited to test-retest reliability assessment only.

The correlation matrix for the sample, provided in the Appendix, was used to analyze the hypothesized models. The CFA estimation proceeded in a two-step approach in which the confirmatory factor models were tested prior to testing the structural model. The results of testing the four models are reported in Table 5. In large samples, the null model serves as a good baseline model against which to compare alternative models for purposes of evaluating the gain in improved fit, and to establish a zero point for the normed fit index (NFI). It is well documented that χ^2 statistics are very sensitive to large sample sizes, and usually significant,

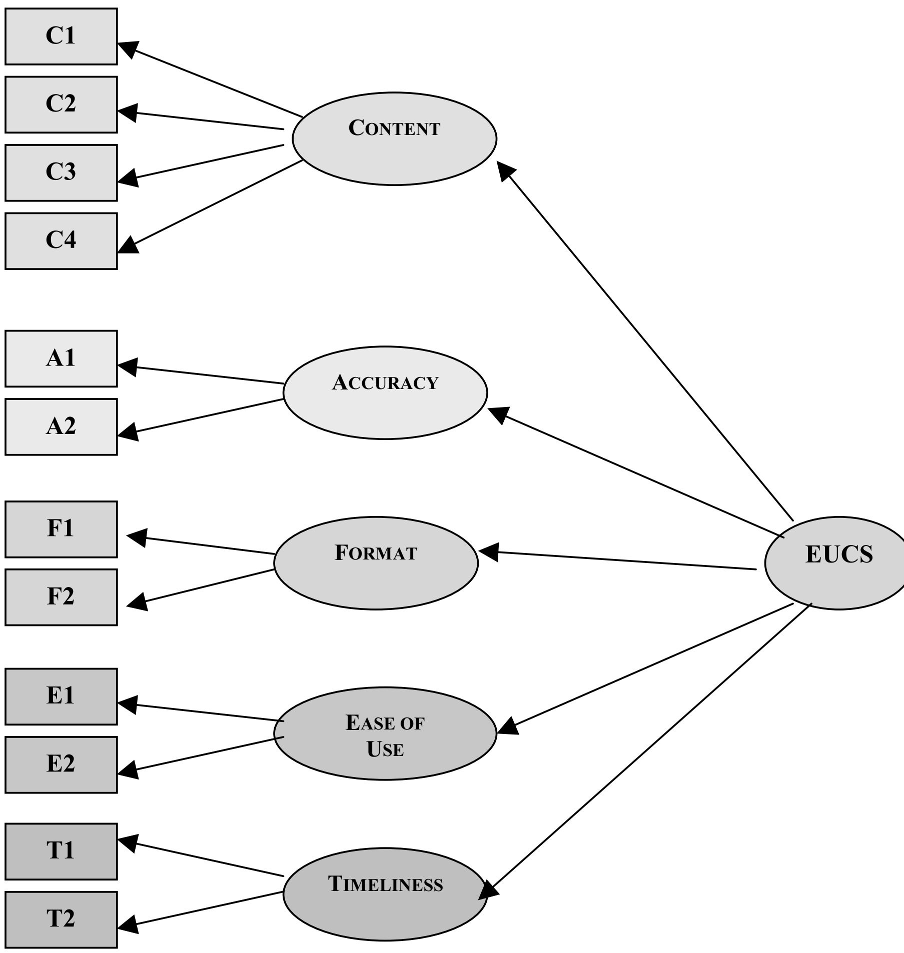
Figure 3: Model 3: Five first-order factors (correlated).



indicating the sample data is not an adequate fit to the hypothesized model (Byrne, 1998; Hoyle, 1995; Maruyama, 1998; Schumacker & Lomax, 1996). Therefore, we use other model-fit indices, which are independent of sample size (Bagozzi & Yi, 1988; Bagozzi, Yi, & Phillips, 1991). As shown in Table 5, six common model-fit measures, which were also used in the comparison studies, assess each model's overall goodness of fit: chi-square, chi-square/degrees of freedom, normed fit index, goodness-of-fit index (GFI), adjusted goodness of fit index (AGFI), and root mean square residual (RMSR).

Doll and Xia (1997) found that neither models 1 nor 2 were even close to being considered a good fit with the sample data. Our results concur with their observations. The χ^2/df ratio and RMSR were above their acceptable threshold. The NFI, GFI, and AGFI were all below the desired threshold of .90. Moreover,

Figure 4: Model 4: Five first-order factors and one second-order factor.



the estimated loadings relating the items to the factors were not statistically significant for either model. Contrary to Doll and Xia (1997), model 2 exhibited better model-data fit than model 1. Model 3, which shows substantial improvement over the first two models as evidenced by the changes in the indices (GFI, AGFI, and RMSR), is comparable to Doll and Xia (1997). However, this model still does not provide a satisfactory solution and is deemed unacceptable.

Model 4 shown in Figure 4 is of greatest theoretical interest since theory in this field suggests the existence of a single overall user satisfaction construct (Doll & Xia, 1997). In our study, model 4 shows the best fit in terms of representing the underlying factor structure and supports the results from previous studies (Doll & Xia, 1997; Doll et al., 1994; McHaney & Cronan, 1998; McHaney et al., 2002; McHaney et al., 1999). Table 6 compares model 4 goodness-of-fit indices from the present study with those of previous studies. Hair et al. (1998) stipulate the use of

Table 4: Characteristics of psychometric stability studies of EUCS.

Code	EUCS Study[a]	Year	Sample	Research Strategy[b]
S1	Doll, Xia, and Torkzadeh original confirmatory study	1994	409 respondents (data gathering methods identical to 1988 study—end users at 18 organizations, using 139 different applications)	Replication with context-only extension
S2	Doll and Xia second confirmatory study	1997	359 working students (end users at 122 organizations, using 146 different applications)	Replication of earlier CFA of EUCS with context-only extension
S3	McHaney & Cronan	1998	411 developers and end users of computer simulation application software	Replication with context-only extension
S4	McHaney, Hightower, and White	1999	123 end users of representational DSS, specifically discrete-event computer simulation	Test-retest administrations and replication with context-only extension
S5	McHaney, Hightower, and Pearson	2002	342 Taiwanese end users of typical business software applications	Replication with context-only extension
	Current Study	N/A	407 end users of ERP systems (one to three end users from same organization representing 214 different organizations and using different applications (modules of ERP software)	Replication with context-only extension

[a]Complete citation provided in reference list for S1 to S5. Validation studies of EUCS were excluded if their focus was limited to test-retest reliability assessment (for example, Hendrickson et al., 1994; Torkzadeh & Doll, 1991).
[b]One degree of freedom research strategies as defined by Berthon et al. (2002).

Table 5: Goodness-of-fit measures for alternative models.

	Measurement Models			
	Model 1	**Model 2**	**Model 3**	**Model 4**
Doll and Xia (1997, p. 28)[a] Goodness of Fit Indexes[b] for Alternative Models of Factor Structure ($n = 359$)	One First-Order Factor	Five First-Order Factors (Uncorrelated)	Five First-Order Factors (Correlated)	Five First-Order Factors, One Second-Order Factor
Chi-Square (*df*)	458.48 (54)	1398.21 (59)	119.08 (44)	175.37 (49)
Chi-Square/*df*	8.49	23.70	2.71	3.58
Normed Fit Index (NFI)	.86	.57	.96	.95
Goodness-of-Fit Index (GFI)	.82	.58	.95	.92
Adjusted Goodness-of-Fit Index (AGFI)	.73	.44	.90	.88
Root Mean Square Residual (RMSR)	.058	.410	.024	.034
Current Study[a] Goodness-of-Fit Indexes[b] for Alternative Models of Factor Structure ($n = 407$)	One First-Order Factor	Five First-Order Factors (Uncorrelated)	Five First-Order Factors (Correlated)	Five First-Order Factors, One Second-Order Factor
Chi-Square (*df*)	1434.666 (54)	685.56 (59)	402.11 (44)	385.33 (49)
Chi-Square/*df*	26.57	11.62	9.14	7.86
Normed Fit Index (NFI)	.47	.74	.85	.90
Goodness-of-Fit Index (GFI)	.67	.78	.89	.91
Adjusted Goodness-of-Fit Index (AGFI)	.53	.72	.81	.81
Root Mean Square Residual (RMSR)	.178	.14	.047	.034

[a]Null Models: Doll and Xia (1997, p. 28): $\chi^2 = 3257.43$ ($df = 66$), $\chi^2/df = 49.36$, GFI = .21, AGFI = .07, RMSR = .45.
Current Study: $\chi^2 = 2682.44$ ($df = 66$), $\chi^2/df = 40.64$, GFI = .50, AGFI = .41, RMSR = .27.
[b] Recommended values for concluding "good" fit of model to data (Hoyle, 1995; Marcoulides & Schumacker, 1996):
$\chi^2/df \leq 2.0$, NFI $\geq .90$, GFI $\geq .80$, AGFI $\geq .90$, RMSR $\leq .10$

Table 6: A comparison of model 4 fit indices.

Goodness of Fit Measures[a]	Current Study	S5	S4	S3	S2	S1
Chi-Square (*df*)	385.33 (49)	115.6 (44)	145.15 (44)	25.74 (5)	175.37 (49)	185.81 (50)
Chi-Square/*df*	7.86	2.62	3.30	5.15	3.58	3.72
Normed Fit Index (NFI)	.90	.98	.899	.979	.950	.940
Goodness-of-Fit Index (GFI)	.918	.98	.866	.977	.920	.929
Adjusted Goodness-of-Fit Index (AGFI)	.810	.91	.762	.932	.880	.889
Root Mean Square Residual (RMSR)	.034	.04	.051	.027	.034	.035

[a]Recommended values for concluding "good" fit of model to data (Hoyle, 1995; Marcoulides & Schumacker, 1996): $\chi^2/df \leq 2.0$, NFI $\geq .90$, GFI $\geq .80$, AGFI $\geq .90$, RMSR $\leq .10$

χ^2 is appropriate for sample sizes between 100 and 200, with the significance test becoming less reliable with sample sizes outside this range. The χ^2/df ratio is better than the χ^2 value, and should be less than three (Carmines & McIver, 1981), or less than two in a more restrictive sense (Premkumar & King, 1994). While Table 6 shows this ratio to be higher than desired and somewhat higher than previous studies, additional support for good model-data fit comes from examining GFI and AGFI, which measure how much the model jointly accounts for the variances and covariance, which are relatively robust against normality, and which are greater than or close to the recommended thresholds. Furthermore, as in previous studies the NFI suggests that the hypothesized model represented an adequate fit to the data. Finally, an examination of RMSR, which is a measure of the average difference between the elements in the sample and the hypothesized covariance matrices, has a value below the recommended .10 threshold (Premkumar & King, 1994), thus indicating good fit. In sum, the absolute indexes (GFI, AGFI, and RMSR) in this study compare favorably with the values reported by the other studies.

Convergent validity was evaluated for the measurement scales in the CFA models using three criteria recommended by Fornell and Larcker (1981): (1) all indicator factor loadings (λ) should be significant, (2) construct reliabilities should exceed .80, and (3) average variance extracted (AVE) by each construct should exceed .50. The λ-values for all scale items in the CFA models were significant at $p \leq .001$. Composite reliabilities (ρ_c) of the latent constructs ranged between 0.72 and 0.89 (content .86; accuracy .89; format .74; ease of use .72; timeliness .75). Further, AVE ranged from .56 to .61 (content .61; accuracy .80; format .59; ease of use .56; timeliness .60). The lowest AVE value (.56) was above the .50 threshold required to ensure that variance extracted by selected items was greater than that due to measurement error. Hence, of the criteria listed above for convergent validity, (1) and (3) were met fully, while criterion (2) was partially supported.

Table 7 shows standardized parameter estimates for the observed variables for model 4. The factor loadings relating the items to factors for all replication studies can be viewed as indicators of validity for the 12 items. Convergent validity is established if the loadings of the measures to their respective constructs are at least .60 (Bagozzi & Yi, 1988). All of the original 12 items demonstrated loadings of .62 or greater and are statistically significant ($t > |2.00|$), suggesting good construct validity similar to other studies. R-square, the proportion of the variance in the observed variables that is accounted for by its latent variable, ranges from 0.39 to 0.88 providing evidence of acceptable reliability for all individual items.

Table 8 provides the standard structural coefficients, corresponding t-values, and R-square values for the latent variables. The structural coefficients exceed .70 and are significant, indicating good construct validity of the latent factors comprising the EUCS construct. R-square values range from .62 to .95, providing evidence of acceptable reliability for all factors. The results are in consonance with the other studies and support the structural equation model and underlying theory. A higher-order EUCS factor is confirmed as accounting for or explaining all variance and covariance related to the first-order factors in capturing end users' satisfaction with ERP systems. The replication of these results enhances our confidence in the generalizability of EUCS, and its robustness as a measure of UIS.

Table 7: A comparison of model 4 standardized parameter estimates (λ) and t-values for λ.

	Current Study		S5		S4		S3		S2		S1	
Item	λ	R^2	λ	R^2	λ	R^2	λ	R^2	λ	R^2	λ	R^2
C1	.847[a]	.72	.76	.57	.855	.73	.837	.70	.83[a]	.70	.826[a]	.68
			(16.1)		(12.77)		(20.55)					
C2	**.876**	.77	.76	.58	.891	.79	.866	.75	.85	.73	.852	.73
	(22.37)		(16.2)		(13.66)		(21.68)		(19.96)		(20.36)	
C3	.620	.39	.70	.49	.758	.58	.621	.38	.80	.64	.725	.53
	(13.58)		(14.5)		(10.66)		(13.58)		(17.98)		(16.23)	
C4	.767	.59	.68	.46	.781	.61	.806	.65	.82	.68	.822	.68
	(18.17)		(13.9)		(11.14)		(19.38)		(18.78)		(19.32)	
A1	**.851**[a]	.72	**.82**	.68	.883	.78	**.871**	.76	**.87**[a]	.75	**.868**[a]	.76
			(17.0)		(13.16)		(21.16)					
A2	**.940**	.88	**.81**	.66	**.944**	.89	**.928**	.86	**.89**	.75	**.890**	.79
	(21.01)		(16.7)		(14.61)		(23.25)		(18.58)		(20.47)	
F1	.694[a]	.48	.64	.40	.757	.57	.694	.48	.85[a]	.72	.780[a]	.61
			(12.1)		(10.49)		(15.21)					
F2	.836	.70	.76	.58	**.900**	.81	**.870**	.76	.86	.73	.829	.69
	(14.59)		(14.6)		(13.34)		(20.09)		(19.52)		(17.89)	
E1	.721[a]	.52	**.81**	.65	**.915**	.84	.695	.48	.84[a]	.71	.848[a]	.72
			(15.9)		(12.91)		(14.83)					
E2	.791	.63	**.81**	.66	.856	.58	.826	.68	**.88**	.78	**.880**	.78
	(13.49)		(15.9)		(10.66)		(18.03)		(15.45)		(16.71)	
T1	.751[a]	.56	.74	.54	.690	.48	.731	.54	.84[a]	.70	.720[a]	.52
			(14.4)		(8.85)		(15.99)					
T2	.799	.64	.67	.44	.880	.78	.855	.73	.76	.58	.759	.58
	(13.95)		(12.9)		(11.72)		(19.29)		(16.38)		(13.10)	

Note: Values in bold represent the three highest loadings for each study.
[a]Indicates a parameter fixed at 1.0 in the original solution. t-values from factor loadings are indicated in parentheses.

Table 8: A comparison of standard structural coefficients and t-values for model 4.

	Current Study		S5		S4		S3		S2		S1	
Item[a]	β	R^2	β	R^2	β	R^2	β	R^2	β	R^2	β	R^2
C	**.972**	.95	.74	.55	**.955**	.91	**.950**	.90	**.97**	.94	**.912**	.68
	(18.33)		(22.4)		(15.22)		(61.40)		(18.18)		(17.67)	
A	.784	.62	**.80**	.64	.77	.59	.776	.60	.83	.69	.822	.73
	(14.32)		(26.8)		(10.86)		(24.85)		(15.43)		(16.04)	
F	**.938**	.88	**.90**	.80	**.855**	.73	.808	.65	.93	.87	**.993**	.53
	(13.81)		(40.9)		(12.70)		(27.69)		(17.58)		(18.19)	
E	.869	.76	.78	.62	.629	.40	**.822**	.68	.71	.50	.719	.68
	(13.24)		(25.6)		(8.30)		(29.21)		(12.01)		(13.09)	
T	.842	.71	.72	.52	.712	.51	.791	.63	**.98**	.95	.883	.76
	(13.40)		(20.8)		(9.74)		(26.18)		(18.41)		(13.78)	

Note: Values in bold represent the two highest loadings for each study.
[a]Content (C), Accuracy (A), Format (F), Ease of Use (E), Timeliness (T). t-values from factor loadings are indicated in parentheses.

DISCUSSION

A better understanding of the factors that can influence user satisfaction needs to develop in order for ERP applications to be used effectively. Usually absent with technological innovation are measures of how well the user is responding to them or using them. Extending the replication of an existing instrument is an approach that has been advocated by various researchers (Berthon et al., 2002; Boudreau et al., 2001; Klenke, 1992). Our study advances previous research by using the EUCS instrument to evaluate end user satisfaction with enterprise systems and examine validation issues related to the instrument. It represents the first comprehensive examination of the EUCS instrument, based on a large-scale survey using multiple informant responses from end users of various ERP applications. Consistent with findings from several previous studies, the EUCS has been shown to be a valid predictor of user satisfaction with integrated systems. Although the psychometric properties of EUCS appear to be robust across studies and user groups, it should not be considered the final chapter in the validation and refinement of these scales. Continuing efforts should be made to validate and extend the instrument.

IMPLICATIONS FOR PRACTICE AND RESEARCH

Researchers have suggested that the EUCS instrument (and others) be tested prior to application in new areas. Our study shows that the EUCS instrument may be used to evaluate ERP systems in organizations. Since users may be reluctant to allow measurement for fear of job loss, the EUCS instrument may prove to be a nonthreatening means of quantifying the efficiency and effectiveness of newly implemented ERP applications. In addition, the instrument provides not only an overall assessment of end user satisfaction, but also the capability to analyze which aspects of ERP implementation efforts are most problematic. The magnitude of path coefficients provides useful insights into the relative importance of each subscale of EUCS and thus the major areas of satisfaction or dissatisfaction with the use of a given ERP application. Managers could focus on those factors as significant contributors to overall satisfaction to improve ERP system effectiveness.

Similar to other studies, content and format had the highest loadings, indicating that these two play a critical role in EUCS. The third highest loading in this study was for ease of use. A fully integrated ERP system is not easy to learn, and ease-of-use problems are gaining greater visibility as more vendors broaden their reach to occasional users. Our results imply the need for ERP vendors to reduce the complexity of their software and make their user interfaces easier to customize. For organizations implementing ERP, the results also underline the need for designing highly effective user documentation or providing additional training to end users. Mirani and King (1994) found user satisfaction increased when support needs were provided. Users who are not satisfied may be tempted to run parallel or informal systems as a way to avoid using the new system. Creating a supportive environment that is responsive to end user concerns and needs, and that works collaboratively with end users in utilizing new software applications, can yield payoffs in favorable attitudes toward the system, as well as increased use and effectiveness. The instrument can thus be used to measure EUC support and policy, and user skill with ERP systems.

A problem associated with implementing packaged software such as ERP is the incompatibility of features with the organization's information needs and business processes (Janson & Subramanian, 1996; Lucas, Walton, & Ginzberg, 1988). The mismatch between business processes and software requirements can create significant problems for users. Companies that change their business processes to better fit ERP applications compel users to simultaneously learn a new way of doing their jobs and master the complexities of the software. Also, technical difficulties such as bugs in the software, problems interfacing with existing systems, and hardware difficulties can lead to frustrated users and lower user satisfaction. End user computing satisfaction may be used to signal to management such mismatches and difficulties.

Our results are also in consonance with Li (1997), who found the top five important IS success factors indicated by the IS managers to be accuracy of output, reliability of output, relationship between users and the IS staff, user's confidence in the system, and the timeliness of output. Thus, information that is timelier, more accurate, and more relevant can lead to improvement in business performance, by reducing costs, improving decision performance, improving process efficiency, and being more responsive to customer requirements. End user computing satisfaction can be used with confidence by IS managers to assess some of these factors.

For researchers, the major contribution of this study lies in the area of measurement by rigorously validating EUCS (Doll & Torkzadeh, 1988) and thus enabling researchers to use the EUCS instrument with increased confidence. With a validated instrument, further research can be conducted into relationships among the antecedents and consequences of end user satisfaction, particularly in the area of ERP and other technological innovation. Seddon (1997) argues that for lack of a better measure, user satisfaction could be a useful measure of net benefits or success of the ERP system. In sum, as a result of our study, EUCS can be better understood and applied as a standardized measure of advanced information technologies, and can provide a summary evaluation for researchers and a means of formally evaluating ERP implementations for practitioners.

CONCLUSIONS

Several widely used instruments have been tested for evidence of acceptable psychometric properties in IS research. For example, recognition of the importance of measuring the service quality of the IS function has recently appeared in the IS literature (Ferguson & Zawacki, 1993; Kettinger & Lee, 1994; Pitt, Watson, & Kavan, 1995). The SERVQUAL instrument measures service quality in a broad spectrum of service sectors (Parasuraman, Zeithaml, & Berry, 1988). Since its introduction, it has evolved, and has been replicated and adapted to a number of contexts. Most recently, Jiang, Klein, and Crampton (2000) reported on SERVQUAL's reliability and validity in IS service quality measurement, followed by Carr's (2002) study, which examined the psychometric properties of the IS-adapted SERVQUAL instrument (Kettinger & Lee, 1994).

Our study continues the trend of replication of a widely used instrument by examining EUCS with users of ERP systems. In the spirit of McHaney and Cronan (1998), Doll and Xia (1997), Doll et al. (1994) and most recently, McHaney et al. (2002), we have attempted to further examine the measurement properties of EUCS identified and operationalized by Doll and Torkzadeh (1988) over a decade ago. The large number of diverse organizations ($n = 214$), the diversity of integrated systems within the organizations, the scope of the implementations (single versus multisite) and the variety of modules/applications (14) used by 407 end users contribute to a better understanding of end user satisfaction with ERP systems, which to date have not been studied in depth (Esteves & Pastor, 2001). [Received: June 2002. Accepted: April 2003.]

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APPENDIX

Correlation Matrix

	Content				Accuracy		Format		Ease of Use		Timeliness	
	C1	C2	C3	C4	A1	A2	F1	F2	E1	E2	T1	T2
C1	1.00											
C2	.76	1.00										
C3	.53	.48	1.00									
C4	.63	.71	.40	1.00								
A1	.54	.59	.37	.59	1.00							
A2	.60	.65	.44	.63	.80	1.00						
F1	.50	.52	.41	.51	.38	.39	1.00					
F2	.64	.62	.52	.58	.55	.62	.58	1.00				
E1	.52	.44	.73	.42	.36	.42	.48	.52	1.00			
E2	.55	.61	.51	.50	.37	.39	.55	.58	.57	1.00		
T1	.52	.52	.43	.45	.41	.47	.48	.48	.41	.43	1.00	
T2	.57	.63	.40	.39	.47	.51	.48	.51	.42	.40	.60	1.00

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