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User developed applications and informationsystems success: A test of DeLone and McLean's model

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McGill, T. J., Hobbs, V. J., & Klobas, J. E. (2003). User developed applications and informationsystems success: A test of DeLone and McLean's model. Information Resources Management Journal (IRMJ), 16(1), 24–45. https://doi.org/10.4018/irmj.2003010103
Document Version: Published (Version of Record)

Published Version: https://doi.org/10.4018/irmj.2003010103

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Information Resources Management Journal

Jan-Mar 2003 Vol. 16, No. 1

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ABSTRACT

DeLone and McLean's (1992) model of information systems success has received much attention amongst researchers. This study provides the first empirical test of an adaptation of DeLone and McLean's model in the user-developed application domain. The model tested was only partially supported by the data. Of the nine hypothesized relationships tested, four were found to be significant and the remainder not significant. The model provided strong support for the relationships between perceived system quality and user satisfaction, perceived information quality and user satisfaction, user satisfaction and intended use, and user satisfaction and perceived individual impact. This study indicates that user perceptions of information systems success play a significant role in the user-developed application domain. There was, however, no relationship between user developers' perceptions of system quality and independent experts' evaluations, and user ratings of individual impact were not associated with organizational impact measured as company performance in a business simulation. Further research is required to understand the relationship between user perceptions of IS success and objective measures of success, and to provide a model of IS success appropriate to end user development.

INTRODUCTION

User-developed applications (UDAs) are computer-based applications for which non-information systems professionals assume primary development responsibility. They support decision-making and organizational processes in the majority of organizations (McLean, Kappelman, & Thompson, 1993). Perhaps the most important benefit claimed for user development of applications is improvement in employee productivity and performance, resulting from a closer match between applications and user needs since the end user is both the developer and the person who best understands the information requirements. However, the realization of these benefits may be put at risk because of problems with information produced by UDAs that may be incorrect in design, inadequately tested, and poorly maintained.

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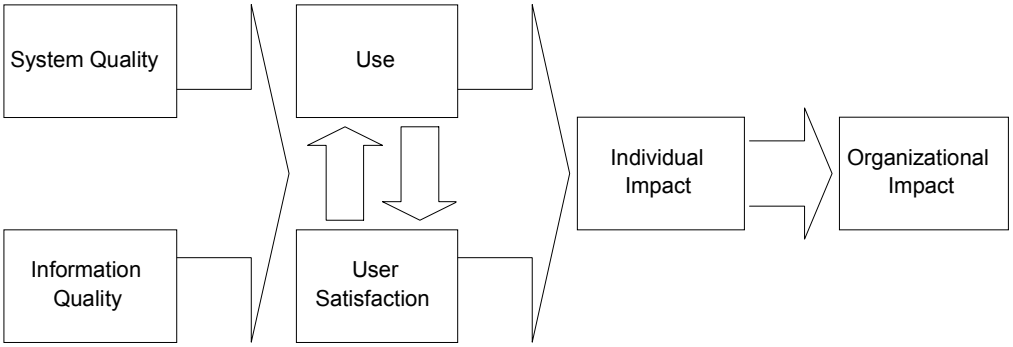
Figure 1: DeLone and McLean's (1992) Model of IS Success



Despite these risks, organizations generally undertake little formal evaluation of the success of applications developed by end users, instead relying heavily on the individual end user's perceptions of the value of the application (Panko & Halverson, 1996). This raises the important issue of the need to be able to measure the effectiveness of UDAs. In view of the scarcity of literature on UDA success (Shayo, Guthrie, & Igbaria, 1999), models of organizational information systems (IS) success can provide a starting point. DeLone and McLean's (1992) model of IS success has received much attention amongst IS researchers (Walstrom & Hardgrave, 1996; Walstrom & Leonard, 2000), and it can provide a foundation for further research on IS success in the UDA domain. This paper describes a study designed to investigate the applicability of an adaptation of DeLone and McLean's (1992) model of IS success to UDAs.

DELONE AND MCLEAN'S (1992) MODEL OF IS SUCCESS

DeLone and McLean (1992) conducted an extensive review of the IS success literature. They found that the success of an IS can be represented by the quality characteristics of the IS itself (system quality); the quality of the output of the IS (information quality); consumption of the output of the IS (use); the IS user's response to the IS (user satisfaction); the effect of the IS on the behavior of the user (individual impact); and the effect of the IS on organizational performance (organizational impact).

DeLone and McLean proposed the model of IS success shown in Figure 1. The model makes two important contributions to the understanding of IS success. First, it provides a scheme for categorizing the multitude of IS success measures that have been used in the literature. Second, it suggests a model of temporal and causal interdependencies between the categories.

Empirical Support for the Model

Until recently there had been no complete empirical test of the relationships implied by the DeLone and McLean model. Roldán and Millán (2000) tested the entire model for executive information systems and found support for some of the relationships. Studies of parts of the model, or individual relationships implied by it (investi-

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Table 1: Summary of research that is consistent with the relationships depicted in DeLone and McLean's model

Relationship	Study
System quality → user satisfaction	Seddon and Kiew (1996) Roldán and Millán (2000) Rivard, Poirier, Raymond and Bergeron (1997)[a]
Information quality → user satisfaction	Seddon and Kiew (1996) Roldán and Millán (2000)
User satisfaction → use	Baroudi et al. (1986) Igbaria and Tan (1997) Fraser and Salter (1995)
Use → individual impact	Snitkin and King (1986) Igbaria and Tan (1997)
User satisfaction → individual impact	Gatian (1994) Gelderman (1998) Igbaria and Tan (1997) Etezadi-Amoli and Farhoomand (1996) Roldán and Millán (2000)
Individual impact → organizational impact	Millman and Hartwick (1987) Kasper and Cerveny (1985)[a] Roldán and Millán (2000)

[a] Involved UDAs

gated both prior to and subsequent to the publication of the model), also provide empirical support for a number of the relationships. The key research that is consistent with DeLone and McLean's model is summarized in Table 1.

Seddon and Kiew (1996) tested the 'upstream' portion of the model and their results provided substantial support for the proposed relationships among system quality, information quality, and user satisfaction. Roldán and Millán (2000) also found support for these relationships. In addition, their study also considered the relationships between system quality and use, and information quality and use, but failed to find a relationship. Baroudi, Olson, and Ives (1986) showed that, although user satisfaction influences use, use does not significantly influence user satisfaction. Igbaria and Tan (1997) and Fraser and Salter (1995) also found support for the influence of user satisfaction on system usage.

The results of an earlier study of decision support system use by Snitkin and King (1986) are consistent with the proposed relationship between use and individual impact. However, neither Gelderman (1998) nor Roldán and Millán (2000) found any evidence of this relationship. The relationship between user satisfaction and individual impact received support in Gatian's (1994) study, in which significant positive relationships were found between user satisfaction and both objective and subjective measures of individual impact. Gelderman's (1998) survey of 1,024 Dutch managers also confirmed the relationship between satisfaction and both subjective and objective individual impact measures. Etezadi-Amoli and Farhoomand (1996) and Roldán and Millán (2000) used only perceptual measures of individual impact, but their results were consistent with the previously mentioned studies of this relationship. Igbaria and Tan (1997) found that user satisfaction has the strongest direct effect on individual impact, but identified a significant role

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for system usage in mediating the relationship between user satisfaction and individual impact. Empirical support for the relationship between individual impact and organizational impact has been provided by Millman and Hartwick (1987) in their study of middle managers' perceptions of the impact of systems, and by Roldán and Millán (2000).

Despite the number of studies that provide a degree of support for DeLone and McLean's model of IS success, it is difficult to compare and interpret their results due to differences in measurement approaches.

Concerns About the Model's Applicability in the UDA Domain

Little is known about the applicability of DeLone and McLean's model in the UDA domain. Most support for elements of the model has come from research in the organizational domain. Only two of the relationships proposed in the model appear to have been specifically investigated for UDAs (these are identified by a superscript in Table 1). The proposed relationship between system quality and satisfaction is supported by Rivard et al. (1997) who found a significant positive correlation between perceived system quality and end user computing satisfaction for UDAs. Kasper and Cerveny's (1985) study provided evidence for the link between individual impact and organizational impact, with the improved performance of the end user developers flowing through to their firm's stock price, market share, and return on assets.

However, the results of a study by McGill, Hobbs, Chan, and Khoo (1998) suggest that the process of developing an application to facilitate an organizational task predisposes an end user developer to be more satisfied with the application than they would be if it were developed by someone else. This may have implications for the role of user satisfaction in the model. Edberg and Bowman (1996) pointed out that users may not only lack the skills to develop quality applications, but may also lack the knowledge to make realistic determinations about the quality of applications that they develop. Therefore, the posited relationships between system quality and user satisfaction, and system quality and use may also be of concern.

The study described in this paper was designed to investigate the applicability of DeLone and McLean's (1992) model of IS success to UDAs. It sought to measure all the IS success factors included in the model, and to demonstrate how they might be related in the UDA domain. In order to enable testing, it was, however, necessary to make several modifications to the model. These are described below.

Model to be Tested

Two modifications were made to DeLone and McLean's model to recognize earlier research results. DeLone and McLean had included both objective and subjective measures of system quality in their single system quality category. However, because of concerns about the ability of end user developers to make judgments about system quality (Edberg & Bowman, 1996), perceived system quality and system quality were specified as separate constructs in the model to be tested here. In addition, because prior research suggests that user satisfaction causes system usage rather than vice versa (Baroudi et al., 1986) the causal path between satisfaction and use was specified in this direction.

In the UDA domain, time spent using a system may be confounded with time

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spent on iterative enhancement of the system, as evolutionary change has been shown to occur in nearly all UDAs (Cragg & King, 1993; Klepper & Sumner, 1990). Because of concerns that perceptions of current UDA use might include time spent iteratively developing the systems, intended use was considered more appropriate for this study. Intended use has been shown to be a satisfactory surrogate for actual use in studies of organizational systems (Ajzen, 1988; Klobas, 1995).

A final modification to the model reflects the difficulty in obtaining objective measures of information quality, since the quality of information in an IS is usually measured by the perceptions of those who use the information. The measures in DeLone and McLean's information quality category were mostly of this kind. In this study, the information quality category is acknowledged to be perceived information quality. The model tested in the study is therefore the model presented in Figure 2.

Hypotheses

The hypotheses that follow directly from this model are:

H1: User developers' perceptions of system quality reflect actual system quality.

H2: User developers are more satisfied with systems of higher perceived information quality.

H3: User developers are more satisfied with systems of higher perceived system quality.

H4: User developers intend to use systems of higher perceived information quality more often.

H5: User developers intend to use systems of higher perceived system quality more often.

H6: Higher levels of user satisfaction result in higher levels of intended use.

H7: The impact of a UDA on an individual's work performance increases as intended use increases.

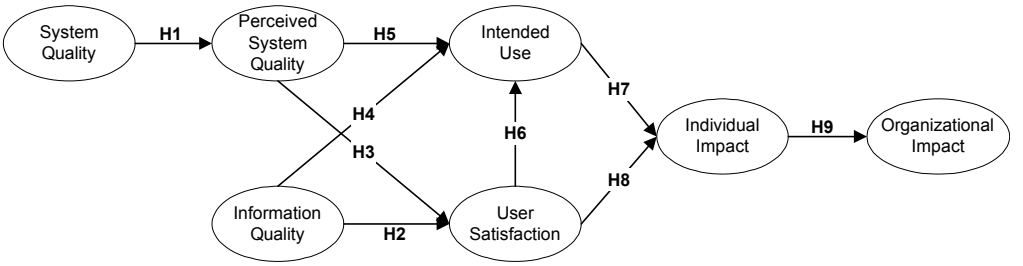
H8: The impact of a UDA on an individual's work performance increases as user satisfaction increases.

H9: The organizational impact of a UDA increases as the impact on an individual's work performance increases.

METHOD

This study was conducted in an environment where UDAs were used to support business decision-making. The UDAs studied were spreadsheet applications and

Figure 2: A Modified and Testable Representation of the DeLone and McLean (1992) Model of IS Success Factors Showing the Hypothesized Relationships



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the decision-making took place in a simulated business environment. The participants were postgraduate business students with substantial previous work experience who were participating in a course on strategic management. They developed and used spreadsheet applications to support decision-making in a business policy simulation 'game.' This research environment was chosen for the study because it provided an opportunity to explore the nature of end user development of applications, the impact of UDAs on organizational outcomes, and the ability of end user developers to make judgments about the quality and success of the applications they develop, in a controlled setting.

The major advantages of the approach chosen were firstly that, within the simulated business, participants acted as real end user developers, developing applications to support their 'work.' While conducted as part of an academic course of study, this situation was less artificial than an experiment because development of spreadsheets was not a requirement of the business game. Whilst all participants were involved in application development for the simulated business, they developed spreadsheets because they recognized the potential value of a UDA for decision support rather than because of any compulsion resulting from the research study.

The second advantage was that because the participants were involved in a business simulation, it was possible to obtain organizational performance measures that should have been directly linked to the performance of the individuals involved. Goodhue and Thompson (1995) stressed the need to go beyond perceived performance impacts and make objective measurements of performance. However, it has proved to be difficult to measure the organizational impact of individual applications (DeLone & McLean, 1992) and in particular UDAs (Shayo et al., 1999), so this situation provided a unique opportunity to explore the full series of relationships represented in DeLone and McLean's (1992) model of IS success. The opportunity to undertake a study in a partially controlled environment, where the possible impact of UDAs on organizational outcomes could be investigated with minimum confounding by extraneous variables, was considered worth trading off against the greater generalizability that could have been obtained from a study of end user development in actual organizations. Thus whilst the artificial nature of the organizational impact measures is an undeniable disadvantage, the strong internal validity of the approach should provide a strong foundation for future studies with a wider range of end user developers.

A further reason for the choice of research environment was the fact that spreadsheets were the tool recommended for participants to develop their applications. Spreadsheets are the most commonly used tool for end user development of applications (Taylor, Moynihan, & Wood-Harper, 1998) and by studying their use, maximum generalizability of results would be possible.

The Game

The Business Policy Game (BPG) (Cotter & Fritzche, 1995) simulates the operations of a number of manufacturing companies. Teams compete with one another as members of the management of these companies, producing and selling a consumer durable good. Individual participants assume the roles of managers, and make decisions in the areas of marketing, production, financing, and strategic planning. Typical decisions to be made include product pricing, production scheduling, and

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obtaining finance. As the simulation model is interactive, decisions made by one company influence the performance of other companies as well as their own.

In this study, the decisions required for the operation of each company were made by teams with four or five members. Each team was free to determine its management structure, but in general, the groups adopted a functional structure, with each member responsible for a different area of decision-making. Formal group decision-making sessions of about one hour were held before each set of decisions was recorded, and these were preceded by substantial preparation. Decisions were recorded twice a week and the simulation run immediately afterwards so that results were available for teams to begin work on the decisions for the next period.

The simulation was run over 13 weeks as part of a capstone course in strategic management. It simulated five years of business performance with each biweekly decision period equating to one financial quarter. Participants drew upon both their previous business knowledge, and that acquired during their program of study. Successful decision-making required applications of equivalent complexity to those used in 'real' businesses (Cotter & Fritzche, 1995). The simulation accounted for 50% of the participants' overall course grade, so successful performance was very important to them. Half of these marks were based directly on the company's performance.

Participants

The 79 participants in this study were end user developers, developing applications to support decision-making as part of their 'work,' in this case for a fictitious manufacturing company as part of the BPG, but ultimately to have an impact on their performance in their unit of academic study. They were all Master's of Business Administration (MBA) students who had at least two years of previous professional employment experience, as this was a condition of entry to the MBA. Most were studying part time while working in business. Their ages ranged from 21 to 49 with an average age of 31.8; 78.5% were male and 21.5% female. They had an average of 9.5 years experience using computers (with a range from 2 to 24 years) and reported an average of 5.9 years experience using spreadsheets (with a range from 0 to 15 years).

The applicability of research findings derived from student samples has been raised as an issue of concern (Cunningham, Anderson, & Murphy, 1974). However, Briggs, Balthazard, & Dennis (1996) found MBA students to be good surrogates for executives in studies relating to the use and evaluation of technology, suggesting that the participants in this study can be considered as typical of professionals who would be involved in user development of applications in organizations.

The User-Developed Applications

The teams developed their own decision support systems using spreadsheets to help in their decision-making. These decision support systems could consist of either a workbook containing a number of linked worksheets, or a number of standalone workbooks, or a combination of standalone and integrated worksheets and workbooks. Where several members of a team worked on one workbook each was responsible for one worksheet, that relating to their area of responsibility. Figure 3 provides an example of the possible decision support configurations for the teams.

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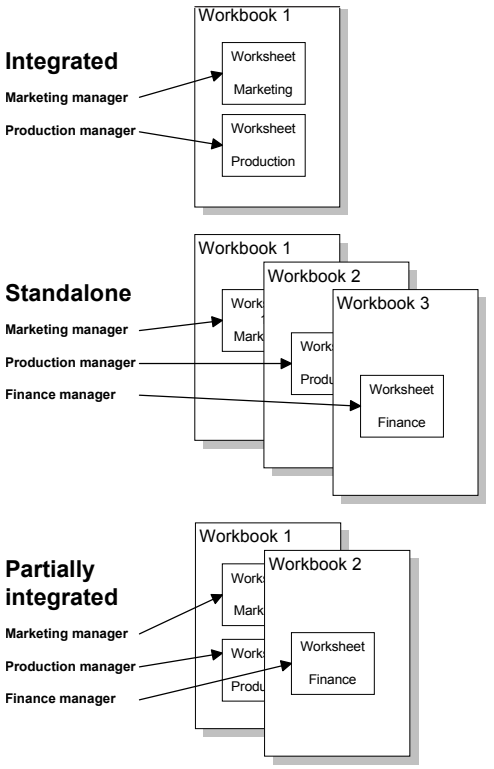
Figure 3: Possible Decision Support Configurations for Teams in the BPG



In each case, a single individual was responsible for the development of an identifiable application: either a whole workbook or one or more worksheets within a team workbook. Hence, the unit of the analysis in the study was an individual's application.

If they wished, the participants were able to use simple templates available with the simulation as a starting point for their applications, but they were not constrained with respect to what they developed, how they developed it, or the hardware and software tools they used. The majority of applications were developed in Microsoft Excel© but some participants also used Lotus 1-2-3© and Claris Works©. The spreadsheets themselves were not part of the course assessment and participants were reassured of this, so there were no formal requirements beyond students' own needs for the game.

The fact that development of applications was optional and unrelated to the purposes of this study reflects the situation in industry where the ability to develop small applications is a necessary part of many jobs (Jawahar & Elango, 2001), yet few spreadsheet developers have spreadsheet development in their job descriptions (Panko, 2000). Because the successful performance of their 'company' had direct and significant implications for their grade in the course, the allocation of grades provided external motivation for performance in the game. Because participants voluntarily developed spreadsheets as a tool to support their performance in the game, and not as a contrived task which was in itself evaluated, motivation to perform in this study is more similar to motivation to perform in a business environment than to past studies that have been criticized for using student participants and contrived tasks (Cunningham et al., 1974).

Procedure for Collection of Data

Each participant was asked to complete a written questionnaire and provide a copy of their spreadsheet on disk after eight 'quarterly' decisions had been made (four weeks after the start of the simulation). This point was chosen to allow sufficient time for the development and testing of the applications. Ninety-one questionnaires were distributed and 79 useable responses were received giving a response rate of 86.8%.

The Instrument

The development of the research instrument for this study involved a review of many existing survey instruments. To ensure the reliability and validity of the

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measures used, previously validated measurement scales were adopted wherever possible.

System Quality and Perceived System Quality

The items used to measure system quality and perceived system quality were obtained from the instrument developed by Rivard et al. to assess the quality of UDAs (Rivard et al., 1997). This instrument was designed to be suitable for end user developers to complete, yet to be sufficiently deep to capture their perceptions of components of quality. For this study, items which were not appropriate for the applications under consideration (e.g., specific to database applications) or which were not amenable to independent assessment (e.g., required access to the hardware configurations on which the spreadsheets were originally used) were excluded. Minor adaptations to wording were also made to reflect the environment in which application development and use occurred. The resulting item set consisted of 40 items, each scored on a Likert scale of 1 to 7 where (1) was labeled 'strongly agree' and (7) was labeled 'strongly disagree.'

In addition to the participants' assessments of system quality, the system quality of each UDA was assessed by two independent assessors using the same set of items. Both assessors were IS academics with substantial experience teaching spreadsheet design and development. The two final sets of assessments were highly correlated ($r = 0.73$, $p = 0.000$).

Perceived Information Quality

The item pool used to measure perceived information quality consisted of Fraser and Salter's (1995) 14-item, 7-point scale instrument where (1) is labeled 'never' and (7) is labeled 'always.' All items in this established scale can be interpreted in relation to UDAs. A typical item on this scale is 'Does the system provide the precise information you need?'

User Satisfaction

Given the confounding of user satisfaction with information quality and system quality in some previous studies (Seddon & Kiew, 1996), items measuring only user satisfaction were sought. Seddon and Yip's (1992) 4-item, 7-point semantic differential that attempts to measure user satisfaction directly was used in this study. A typical item on this scale is 'How effective is the system?', measured from (1) 'effective' to (7) 'ineffective.'

Intended Use

Development and use of decision support systems was optional in the BPG, so use is a pertinent measure of success in this study (DeLone & McLean, 1992). Because of concerns that perceptions of current use might include time spent iteratively developing the systems, intended use was considered more appropriate. Participants were asked to indicate their intended use of the system over the next four quarterly decisions in the BPG. This item was based on Amoroso and Cheney's (1992) item to measure intended use and was measured on a five- point scale ranging from (1) 'rarely' to (5) 'often.' The timing of data collection for this study means that intended use would reflect responses to the success of the IS during the preceding four weeks.

Individual Impact

Individual impact was measured by perceived individual performance impact since objective measures of individual impact were not available from the BPG. The

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two items used by Goodhue and Thompson (1995) in their study on task-technology fit and individual performance were adopted for this study. These items are measured on a 7-point Likert scale ranging from (1) 'agree' to (7) 'disagree.'

Organizational Impact

The BPG provides an objective measure of organizational performance. The Z-Score measure of organizational performance is a weighted sum of Z-scores on 17 performance variables. These performance variables include: net income, sales (percent of market), total equity, unit production cost, investor's ROI, stock price, and earnings per share. Cotter and Fritzche (1995) consider that the Z-Score measure closely matches both the subjective assessments of the writers of the BPG and those of business people who have judged intercollegiate competitions of the game. It was thus chosen as a single composite measure of organizational impact.

DATA ANALYSIS

The relationships in the model were tested using structural equation modeling (SEM). Maximum likelihood estimates of the measurement and structural models were made using Amos 3.6. Goodness of fit was measured by the likelihood ratio chi-square (χ^2), the goodness of fit index (GFI), the root mean square error of approximation (RMSEA), the Tucker-Lewis index (TLI), and the comparative fit index (CFI). The guidelines used for good model fit were: a non-significant χ^2 ($p>0.05$); GFI of 0.9 or greater; RMSEA of less than 0.05 (Schumacker & Lomax, 1996); TLI of 0.90 or greater; and CFI of 0.90 or greater (Kline, 1998).

Measurement Model Estimation

Although both structural and measurement models can be estimated simultaneously using SEM, the measurement model was developed first in this study. This approach was appropriate because the measures had not been tested in the UDA domain before, and because the sample size was small (Anderson & Gerbing, 1988).

After indicator variables with low inter-item correlations were omitted, SEM was used to estimate a one-factor congeneric measurement model for each multi-item construct. Validity and unidimensionality were demonstrated when all included indicators were statistically significant and the one factor measurement model that represented the construct had acceptable fit (Hair, Anderson, Tatham, & Black, 1998). Three estimates of reliability were calculated for each construct: Cronbach's alpha coefficient, composite reliability, and average variance extracted. For unidimensional scales, values for Cronbach's alpha of 0.7 or higher indicate acceptable internal consistency (Nunnally, 1978). A commonly used threshold value for composite reliability is 0.7 (Hair et al., 1998) and a variance extracted value greater than 0.5 indicates acceptable reliability (Hair et al., 1998). Although not all of the goodness of fit measures met the guidelines, overall fit for each measurement model was considered acceptable. The three measures of reliability were all acceptable for each scale (see Table 2).

The measurement model for each construct provided a composite value for inclusion in the structural model; variables estimated in this way are described as 'composite variables.' Composite variables were created for perceived information quality, system quality, perceived system quality, and user satisfaction using the fac-

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Table 2: Summary of the Information from the Measurement Models Used to Specify Parameters in the Structural Models

Construct	Cronbach's alpha	Composite variance	Variance extracted	Mean	SD	Loading	Error
System Quality[c]	0.84	0.84	0.52	3.03	0.64	0.5940	0.0675
Perceived System Quality[c]	0.73			3.60	0.80	0.6865	0.1743
Perceived Information Quality[c]	0.93	0.94	0.72	5.25	1.06	1.0301	0.0703
User Satisfaction[c]	0.75	0.77	0.53	4.86	1.21	1.057	0.3361
Intended Use[s]				3.62	1.29	1	0
Perceived Individual Impact*	0.92	0.92	0.86				
Organizational Impact[s]				0.046	0.61	1	0

[c] Composite variable; * Two items; [s] Single item

tor score weights reported by Amos 3.6. The loading of each composite variable on its associated latent variable and the error associated with using the composite variable to represent the latent variable were estimated as described by Hair et al. (1998). Table 2 provides a summary of the information from the measurement models used to specify parameters in the structural models.

Structural Model Evaluation

Once measurement models were established, it was possible to estimate the hypothesized structural model of UDA success. The Appendix at the end of this paper contains a list of all the items used in the structural model to measure the constructs in the DeLone and McLean model. This model was evaluated on three criteria: goodness of fit, the ability of the model to explain the variance in the dependent variables, and the statistical significance of estimated model coefficients.

The dependent variables of most interest in the DeLone and McLean model are individual impact and organizational impact. The squared multiple correlations (R^2) of the structural equations for these variables provided an estimate of variance explained (Hair et al., 1998), and therefore an indication of the success of the model in explaining these variables.

If the hypothesized model is a valid representation of end user-developed application success, all proposed relationships in the model (the relationships reflected in H1 to H9) should be significant. All of the hypotheses specify a direction for the proposed relationship so a one-tailed t-value of 1.645 indicates significance at the 0.05 level (Hair et al., 1998).

RESULTS AND DISCUSSION

Table 3 shows the goodness of fit measures, model coefficients, standard errors, and t-values for the model. Figure 4 shows the standardized coefficients for each hypothesized path in the model and the R^2 for each dependent variable.

The first criterion considered, goodness of fit, provided conflicting information. Model χ^2 was 27.74, with 16 degrees of freedom, significant at 0.034. RMSEA was also above the recommended level at 0.097. However, the GFI (0.921), TLI (0.904), and CFI (0.945) all indicated good fit. Although not all of the goodness of fit measures met the guidelines, overall fit was considered acceptable.

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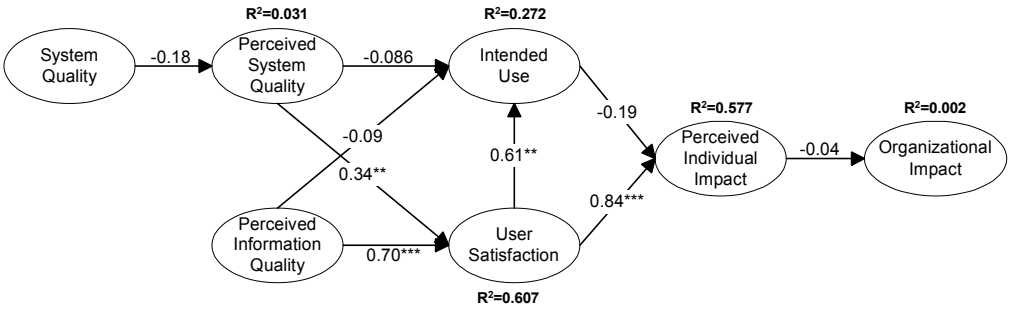
Table 3: Goodness of Fit Measures Model Coefficients, Standard Errors, and T-Values for the Model

Path From	To	Estimate	Standard error	*t*-value
System Quality	Perceived System Quality	-0.179	0.144	-1.240
Perceived Information Quality	User Satisfaction	0.643	0.095	6.798***
Perceived System Quality	User Satisfaction	0.310	0.105	2.955**
Perceived Information Quality	Intended Use	-0.113	0.258	-0.439
Perceived System Quality	Intended Use	-0.111	0.195	-0.568
User Satisfaction	Intended Use	0.843	0.336	2.513**
Intended Use	Perceived Individual Impact	-0.183	0.118	-1.547
User Satisfaction	Perceived Individual Impact	1.131	0.197	5.735***
Perceived Individual Impact	Organizational Impact	-0.022	0.058	-0.376
Goodness of fit measures				
Chi-square (χ^2)		27.74		
Degrees of freedom (df)		16		
Probability (p)		0.034		
Goodness of fit index (GFI)		0.924		
Root mean square error of approximation (RMSEA)		0.097		
Tucker-Lewis index (TLI)		0.904		
Comparative fit index (CFI)		0.945		

** p < 0.01 (one tailed test) *** p < 0.001 (one tailed test)

Figure 4: Structural Equation Model Showing the Standardized Path Coefficient for Each Hypothesized Path and the R^2 for Each Dependent Variable



The model explains the variance in perceived individual impact moderately well: R^2 was 0.577 (i.e., 57.7% of the variance was explained). However, the R^2 for organizational impact was only 0.002, indicating that almost none of the variance in organizational impact was explained by the model.

The third criterion on which the model was evaluated was the statistical significance of the estimated model coefficients. As can be seen from the t-values in Table 3, four of the paths in the model were significant, supporting the hypothesized relationships between the constructs.

Hypothesized Relationships Supported by this Research

The hypothesized relationships supported by this study were: perceived system quality and user satisfaction (H3); perceived information quality and user satisfaction (H2); user satisfaction and use (H6);

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and user satisfaction and individual impact (H8). These are illustrated in Figure 5.

User Satisfaction Reflects Perceived Information Quality and Perceived System Quality

The findings that perceived information quality had a large positive influence on user satisfaction, and that perceived system quality had a significant positive influence on user satisfaction, are consistent with the findings of Seddon and Kiew (1996) for organizational systems. Seddon and Kiew (1996) suggested that user satisfaction might be interpreted as a response to three types of user aspirations for a system: information quality, system quality, and usefulness. Perceptions of information quality and system quality should then explain a large proportion of variance in user satisfaction.

User Satisfaction Influences Intended Use

User satisfaction had a significant positive influence on intended use. Thus, the more satisfied with an application an end user was, the more they intended to use the application in the future. This is consistent with Baroudi et al.'s (1986) findings in the organizational domain.

The issue of a two-way relationship between use and satisfaction, as in DeLone and McLean's original model, whilst not formally explored in this paper was addressed in post hoc analysis. When the model was altered to include a two-way relationship between use and satisfaction and then tested using AMOS, there was an identification problem, which meant that the model could not be uniquely estimated. It hence could not be accepted. This post hoc analysis does not, however, preclude a more complex relationship, which should be tested in future research: user satisfaction may explain intended use, while actual use may affect subsequent user satisfaction.

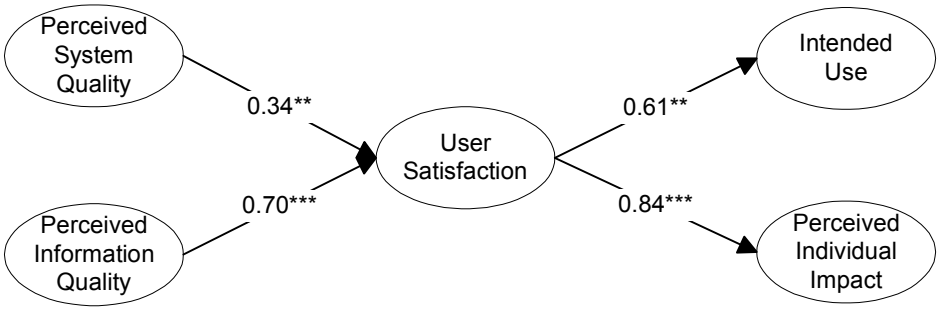
User Satisfaction Influences Perceived Individual Impact

User satisfaction strongly influenced the perceived impact of the UDA on the individual user ($R^2 = .577$). Again, this finding is consistent with the results of studies conducted with organizational systems (e.g., Gatian, 1994; Gelderman, 1998; Roldán & Millán, 2000). In this study, the more satisfied the user developers were with their systems, the more strongly they agreed that the system helped them perform well in the business game.

Hypothesized Relationships Not Supported by This Research

The hypothesized paths that were not

Figure 5: Relationships Between IS Success Factors Supported by this Research in the UDA Domain



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supported by this study were: system quality→perceived system quality (H1); perceived information quality→use (H4); perceived system quality→use (H5); use → individual impact (H7); and individual impact →organizational impact (H9).

System Quality Does Not Influence Perceived System Quality

The lack of relationship between system quality and perceived system quality in this study provides justification for the concerns expressed in the literature about the ability of end users to make realistic judgments of system quality (Edberg & Bowman, 1996).

The lack of relationship between system quality and perceived system quality might be due to two factors. Firstly, end user developers' perceptions of system quality might be compromised if they lack the knowledge to make realistic judgments. Secondly, their judgment might be clouded by their close involvement with both the application development process and with the application itself. Cheney, Mann, and Amoroso (1986) argued that end user development can be considered as the ultimate user involvement. End user developers are not only the major participants in the development process but also often the primary users of their applications. Applications can come to be viewed as much more than merely problem-solving tools.

Perceived Information Quality and Perceived System Quality Do Not Directly Influence Intended Use

Neither perceived information quality nor perceived system quality influenced intended use directly. Post hoc analysis (Baron & Kenny, 1986) showed that information quality has a significant ($p < 0.05$) indirect effect on use via user satisfaction, but that the indirect effect of perceived system quality on use via user satisfaction was not significant. The indirect influence of perceived information quality on intended use has been demonstrated in research on other types of systems (Klobas & Clyde, 2000; Klobas & Morrison, 1999). These observations confirm the need for further research on how perceived quality affects intended system use, with the mediation of attitudes including (but not limited to) user satisfaction.

The lack of evidence for any linear influence (either direct or indirect) of perceived system quality on intended frequency of use may point to a different influence function. Users may need to use a poor quality system more frequently to meet their needs. Alternatively, they may choose to use a high quality system more frequently because it meets their needs well. Further research is needed to understand reasons for differences on intended frequency of use.

Intended Use Does Not Influence Perceived Individual Impact

No significant relationship was found between intended use and perceived individual impact. This is consistent with Gelderman's (1998) and Roldán and Millán's (2000) observations in the organizational domain and Seddon's (1997) contention that the causal relationship between use and individual impact proposed by DeLone and McLean may not exist.

In this study, anticipated higher frequency of use over subsequent decision periods was not associated with any increase in perceptions that using the system would have greater impact on success in the business game. If we assume that, given the close proximity between future use and survey completion, intended use is a good surrogate for past use in this case, we need to explain why higher frequen-

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cies of use are not associated with higher perceived individual impact. One reason was identified earlier: higher frequency of use may reflect an inefficient system and therefore low productivity rather than frequent use to obtain substantive benefits. In the UDA domain, an additional issue is that time spent using the system may be confounded with time spent on iterative enhancement of the system. In their 18 month study of 51 UDAs, Klepper and Sumner (1990) found that evolutionary change occurred in nearly all the UDAs. Frequency of use may be a less valuable indicator of system success in the UDA domain than in the organizational domain, unless researchers are able to differentiate time spent on development and time spent on unproductive work from time spent using the system to obtain information or to assist directly with decision-making.

Individual Impact does not Influence Organizational Impact

Individual impact did not have a significant influence on organizational impact. The participants in the study evidently felt their UDAs were contributing to their individual performance, yet this was not reflected in the game outcome. The relationship between individual impact and organizational impact is acknowledged to be complex (Ballantine et al., 1998; Shayo et al., 1999). Organizational impact is a broad concept, and there has been a lack of consensus about what organizational effectiveness is and how it should be measured (Thong & Chee-Sing, 1996). Roldán and Millán (2000) used four measures of individual impact and four measures of organizational impact in their investigation of the applicability of DeLone and McLean's model in the executive IS domain. They tested relationships between each possible pair of individual impact and organizational impact measures and obtained inconsistent results.

Whilst changes in quantitative indicators of organizational effectiveness would provide a clear signal of organizational impact, more subtle impacts may be involved. DeLone and McLean (1992 p. 74) recognized that difficulties are involved in "isolating the effect of the I/S effort from the other effects which influence organizational performance." Again, this issue is likely to be magnified in the UDA domain, where system use may be very local in scope. Any changes in organizational impact for a particular organization would be the result of the combined individual effects of the UDAs in the organization, which may well be of varying quality. Individual UDAs could have potentially conflicting effects on each other's use as well as on organizational effectiveness, making it difficult to detect a systematic effect.

In the study in which they reported a relationship between individual impact and organizational impact, Kasper and Cerveny (1985) used objective measures for both constructs. It is possible that perceived individual impact is not a realistic indicator of actual individual impact, but rather is biased because of factors not included in this model, distorting its relationship with organizational impact. This would suggest that user developers are not only poor judges of the quality of their systems, but also poor judges of the impact of their systems on their own performance.

Demonstrating UDA Impact and Success Within the DeLone and McLean Framework

The four hypothesized DeLone and McLean model paths that were supported in this study suggest that the impact of a UDA is mediated via user satisfaction.

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Perceived system quality and perceived information quality result in increased satisfaction, which, in turn, is associated with increased intended use and increased perceived individual impact.

A major benefit claimed for user development of applications is improved quality of information because end users should have a better understanding of the information they require. If end users are 'experts' with respect to their information, then the strong positive relationship between perceived information quality and user satisfaction is a valuable one. It should reassure organizations that rely on user satisfaction with UDAs as the sole measure of application success that the satisfaction of end users will not be disproportionate to the quality of information provided by the applications, and that end user developers can recognize when use of an application might require caution or be inadvisable. This conclusion, however, rests on the assumption that end user developers are 'experts' with respect to the quality of information they use. Given the lack of relationship between system quality and perceived system quality in this study, this assumption should be explored in future research.

The lack of relationship between system quality and perceived system quality suggests another reason for caution on the part of organizations. Most organizations place a heavy reliance on the individual end user's perceptions of the value of applications they develop. If the satisfaction of the user developer is the sole measure of application success, and satisfaction does not reflect system quality, then the benefits anticipated from end user development of applications may be compromised, and the organizations may be put at risk.

It appears that Melone's (1990) caution that the evaluative function of user satisfaction can be compromised by the role of attitude in maintaining self-esteem is particularly relevant in the UDA domain. The literature on user involvement indicates that increased involvement is associated with increased user satisfaction (Amoako-Gyampah & White, 1993; Barki & Hartwick, 1994; Doll & Torkzadeh, 1988; Lawrence & Low, 1993), and that this might be mediated via increased perceived quality, but if perceived quality does not reflect actual quality, other benefits of higher involvement must be demonstrated.

On the other hand, the observed influence of user satisfaction on perceived individual impact is encouraging. It suggests that organizational reliance on end user developers' satisfaction with the applications they develop may not be misplaced. It would, however, be useful to have this finding confirmed using an independent measure of individual impact, particularly given the lack of a relationship between perceived individual impact and organizational impact in this study. Differences attributable to the user also being the developer could be identified, and an explanation of the relationship between perceived and actual individual impact and organizational impact identified.

Alternatives to the DeLone and McLean Model

Seddon (1997), identifying some problems with DeLone and McLean's model as a model of IS success, suggested that, rather than a single sequence of relationships, there were two linked sub-systems: one that explained use, and another that explained impact. He argued that use is not an indicator of IS success, but that user satisfaction is because it is associated with impact. There are no published empirical tests of the full proposed model, but this study provides support for Seddon's pro-

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posal to separate impact measures from one another and from use: there was no evidence of correlation between use, individual impact, or organizational impact. This study does not, however, support Seddon's proposal for two separate sub-systems; rather, it suggests that user satisfaction is a key indicator of subsequent outcomes, including use and individual impact. A single model that explains user satisfaction is therefore more appropriate than Seddon's proposed dual system model.

The DeLone and McLean model was also analyzed critically by Ballantine et al. (1998) who, like Seddon, proposed but did not test an alternative. The Ballantine model suggested that a three-dimensional model of success may be more appropriate, but again the present study does not support such a separation.

A different approach has been followed by Goodhue and colleagues (Goodhue, 1988; Goodhue, 1995; Goodhue, Klein, & March, 2000; Goodhue & Thompson, 1995). Drawing on the job satisfaction literature, they proposed that an explanation of IS success needs to recognize the task for which the technology is used and the fit between the task and the technology. They proposed a Technology to Performance Chain that is consistent with DeLone and McLean's model in that both use and user attitudes about the technology lead to individual performance impacts. Reflection on Goodhue's concept of task-technology fit suggests that the lack of observed relationship between use and impact in the study reported here may be explained by the need to use the system for more tasks (learning and development) than the functional tasks on which impact (performance) measures were based. Nonetheless, Goodhue's model does not resolve the questions of relationship between use and user attitudes raised by both the results reported here and the criticisms of the DeLone and McLean model offered by Seddon and Ballantine and his colleagues.

Behavioral intention models may also be useful in understanding UDA success. The most popular use model in recent IS literature, the Technology Acceptance Model (Davis, 1986), has been used consistently to demonstrate that perceived usefulness of a system is associated with its use (Adams, Nelson, & Todd, 1992; Davis, 1989, 1993; Taylor & Todd, 1995). It makes intuitive sense to propose that perceived usefulness is associated with actual usefulness and therefore with the impact of an IS. Several richer use models have been developed from Ajzen and Fishbein's work on the social psychology of human behavior (the Theory of Reasoned Action, (Fishbein & Ajzen, 1975); the Theory of Planned Behavior (Ajzen, 1991)). These models characterize use as a human behavior influenced by beliefs about, and attitudes to, the outcomes of use, and usefulness as one of the desired outcomes associated with use. One such model, the Planned Behavior in Context (PBiC) model (Klobas & Clyde, 2000; Klobas & Morrison, 1999), has been used to demonstrate that users' attitudes to a range of individual impacts (outcomes), including but not limited to usefulness, influence their intention to use Internet-based ISs. Provided there is a relationship between the outcomes of use that are valued by individual users and the impact of systems on individuals and organizations, the PBiC and other use models based on Ajzen and Fishbein's work may contribute to more satisfactory explanations of IS success. Further research in this direction is recommended.

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CONCLUSIONS

This study has provided the first empirical test of an adaptation of the DeLone and McLean model in the UDA domain. The model was only partially supported by the data. Of the nine hypothesized relationships tested by SEM, four were found to be significant and the remainder not significant. The analysis provided strong support for relationships between perceived system quality and user satisfaction, perceived information quality and user satisfaction, user satisfaction and intended use, and user satisfaction and perceived individual impact.

It is notable that the model paths that were supported in this study are those that reflect user perceptions rather than objective measures. User satisfaction reflects a user's perceptions of both quality of the system itself and the quality of the information that can be obtained from it. Intended ongoing use of the IS reflects user satisfaction, and the impact that an individual feels an IS has on their work reflects their satisfaction with the IS. However, no significant paths were found involving the objectively measured constructs system quality and organizational impact. System quality did not influence perceived system quality, and perceived individual impact did not influence organizational impact.

This study indicates that user perceptions of IS success play a significant role in the UDA domain. Further research is required to understand the relationship between user perceptions of IS success and objective measures of success, and to provide a model of IS success appropriate to end user development.

APPENDIX

Items used to measure constructs in the DeLone and McLean model

Information Quality

Do you get the information you need in time?
Does the system provide output that seems to be just about exactly what you need?
Does the system provide the precise information you need?
Does the system's information content meet your needs?
Is the information provided by your system understandable?
Is the information provided by your system complete?

System Quality and Perceived System Quality

Economy

The system increased my data processing capacity

Portability

The system can be run on computers other than the one presently used
The system could be used in other similar organizational environments, without any major modification

Reliability

Unauthorised access is controlled in several parts of the system
The data entry sections provide the capability to easily make corrections to data
Corrections to errors in the system are easy to make

Understandability

The same terminology is used throughout the system
Data entry sections are organized in such a way that the data elements are logically grouped together
The data entry areas clearly show the spaces reserved to record the data
Data is labeled so that it can be easily matched with other parts of the system
The system is broken up into separate and independent sections
Each section has a unique function
Each section includes enough information to help you understand its functioning
The documentation provides all the information required to use the system
The documentation explains the functioning of the system

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Userfriendliness

Using the system is easy, even after a long period of non-utilization
The system is easy to learn by new users
The terms used in data-entry sections are familiar to users
Queries are easy to make

User Satisfaction

How efficient is the system used for your area of responsibility? (inefficient …..efficient)
How effective is the system? (effective……ineffective)
Overall, are you satisfied with the system? (dissatisfied……..satisfied)

Use

Overall, how would you rate your intended use of the system over the next year of the BPG? (rarely….often)

Individual Impact

The system has a large, positive impact on my effectiveness and productivity in my role in the BPG
The system is an important and valuable aid to me in the performance of my role in the BPG

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