Exploring Some Determinants of ES Quality

by

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ABSTRACT

Some important determinants for Expert Systems (ES) quality are field tested. To reduce possible confounding results that may occur due to interorganizational differences, a case study approach to data collection in a single company has been used. The company is E.I. DuPont de Nemours & Company, Inc., which since 1986 has implemented over 1200 ES within the organization. The results corroborate four of the five hypothesized determinants of ES quality. One of the most important factors is the selection of an appropriate ES development shell which matches the business problem. Developer skills and the end-user characteristics addressed in this study are also directly related to ES quality as measured by user satisfaction with ES friendliness, usefulness of system documentation, and the quality of the information provided by the ES.
KEYWORDS: Expert Systems, Quality, User Satisfaction, Quality Factors.

INTRODUCTION

As a reaction to the need to increase competitiveness American industry embarked in a widespread effort to improve quality of its products, services, and business processes on a continuous basis. At the same time, information systems have gained an increasingly important role in accomplishing such company objectives. As business dependence on software systems increases, so does the need to ensure that it performs according to specifications and/or user needs and wants. Thus, considerable attention is being paid to improving software quality. Industry standards for software systems quality control include those in the Malcolm Baldrige National Quality Award and the ISO 9000 series. Baldrige Quality Award requires that candidate organizations must use software quality metrics and sophisticated quality measurement systems. ISO 9000 series quality standard requirements for software development include the definition of management responsibility in quality control, document control, implementation of process control by inspection & testing and verification of test results, performing corrective actions when appropriate, internal quality audits, personnel training, and after-delivery servicing statistical analysis.

From another perspective, despite continuous efforts to improve the software development process, controlling software quality remain difficult in today's software development environment. The fundamental principles of Total Quality Management concept stated that in order to properly control quality, it must be measured [Hoffer, George and Valacich, 1996]. However, recent study by Pearson, McCahon & Hightower [1995] found that it normally takes three-to-five years for the quality program to yield significant benefits in areas of customer satisfaction and quality of product and services. A study by Jones [1986] found the costs of defect removal among the top expenses in software development projects. Furthermore, inadequate and insufficient published empirical studies on software quality have made it difficult for project managers to effectively apply available software metrics and strategies in management and quality control.

The complexity of assessing the many dimensions of software system quality stems from its many dimensions. Humphrey [1989] classifies the measurement of software quality into five general classes: development, product, acceptance, usage, and repair. These classes are to be measured in terms of objectivity, timeliness, availability, representativeness, and ability to control by developers. The critical software system quality management issues are many, including: What are the different ways to measure software quality? What are the strengths and weaknesses of each approach? To investigate these questions, the following sections present the conceptual framework for the study, and the methodology used. That is followed by the results from the study and conclusions.

<u>User Information Satisfaction (UIS)</u>

Measures of user satisfaction (UIS) with computerized system have been widely used as measures for system quality [Guimaraes, Igbaria and Lu, 1992; Yoon, Guimaraes and O'Neal, 1995]. UIS is defined as the extent to which users believe the information system available to them meets their information requirements. The summary results obtained from the UIS instrument provides a subjective assessment of system success. User satisfaction with a system deals with how users view their information system but not the technical quality of the system. In other words, it measures users' perception of the information services provided, rather than a direct assessment of the functional capabilities of the system. UIS is a widely used method [DeLone and McLean, 1992] to measure whether users believe their IS meets their information requirements. This is a very reliable construct that has been rigorously tested and validated by many researchers [Bailey and Pearson, 1983; Baroudi and Orlikowski, 1988; Gallagher, 1974; Ives, Olson and Baroudi, 1983; Jenkins and Ricketts, 1986; Larcker and Lessig, 1980]. Using Likert scales, it collects user perceptions about the system such as accuracy of information produced, timeliness of reports, and attitude of support staff.

System Quality as Its Ability to Satisfy User Requirements

From an engineering perspective, the quality of a product or service is commonly measured in terms of its fitness for intended use, i.e., it must be adequate for the application the customer has in mind [Dilworth, 1988]. According to the American National Standards Institute, quality "is the totality of features and characteristics of a product or service that bears on its ability to satisfy given needs" [ANSI/ASQC, 1978]. Quality control activities are undertaken with the objective of designing, developing, and tailoring a product to satisfy user's requirements [Evans and Lindsay, 1980]. Enterprises that have attained high levels of quality state that the ultimate yardstick of quality is attaining maximal satisfaction of customer's needs and expectations [Chief Information Officer CIO, 1991].

An Expert System (ES) is a computer system which mimics the behavior of human experts by encapsulating their expertise in solving problems in a particular domain. Due to its nature, ES has demonstrated potential for improving the productivity of organizations by enabling business process improvements and supporting end-user tasks. For many companies, the rewards from successful ES have been considerable [Feigenbaum, McCorduck, & Nii, 1988; Shpilberg, Graham, & Schatz, 1986]. For example, XSEL and XCON have saved approximately 40 million each year for DEC [Liebowitz, 1990]. On the other hand, success is not guaranteed and many ES projects have failed miserably. Constructing ES in many cases is a difficult task. There are many ES which have failed to be operationalized and/or were not accepted by target end-users [Guimaraes, Igbaria, & Lu, 1992; Keyes, 1989b; Sloane, 1991]. The mixed results calls for a better understanding of the major factors leading to the success or failure of an expert system.

The mainstreams of ES research have remained focused on ES technical aspects. A few studies have been conducted to address ES managerial aspects [e.g. Barsanti, 1990; Hayes-Roth & Jacobstein, 1994; O'Neal, 1990; Prerau, 1990; Turban, 1992b]. Mumford and MacDonald [1989] discussed managerial issues, based on experience building XCON and XSEL. However, prior studies on ES managerial issues have been based predominantly on the opinion and personal experience of individuals and have not been tested [Ignizio, 1991; Keyes, 1989b]. A few empirical studies, however, have been conducted to identify the factors influencing ES information quality and success as measured by end-user opinion [Byrd, 1992; Byrd, 1993; Tyran,1993; Will, McQuaig & Hardway, 1994].

The purpose of this study is to field test a small collection of likely determinants for ES quality. Due to the wide recognition of user satisfaction with the system as a useful surrogate measure of system quality, it is used in this study.

THEORETICAL FRAMEWORK

ES Quality

Gatian [1994] tested the validity of using user satisfaction as a surrogate measure of system effectiveness and confirmed its construct validity. On the other hand, the success of most expert systems has been measured by their cost saving and/or tangible benefits [Liebowitz, 1990; Sviokla, 1990], but this frequently overlooks the intangible benefits. Thus, we chose user satisfaction as the dependent variable.

Developer Skills

The importance of skillful ES developers has been emphasized by several authors [e. g. Couger & McIntyre, 1987-1988; Liebowitz, 1993; Mykytyn, P. P., Mykytyn, K. & Raja, 1994; Payne & Awad, 1990; Shacklett, 1990]. From the start knowledge engineers have been critical members of ES development teams. An ES requires developers to elicit the decision rules employed by domain experts. In order to elicit those, developers must ask relevant questions and quickly comprehend the decision procedures. The knowledge elicitation procedure is the major bottleneck in ES development. A developer with poor communication skills may not be able to perform the critical knowledge acquisition task, causing failure. Once knowledge is elicited, it is represented and stored in a knowledge base using a programming language or an ES shell. For this purpose, a developer should be familiar with at least one knowledge representation paradigm and one or more ES building tools. The following hypothesis is formulated:

H1: Developer(s) characteristics is directly related to ES quality .

End-User(s) Characteristics

The dominant end-user characteristics affecting ES **quality** include user attitude, user expectation and user knowledge of computer and ES technology, user confidence with system, and user commitment to learn how to use the system [e. g. Liebowitz, 1991]. Users often have fears about the ES affecting their job security, thus they develop negative attitudes and challenge the system [e.g. Lu & Guimaraes, 1988]. The problem of negative user attitude and resistance is more apparent with ES since they may significantly change the nature and requirements of a job and replace human tasks with artificial systems, i.e. the effect of XCON. Unlike ES developers who are expected to know a great deal about AI and ES techniques, end-users should primarily learn how to use the system and generate suggestions for continuous improvement. The above discussion strongly indicates end-users importance to ES **quality;** thus we propose the following hypothesis:

H2: End-user characteristics are directly related to ES quality .

Shell Characteristics

Prior studies have stressed the importance of building tools [Harmon, Maus & Morrisey, 1988; Kim & Yoon, 1992; Vedder, 1989; Vedder, Fortin, Lemmermann & Johnson, 1989] such as ES shells. Employing an appropriate shell is vitally important to the ES quality. For many applications, shells must enable the ES to be easily integrated with existing database and other systems [Keyes, 1989a], but many ES are capable of only limited interface. Similarly, a user-friendly interface and rapid shell execution time are important [Plant & Salinas, 1994]. Thus, the following hypothesis is formulated:

H3: Shell characteristics are directly related to ES quality .

User Involvement

ES development is thought to require a higher level of user involvement during the verification and validation phases. Medsker and Liebowitz [1994] have warned that insufficient user involvement is likely to result in ES failure and have suggested the use of project leaders who have good track records with the user community; Keyes argued that, if the end-users were excluded up front, they would exclude themselves at the end. Thus, we propose the hypothesis:

H4: User involvement is directly related to ES quality .

Management Support

Management commitment to ES development, utilization and maintenance has been recognized as a CSF for ES development [e.g. Leonard_Barton, 1987; Leonard_Barton & Deschamps, 1988; Sloane, 1991]. Keyes [1989b] reported that lack of management support was a critical barrier to ES effectiveness, and Barsanti [1990] said that a key predictor of ES effectiveness in an organization is the existence of top management support. The latter is likely to help ensure the availability of the necessary resources (appropriate shells, methods, ES developers), appropriate training, and political support in dealing with end-users. These in twin, play an important role in the development of quality ES. Thus, we propose the following hypothesis:

H5: Management support is directly related to ES quality .

STUDY METHODOLOGY

The Study Setting

In 1986, the host organization, E.I. DuPont de Nemours & Company, Inc., made the decision to pursue the use of ES to help make better decisions. At that time an Artificial Intelligence Task Force was created and charged with the broad implementation of ES technology throughout the company. This Task Force is still functioning with the same vision: *"ALL critical decisions will be made with our cumulative best knowledge and relevant information at the point of decision making."*

Since 1986, DuPont has implemented over 1200 ES throughout the organization. DuPont's way to implement ES is very different from the text book approach. Low cost tools (shells), were provided for easy to use system development. The domain experts were trained to use the tools without the need for computer group support. Corporate licenses were set-up and about 700 employees were trained so that approximately 80% of the ES have been developed by domain experts themselves.

For most ES development projects, the project leaders are the developers. ES development teams are usually very small, often just one person (70-80%). Sometimes there are two, and only a few have more than two people in the development team.

Sampling Procedure

In an attempt to acquire unbiased data, the questionnaire has two parts. One is designed to collect the data from the project leader/developer, in charge of the development and maintenance of the ES. The other gathers the data directly from the end-users. The questionnaire for project leaders/developers consists of questions regarding ES shell characteristics, managerial support, and ES developers' skills. On the other hand, the questionnaire for end-users has questions on user satisfaction with the ES quality, end-user characteristics, and extent of user involvement in the ES development.

Project leaders/developers and primary end-users of 150 operational ES were invited to participate in this study. One or more frequent end-users for a particular ES were chosen by one of the authors. This should be viewed as a convenience sample, since many ES were excluded because their developer was not known or no longer worked for the company, or it has been discontinued, or the project leader/developer could not be reached or was too busy to participate. In order to obtain the end-users own opinion without undue influence from other parties, the 150 end-users were asked to return their part of the questionnaire directly to the researchers. Of the 150 questionnaires which were mailed out, 114 matched sets (project leader/developer and end-user) were returned in time to be processed (a response rate of 76%). The pairs have a diverse background. Table 1 shows demographic information for project leaders/developers and end-users. The 114 related ES applications reported on fall in the following areas: service (10), manufacturing (50), finance (5), management (9), personnel (3), marketing (3), research (9), IS (22), and others (3). The ES deal with the following problem categories: control procedure (26), planning (8), education (4), configuration (4), selection (24), diagnostic (25), forecasting (4), and others (19).

Table 1: Demographic Information of Respondents

Project Leader/Developers		End-Users	
Work Experience *	F	Work Experience *	F
1-3 years	42	1-3 years	8
4-6 years	28	4-6 years	17
7-10 years	18	7-10 years	38
11-20 years	15	11-20 years	41
Over 20 years	10	Over 20 years	10
No response	1		
Education		Education	
High School	10	High School	71
Bachelor	49	Bachelor	34
Master	46	Master	7
Doctoral	7	Doctoral	2
No Response	2		
Age		Type	
26-30	10	Staff	33
31-40	54	Clerical	7
41-50	34	Blue Collar	60
51-60	13	Supervisors	8
over 60	1	Middle Managers	3
No response	2	Top-level managers	2
		Engineers	1

* In current jobs

Measurement of Variables

The questionnaire for this survey was pretested for content and readability through personal interviews with several practitioners and academics. It asked respondents to indicate their agreement or disagreement with each statement using a standard seven-point Lickert rating scale ranging from (7) completely agree to (1) completely disagree. For example, one question states: "on the average, the ES provides extremely reliable output."

ES Quality. We adapted a measure from pretested and validated instruments of user satisfaction with the information produced by their IS. It is a 9-item instrument adapted from the questionnaire used by Bailey & Pearson [1983], Raymond [1985] and Lucas [1978]. It excluded items deemed to be inapplicable for user satisfaction with the quality and user-friendliness of an ES. The 9 items include output value, timeliness, reliability, response/turnaround time, accuracy, completeness, ease to use, ease to learn, and the usefulness of a documentation. For each subject, the average response the measure of ES quality. The internal consistency reliability coefficient (Cronbach's alpha) of the nine-item scale is .81.

Developer Skills. Debenham [1990] listed four essential skills of knowledge engineers: to extract accurate and complete knowledge from human experts; to represent and implement knowledge; to design an ES for maintenance; and to design an ES that exploits existing investments in IS. A comprehensive list of knowledge and skills was developed by Payne and Awad [1990]. It includes knowledge of: computer technology, general fact-finding techniques, prototype methods, human factors, functional areas, communication skills, project planning skills, human relations skills, organizational skills, and personal attributes. Behavioral and interpersonal skills of knowledge engineers have been emphasized by Mykytyn, et. al [1994]. Developer's skills and abilities can be classified into six major categories, according to Nunamaker, Couger, & Davis [1982]: people skills, i.e. communication and interpersonal ability; models skills, the ability to formulate and solve models in OR; systems skills, the ability to view and define a situation as a system, specifying components, scope, and functions; computer skills; organizational skills, knowledge of the functional areas of the organization; and society skills, to articulate and defend a personal position on important issues of IT and its impact on society. The average response to these six items represent the measure of developer(s) skills. The internal consistency reliabilities (Cronbach's alpha) of the six-item scale was .76.

End-User(s) Characteristics. Respondents were asked to indicate their agreement with five items used to assess end-user(s) characteristics: education, experience, positive attitudes toward the ES, expectations on the ES, and computer and AI knowledge. The internal consistency reliability coefficient (Cronbach's alpha) for this scale was .64. The average response to these five items is the measure of end-user(s) characteristics.

Shell Characteristics: Based on many studies (e.g. [Brody, 1989; Guimaraes, Yoon & O'Neil, forthcoming]), the general features selected for this study were: flexibility for knowledge representation for the inference engine: the quality of the developer interface, end-user interface, and system interface, the portability among different platforms; ease to use and to learn; availability of training and vendor support; response time, and a shell's appropriateness to the problem. The average score for the ten items was computed to measure ES shell quality. The internal consistency coefficient for the scale was .86.

User Involvement: The measurement of end-user's involvement was also adapted from the validated measures used in the context of IS with an instrument validated through several studies [Doll & Torkzadeh, 1990; McKeen, Guimaraes & Wetherbe, 1994; Torkzadeh & Doll, 1994]. The measure was slightly modified to include items measuring the following user involvement in ES implementation: initiating the project, establishing the objective of the project, determining user requirements, accessing ways to meet user requirements, identifying the sources of data/ information, outlining the information flow, developing the input forms/screens, developing the output forms/screen, and determining the system availability/access. The average score is the measure of user involvement. The internal consistency coefficient (Cronbach's alpha) for this scale was .95.

Management Support: This was measured by four items: management understanding of the ES potential benefits, encouragement by management to use ES in their job, providing the necessary help and resources for effective use of ES, and management interest in having employees satisfied with ES technology. The items were averaged to compute a measure of management support, with an internal consistency reliability coefficient of .89.

Data Analysis Procedures

To test the relationships hypothesized, the correlation coefficients among the major study variables were computed. Multivariate Regression Analysis was performed to assess the contribution of the major study variables as a group to the prediction of ES **quality** as measured by user satisfaction. The contribution of each independent variable in explaining the variance in the dependent variable was determined by the increment in R squared which occurred when a given variable entered the regression equation.

RESULTS

Results Regarding Hypotheses Testing

The means, standard deviations, and the matrix of intercorrelations among the major study variables are shown in Table 2. The correlations reveal that developer skills and shell characteristics are significantly correlated with ES quality at the 0.01 level or better. Therefore, the following hypotheses are accepted:

H1: Developer(s) characteristics is directly related to ES quality.

H3: Shell characteristics are directly related to ES quality.

Table 2: Matrix of Intercorrelationships Among Major Study Variables

	Mean	STD	1.	2.	3.	4.	5.	6.
1. ES Quality	5.34	0.81	1.00					
2. Developer Skills	5.69	0.74	. 34**	1.00				
3. End User Characteristics	3.72	0.89	.19*	.36**	1.00			
4. Shell Characteristics	5.13	1.02	.37**	.48**	.07	1.00		
5. User Involvement	3.94	1.82	.20*	-.02	.21*	-.05	1.00	
6. Managerial Support	3.86	1.46	.01	.34**	.23*	.34**	-.06	1.00

* $p \leq .05$
** $p \leq .01$

While the results from multivariate regression show no contribution of end-user characteristics in explaining the variance in ES quality due to the order in which the former entered the regression equation, ES quality is positively correlated with end-user characteristics, as well as user involvement at the 0.05 significant level or better. Thus, the following hypotheses are accepted at this level:

H2: End-user characteristics are directly related to ES quality.

H4: User involvement is directly related to ES quality.

The extremely small correlation coefficients between ES quality and managerial support, may lead to the rejection of the hypothesis

H5: Management support is directly related to ES quality.

However, very likely this study has not properly tested this hypothesis, since within this organization management support is relatively even across ES projects. Perhaps, a multi-company study is required to properly test this hypothesis.

Other Results

Besides providing evidence to support four of the five hypotheses formally proposed in this study, Table 2 provides other interesting results. While management support is not directly related to ES quality, it does have direct relations with developer skills, end-user characteristics, and ES building tool characteristics, which are directly related to ES quality. The results also indicate a direct relationship between developer skills and shell characteristics. This can be interpreted as skillful developers tend to use more capable shells for ES development. Alternatively, it can be construed that better quality shells reflect favorably on ES developers. Similarly, developer skill is directly related to user characteristics, suggesting that skillful developers are able to motivate users, elicit a better attitude, harness their computer and AI knowledge, and manage their expectations from the ES. Alternatively, one may surmise that users with the "right" characteristics may help the ES developers perform their jobs more proficiently.

Results From Multivariate Regression Analysis

The inter-correlation analysis discussed earlier provided evidence about the relationships of each independent variable with the dependent variable. However, such analysis does not address possible interrelations among the independent variables as in combination they affect the dependent variable. In order to test this, an integrated model for ES quality was tested using multivariate analysis.

Table 3: Results of Multiple Regression Using Stepwise Method

Variables Entered into Regression Equations in Sequence	Incremental R Square	Significance Level	Condition Number
1. Shell Characteristics	.20	.00	15.3
2. Developers Skills	.11	.02	13.0
3. User Involvement	.04	.04	20.5
4. End-Users Characteristics	.02	.48	14.1
5. Managerial Support	.00	.83	33.6
Total Variance Explained	**.37**		

The results on Table 3 indicate that using the stepwise method for first entering the independent variables making the largest contribution to R squared, this integrated model explains approximately 37 percent of the variance in the dependent variable. The condition index method [Johnson, 1991] was used to test for possible multicollinearity among the independent variables. If the condition number is less than 100, multicollinearity is not to be considered a problem. The results on Table 3 show that the highest condition number is 33.6, well below the safe limit. It also presents three statistically significant determinants to ES quality at the 0.05 level or better: shell characteristics explaining 20 percent of the variance in ES quality, developer skills explaining 11 percent, and user involvement explaining another 4 percent. The contributions of the other variables, given the order in which they have entered the regression equation, are not statistically significant.

CONCLUSIONS AND MANAGERIAL RECOMMENDATIONS

The results corroborated the importance of four of the five determinants of ES quality. The exception forces the conclusion that the widely held belief that management support is an important determinant of ES quality is not always true.

The results indicate that ES quality, as measured by user satisfaction with the quality of the information provided by the ES, is related to several major factors. While some of these cannot be directly controlled in the short run, ES development managers can be more aware of potential ES development difficulties, attempt to pre-empt the likely problems and establish plans to facilitate the development of higher quality ES applications.

Considered individually, the most important major variables affecting user satisfaction are developer characteristics, shell characteristics and user involvement in ES development. According to the integrated model developed in this study, based on the percentage of variance in the dependent variable explained by the particular independent variable, the order of importance is the same. In general, it behooves managers championing the introduction of ES technology to their organization not to embark in ES development without first recruiting and training knowledgeable developers, using quality shells, encouraging user involvement in ES development, and cultivating management support and a user community with the characteristics discussed in this study.

Wells and Guimaraes [1992] have underscored the wasteful lack of cooperation between ES professionals and end-users within most organizations, and the need for improved communication. The importance of user communities as partners in ES development is corroborated. The selection of an appropriate shell is also an important factor. Managers should stop ES development groups from acquiring shells with undesirable characteristics. Yoon and Guimaraes [1993] have provided guidelines for matching specific problem characteristics with shells. Unfortunately, in comparison, most organizations today are woefully unprepared for the wide variety of ES application opportunities. Nevertheless, developers and project managers should carefully select shells along the important features outlined in this report.

The need for training developers and end-users is also clear. Developers must be trained to develop people skills, formulate models of business problems, and be able to use a systems approach to problems. Managing end-user attitudes and expectations from a specific system should be an important item for ES project managers to include in meeting agendas. Improvement may call for substantial changes from what is going on in industry today since training for ES developers and end users has been found lacking in most organizations [Wells & Guimaraes, 1992].

Despite the fact that the knowledge for an ES will come from a domain expert who expectedly has more knowledge about the problem than most users, user involvement seems to significantly affect ES quality. ES developers should strive to give end-users a chance to feel ownership in ES development. It is interesting to note that at a time when end-users are independently developing their own systems, relatively few end-users develop ES without knowledge engineers. However, as the user interface for more advanced ES shells become commercially available, end-users are more likely to independently develop ES.

STUDY LIMITATIONS AND RESEARCH OPPORTUNITIES

This study represents a field test surveying the ES applications within one organization with considerable experience using and managing ES technology. The general application of this study's results can be questioned in terms of industry differences and the sophistication of the ES development environment. We have no reason to suspect that the results and conclusions are applicable only to manufacturing organizations, however, that needs to be tested. On the other hand, there is much to be learned from such a sophisticated ES development environment, with hundreds of ES developers and users with many years of experience. Despite its limitations, this study represents one of the first systematic attempts to identify and field test some important factors influencing ES quality. Given the growing investment in ES technology, the impressive results many organizations have derived from it already, and its future potential, it is imperative that management consider these factors important to improving ES applications.

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