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MEASURING ORGANIZATIONAL LEVEL IS USAGE AND ITS IMPACT ON MANUFACTURING PERFORMANCE

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Abstract

Computer-based information systems (IS) technologies are continuously altering the nature of manufacturing competition. The effective use of IS in manufacturing industry has become a critical enabling factor for firm success. While the IS usage concept has been widely addressed in the IS literature, its linkage to manufacturing performance has not been well documented by empirical studies. Meanwhile, a comprehensive and reliable measurement instrument for organizational level IS usage is also not available. This study first develops a valid and reliable measure of organizational level IS usage through large-scale survey data collection and rigorous statistical validation. The relationship between IS usage and manufacturing performance is then examined using structural equation modeling. The study indicates that firms with high levels of IS usage generally have better manufacturing performance.

Keywords: IS usage, manufacturing performance, instrument development

Introduction

In today's highly competitive and uncertain marketplace, computer-based information systems (IS) technologies may well be the primary strategic resource for sustaining competitive advantage (Sabherwal and King, 1991; McGee and Prusak, 1993). Porter and Miller (1985) were among the first to address how information technology can create tremendous competitive advantage by transforming the entire supply chain, changing industry structure and spawning new business opportunities. Over the past two decades, U.S. manufacturing firms benefited tremendously from the rapidly advancing power and speed of IS technologies. Doll and Vonderembse (1991) described the transformation from industrial to post-industrial manufacturing enterprise as market-driven and *information technology-enabled*. Most manufacturers have been investing heavily in IS technologies in the expectation of gaining or maintaining the competitive edge. The use of office automation and electronic communication systems help firms to improve internal operations efficiency. Electronic data interchange systems greatly enhance business-to-business information exchange and cut down transaction costs. The recent trend of large scale deployment of Enterprise Resource Planning (ERP) systems is a good example of U.S. manufacturers' determination to achieve a truly integrative and responsive computerized supply chain management system (Callaway, 1999).

However, while IS technologies present new strategic options for manufacturing firms, the real management challenge lies in how to use IS in a more effective manner that actually improves performance (Boddy, McCalman and Buchanan, 1988). Although the IS usage concept has been widely addressed in the IS literature, its actual impact on manufacturing performance has not been well documented by empirical studies. Moreover, most existing studies on IS usage have an internal focus on the individual or task level issues (Doll and Torkzadeh, 1995), while the organizational and inter-organizational impacts of IS usage (such as ERP system usage) have not been fully explored. A comprehensive measurement instrument for organizational level IS usage is also not available.

This study first developed a valid and reliable instrument for assessing organizational level IS usage through large-scale questionnaire survey of senior manufacturing managers. The linkage between IS usage and manufacturing performance is then examined using structural equation modeling analysis.

The Conceptualization of Organizational Level IS Usage

The concept of IS usage has long been used in the IS literature as a measure for system success (Ein-Dor-and Segev, 1978). But earlier empirical studies of IS usage were characterized by a narrow and quantitative conceptualization of usage, such as hours of usage (Ettema, 1985) and frequency of usage (Benbasat et al., 1981). However, more use does not necessarily mean better use. Cooper and Zmud's (1990) technology innovation process model clearly demonstrated the six system usage levels from initiation to infusion or full use. Thus later studies shifted to more qualitative and behavioral variables of IS usage. One of the most well know research streams is the Technology Acceptance Model (TAM) that addresses the effects of perceived usefulness and perceived ease of use on user acceptance and usage of IS technologies (Davis, 1989). The TAM model stimulated an extended line of research that covers other related variables such as user participation (Hartwick and Barki, 1994), user training and satisfaction (Torkzadeh and Dwyer, 1994), user self-efficacy (Igbaria and Iivari, 1995), user prior experience (Taylor and Todd, 1995), actual usage vs. self-report usage (Szajna, 1996), intrinsic motivation (Venkatesh, 2000) and individual performance (Igbaria and Tan, 1997). While these studies are thorough and extensive, their definition of IS usage are mostly at the individual or task level, emphasizing user satisfaction and individual performance. Delone and McLean (1992) proposed a sequence of six categories of IS success: system quality, information quality, use, user satisfaction, individual impact, and organizational impact. A careful review of existing literature indicates that very few studies look into the organizational impact of using IS and inter-organizational IS effectiveness issues. The measures for IS usage in many existing studies are either actual usage time logs or single item instrument with limited reliability and validity. Comprehensive and reliable measurement scales for IS usage at both individual and organizational level are necessary to facilitate research in this field.

Doll and Torkzadeh (1995) are the first to develop an instrument for IS usage patterns at the task level. They conceptualize the IS usage pattern into five dimensions: 1) problem solving: the extent that an application is used to analyze cause and effect relationships; 2) customer service: the extent that an applications is used to service customers; 3) decision rationalization: the extent that an application is used to improve the decision making processes or explain/justify the reasons for decisions; 4) vertical integration: the extent that an application is used to coordinate one's work vertically with superiors and subordinates; and 5) horizontal integration: the extent that an application is used to coordinate work activities with others in one's work group. Although this instrument focused primarily on individual and work group mechanisms, it did offer some useful directions for conceptualizing the organizational level IS usage construct. Using Doll and Torkzadeh (1995) instrument as starting point, along with comprehensive literature review, the organizational level IS usage construct is re-conceptualized as the extent to which IS is used by the firm to promote integration, support decision making and assist in strategic planning. In the current study, IS refers to those computer-based systems used to organize, store, retrieve, transfer, process data and information, and facilitate communication and problem solving, such as electronic mail systems, data conferencing systems, management information systems, decision support systems, expert systems, and enterprise resource planning systems.

The process of adapting Doll and Torkzadeh (1995) IS usage pattern instrument to an organizational level construct involved: 1) exclusion of dimensions inappropriate for organizational level analysis such as problem solving, a dimension that reflects individual activities; 2) consolidating dimensions to fit organizational level analysis, such as the merger of vertical integration and horizontal integration to form the organization's Internal Integration dimension; 3) expanding dimensions to reflect organizational level activities, such as the change of customer service dimension to External Integration to incorporate not only customers, but also suppliers and other external relationships; 4) adding new dimensions to address organizational level issues, such as the addition of a Strategic Planning Support dimension to address the issues of strategic IS planning that was not relevant at the task level. Also note that decision rationalization dimension was re-conceptualized as Operational Decision Support.

Further theoretical justification of the operational support vs. strategic support conceptualization can be found from Boynton et al.'s (1994) measure of IT use. This is a organizational level instrument that consists of four dimensions: 1) cost reduction: information systems developed to reduce the cost of business activities; 2) management support: information systems developed to assist in monitoring, controlling, and designing business activities; 3) strategic planning: information systems developed to assist in formulating business strategies; and 4) competitive thrust: information systems developed to establish a competitive advantage in the market. Cost reduction is an outcome of using IS, thus not a valid dimension of IS usage. Management support captures the operational decision support dimension. Strategic planning and competitive thrust can be justifiably combined to form the Strategic Planning Support dimension.

In summary, four major dimensions of organizational-level IS usage were proposed and their definitions are listed below:

Operational Decision Support. The extent that IS is used by the firm to help monitoring, justifying and improving daily operational decision processes (Doll and Torkzadeh - Decision Rationalization; Boynton et al. - Management Support).

***Strategic Planning* Support.** The extent that IS is used by the firm to help formulating, justifying, improving long-term business planning processes and establishing competitive advantage (Boynton et al. – Strategic Planning & Competitive Thrust).

***Internal Integration*.** The extent that IS is used by the firm to facilitate information sharing and coordinate work activities within the organization (Doll and Torkzadeh – Vertical Integration & Horizontal Integration).

***External Integration*.** The extent that IS is used by the firm to service and communicate with external constituencies, such as customers, suppliers, government agencies, research institutions, etc. (Doll and Torkzadeh – Customer Service).

Research Hypothesis

With the increasing interest among U.S. manufacturing firms to implement Enterprise Resource Planning systems (e.g. SAP), the linkage between the use of such systems and manufacturing performance becomes a critical research focus. Boddy et al. (1988) suggested that the advantages of new information technology can be evaluated at both strategic and operational levels. Studies have shown that for most manufacturers, at the strategic level, IS is expected to 1) improve strategic flexibility and achieve economy of scope (Hayes and Pisano, 1994; Lei, Hitt and Goldhar, 1996), 2) creating competitive advantage by increasing entry barrier, changing bargaining power of buyers and suppliers, creating new business opportunities (Porter and Miller, 1985), or even altering the existing industry structure (Segars and Grover, 1995), and 3) facilitating global manufacturing strategy. At the operational level, the anticipated benefits of using IS include reduced production cost, improved quality, increased productivity, better financial performance, (Boer and Hill, 1990; Small and Chen, 1995), enhanced internal and external integration through better communication, improved decision-making processes, and better customer service (Sethi and King, 1994; Doll and Torkzadeh, 1995). In this research, manufacturing performance is defined as the level of attainment of five manufacturing objectives, including Cost reduction, Quality assurance, Delivery timeliness, Flexibility in production, and Innovation of manufacturing process (Miller and Roth, 1994). It is hypothesized that: *There is a positive relationship between IS usage and manufacturing performance.*

Research Methodology

In this section, research methods are described for survey instrument development and hypothesis testing. The instrument development process for IS Usage (ISU) and Manufacturing Performance (MP) included four major phases: item generation, pre-pilot study, pilot study, and large-scale data collection and analysis.

Item Generation and Pilot Study

Generating items that cover the domain of a construct determines the validity and reliability of an instrument (Churchill, 1979). A comprehensive literature review was completed to define the constructs and identify an initial list of items. To improve content validity, a pre-pilot study was completed that involved four manufacturing managers and six academic experts. During the structured interviews, the definitions of ISU and MP was presented to the executives and open-ended questions were asked about how the constructs should be measured. Items they felt did not belong to the construct domains were removed, and new items were suggested if applicable. The interview results were carefully analyzed and a common pattern of thinking was recognized, which formed the basis for further revision of the research constructs and measurement items. A copy of the revised definition and measurement items was sent to twelve faculty members. They had the opportunity to suggest changes in the definition as well as to “Keep,” “Drop,” or “Modify” each item. They were instructed to suggest new items if they felt that existing ones did not cover the entire content domain.

A pilot study was then completed that targeted senior manufacturing managers. The study provided valuable preliminary information about the reliability and validity of the measurement scales. It gave a final opportunity to purify the scales. There were forty usable responses. Corrected Item-Total Correlation (CITC) was used to purify the scales (Kerlinger, 1978). An item was eliminated if its correlation with the corrected item total was below 0.50. A slightly lower CITC was acceptable if that item was considered to be important to the construct. Factor analysis was used to assess the unidimensionality of the scales. Reliability, a measure of scale consistency, concerns the extent to which a measurement scale yields the same results on repeated tests. This study used the most popular method of evaluating scale reliability, Cronbach alpha (1951). Alpha values over 0.7 were considered acceptable (Nunally, 1978). Based on the pilot study results, the questionnaire was further revised and ready for large-scale data collection phase.

Large-Scale Data Collection

A key success factor in a large-scale empirical study is the quality of respondents. For this study, respondents should have detailed knowledge in more than one functional area plus in-depth understanding of manufacturing. Respondents should represent different geographical areas, industries, and firm sizes, so that the results can be generalized. To achieve these goals and to obtain an acceptable response rate, the large-scale sample was obtained from the Society of Manufacturing Engineers (SME). SME is a well know and well respected organization of manufacturing managers and engineers, with 65,000 active members all over the world and in almost every industry.

The final version of the questionnaire was administered through large-scale mailing to 2831 manufacturing managers who were randomly selected from SME's U.S. membership database. There were a total of 320 responses from the mailings, of which 303 were complete and usable. Detailed demographic information of the 303 respondents, such as industry classification and firm size is available from the author.

Assessment of Measurement Properties

There is general agreement in the literature that tests of unidimensionality, discriminant validity, and reliability are important for establishing construct validity (Sethi and King, 1994). The assessment of these measurement properties will be discussed for Information Systems Usage (ISU) and Manufacturing Performance (MP).

Information Systems Usage (ISU)

The ISU construct was initially represented by four dimensions comprising 25 items in the large-scale survey, including Operational Decision Support (ODS) (4 items), Strategic Planning Support (SPS) (5 items), External Integration (EXI) (9 items), and Internal Integration (INI) (7 items).

Reliability Analysis. Initial reliability analysis for each of the four ISU dimensions showed that the CITC scores for all items were above 0.50. However, the "Alpha if deleted" score indicated that removing EXI1 would improve reliability of EXI dimension. Thus item EXI1 was dropped at this stage. The resulting Alphas were 0.81 for ODS (4 items), 0.93 for SPS (5 items), 0.91 for EXI (8 items), and 0.86 for INI (7 items).

Dimension-Level Exploratory Factor Analysis. To further ensure the unidimensionality of each dimension in the Information Systems Usage construct, dimension-level exploratory factor analysis was performed for each of the four dimensions. A single factor emerged for the ODS, SPS, and EXI dimensions with all factor loadings above 0.70. Factor analysis of the INI dimension revealed two factors (Factor 1: INI1, INI2, INI3, INI6, INI7 and Factor 2: INI4, INI5). Referring to the contents of each item, Factor 2 does not make too much theoretical sense. It was thus decided that items INI4 and INI5 be removed. Dimension-level factor analysis was again performed on the remaining items of INI dimension. One clear factor emerged with all factor loadings above 0.70.

Construct-Level Exploratory Factor Analysis. In this step, all the remaining 22 ISU items were submitted to construct-level exploratory factor analysis to check for discriminant validity of the measurement instrument. Four factors emerged from the factor analysis with all factor loadings above 0.50 and most above 0.60. Serious cross-loading occurred on item INI7. Hence item INI7 was dropped. The remaining 21 items were again put into construct-level exploratory factor analysis. This time four clear factors emerged with all items loaded correctly on the expected dimensions. Most factor loadings were above 0.60. No cross-loading was observed. The KMO measure of 0.93 indicated outstanding sampling adequacy. The final set of measurement items for the ISU construct organized by factor loadings are shown in Table 1.

Manufacturing Performance (MP)

The MP construct was conceptualized as having five dimensions and 18 items. To ensure the discriminant validity of the five sub-dimension of the MP construct, an exploratory factor analysis was performed using all 18 items that measure MP. Five clear factors emerged with most factor loadings above 0.70. All items loaded on their expected sub-dimensions and no cross-loading was observed, indicating very good discriminant validity of the MP instrument.

Table 1. Final Construct Measurement Items for IS Usage

Code Names		*Questionnaire Items*
Factor 1: External Integration (EXI)		
EXI8	We Use IS to…	collect information about new technologies in our industry
EXI9		collect information about competitor products
EXI5		keep suppliers involved in our product design and production processes
EXI2		collect information about best practices in our industry
EXI3		exchange information with research institutions
EXI7		keep suppliers informed of our specific requirements
EXI4		collect information about customer requirements
EXI6		exchange information with customers
Factor 2: Strategic Planning Support (SPS)		
SPS3	We Use IS to…	help justifying long-term business plans
SPS2		help formulating long-term business plans
SPS1		help improving the effectiveness of long-term strategic planning processes
SPS5		help generating long-term strategic advantage
SPS4		help creating new ways of doing business
Factor 3: Internal Integration (INI)		
INI3	We Use IS to…	facilitate information sharing between different management levels
INI2		facilitate information sharing among employees
INI6		facilitate information sharing among different departments
INI1		facilitate information distribution throughout the organization
Factor 4: Operational Decision Support (ODS)		
ODS1	We Use IS to…	help justifying daily operational decisions
ODS2		help improving the efficiency of daily operational decision processes
ODS3		help analyzing why problems occur in daily operations
ODS4		help monitoring the daily operational decision processes

To check for unidimensionality and determine whether these five sub-dimensions are part of the overall MP construct, a composite item was calculated for each of the five sub-dimensions by taking the average of items in each sub-dimension. Exploratory factor analysis was performed on the five composite items and one single factor emerged with all factor loadings above 0.70, indicating good unidimensionality and convergent validity of the MP instrument. To check for reliability of the MP scale, alpha scores were calculated for all five sub-dimensions of MP instrument (Table 2). All scores are well above the recommended 0.70 minimum level, indicating very good reliability of the measurement instrument.

Table 2. Reliability Assessment of MP Sub-dimensions

Item	**Description**	**Reliability (α)**
Manufacturing Performance Sub-dimensions		
1	Cost Performance	0.77
2	Quality Performance	0.84
3	Delivery Performance	0.90
4	Flexibility Performance	0.77
5	Innovation Performance	0.74

Structural Equation Modeling Results and Hypotheses Testing

To test the relationships between ISU and MP, LISREL structural equation modeling method was used. Because ISU and MP were measured by multiple sub-dimensions and each contains multiple items, an average score was taken for the multiple items under each sub-dimension. The average scores were then used as input to the LISREL measurement and structural modeling. Several statistics are used to assess model fit, including Root Mean Square Residual (RMSR), Goodness-of-fit index (GFI)

Adjusted Goodness-of-Fit Index (AGFI), and Comparative Fit Index (CFI). The ratio of χ^2 to degrees of freedom provides information on the relative efficiency of competing models in accounting for the data. The recommended maximum value for RMSR is 0.10 (Chau, 1997). For GFI, AGFI and CFI, a commonly recommended minimum value for a very good fit is 0.90 (Segas and Grover, 1993; Hair, et al., 1992). The ratio of χ^2 to degrees of freedom is recommended to be less than 3.0 to indicate a reasonable fit (Segas and Grover, 1993). As illustrated in Figure 1, the LISREL structural model fit was very good with all indices meeting the recommended criteria.

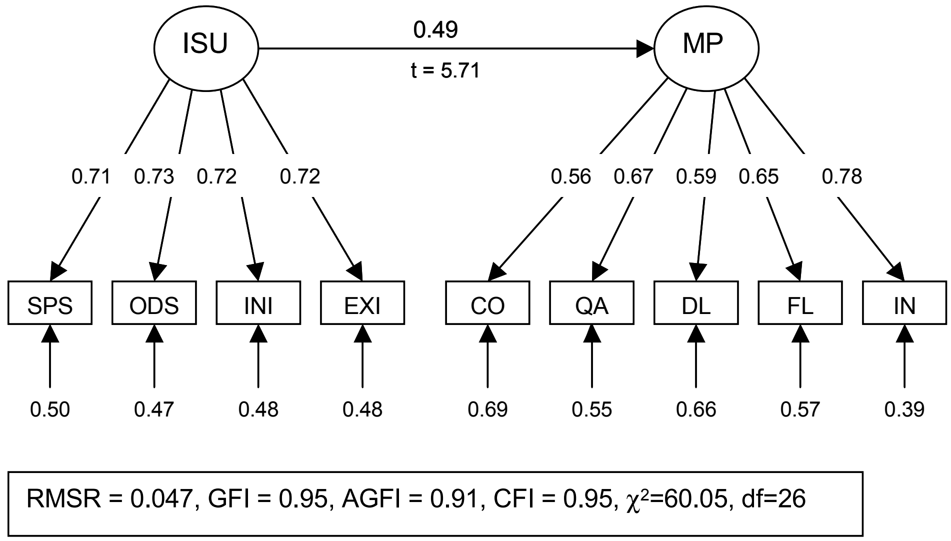

Figure 1. LISREL Structural Equation Model

The results of the structural equation model in Figure 1 support the research hypothesis, which claims that organizations with high-levels of information system usage have high-levels of manufacturing performance. The LISREL path coefficient is 0.49, which is statistically significant at $p<0.01$ ($t = 5.71$).

Discussions and Conclusion

Advanced information systems technologies have become an inevitable strategic choice for many firms operating in the globally competitive twenty-first century. As customers become more demanding, it is essential that management understand how to effectively use IS to design and operate manufacturing systems that can quickly meet specific customer needs while improving manufacturing performance. This study represents one of the first large-scale empirical efforts to systematically investigate the concept of organizational level IS usage and its impact on manufacturing performance. Valid and reliable instruments were developed to assess ISU and MP. Extensive efforts were made to ensure content validity during instrument development by carefully designing processes for item generation, pre-testing, and pilot study testing. Unidimensionality and discriminant validity of the measurement instruments were ensured through rigorous exploratory factor analysis and instrument refinement process. The empirical results along with the validated measurement instruments for ISU and MP should provide both researchers and practitioners with valuable insights to the effective use of information systems technologies in the manufacturing setting. They can also become a set of useful tools for relevant academic research projects and practical assessment of organizational level IS usage.

Future studies can collect new data set for confirmatory analysis of the measurement instruments developed in this study. This will provide further evidence for the validity and reliability of the instruments. Future research can also examine the proposed relationship in a contingent manner by incorporating some contextual variables such as market turbulence level, industry type and size of the firm. Finally, it will be interesting to further examine the differing impact of the four sub-dimensions of organizational level IS usage on each of the five sub-measures of manufacturing performance.

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