

Synergies between information technology and quality management

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ABSTRACT:

The present study draws on the information technology, quality management, and organization literature to examine the interaction between information technology usage and quality management and their effect on operational performance. Taking the perspective of the resource dependence view of the firm, we propose that the integration between information technology and quality management could lead to the development of cumulative capabilities and result in a positive impact on operational performance. Using multiple regression analysis, we empirically test a number of hypothesized relationships based on a sample of 420 Spanish manufacturing firms. The results provide support for the interaction between information technology constructs (Internet systems, EDI, enterprise systems; network systems, decision support systems, manufacturing systems; design systems) and quality management and the link with operational performance. Practical implications and guidelines for managers focus upon leveraging this relationship as a competitive weapon.

INTRODUCTION

Rapid advances in information systems (IS) are having major impact on the management of supply chains. Organizations are increasingly investing in information systems, such as electronic data interchange (EDI) or internet-based networks to support manufacturing operations. Investments in IS are used in combination with investments in quality management practices to respond quickly to rapidly changing business conditions.

It is frequently argued that investments in information systems are a very important factor in increasing productivity and reducing costs (e.g., Bessen, 2002; Kagan, 1994; Kotha & Swamidass, 2000; Torkzadeh & Doll, 1999; Weston, 1993). Evidence of positive and significant returns from IS investment can be found in Byrd and Marshall (1997), Brynjolfsson and Hitt (1996), Dewan and Min, Kelley (1997) and Rogers *et al.* (1996). Other firm level studies by Menon *et al.* (2000) and Devaraj and Kohli (2000) have found evidence of positive effect of IS capital and labour on outcome measures among hospitals. However some other studies show contradictory results that information system practices do not increase productivity and reduce costs (e.g., Mahmood & Mann, 1993; Swamidass & Kotha, 1998; Willcocks & Lester, 1997) and have failed to find a significant increase in financial performance or competitive advantage resulting from information systems (e.g., Bakos, 1987; Loveman, 1994; Lucas, 1981; Powell & Dent-Micalef, 1997; Strassmann, 1997). In this respect, some authors have argued that the general influence of IS may not necessarily be fully reflected in firm-level financial outcomes (Strassmann, 1997), but rather manifested at a more operational level (e.g., shorter cycle time, increased customer satisfaction) as some studies have shown (e.g., Doll & Vonderembse, 1987; Handfield & Pagell, 1995).

This study examines the moderating role of quality management in the relationship between information systems and operational performance in the context of the resource-

based view (RBV) of the firm (Barney, 1986; 1991). In addressing this objective, we define information systems as the adoption and usage of computer-enabled information technologies and software applications of particular relevance for a company's manufacturing operations. Specifically, we consider five types of information systems: electronic data interchange, internet, knowledge/ decision support systems, enterprise planning systems, and computer design/manufacturing systems. Quality management refers to implementation of quality management principles in information analysis, workforce management, customer relationships, supplier relationships, product design process and process flow management (Martinez-Lorente *et al.*, 2000). Measures of a firm's operational performance typically include production costs, on-time delivery, volume-flexibility, cycle time, and product quality. Our research extends previous research in the operations literature by studying the relationship between information systems and quality management in manufacturing plants and their ability to develop idiosyncratic capabilities in pursuit of better performance and competitive advantage. Capabilities in functional areas of the firm, such as manufacturing, contribute to the development of deployable resources for the firm. Because they cannot be easily duplicated and have no substitutes, their positive contribution to performance may also confer advantages compared to competitors. We develop and test a multivariate model to examine what information systems interact with quality management and are associated with competitive operational performance. We develop five constructs to measure the use of information systems in manufacturing, one to measure quality management and we test hypotheses in a cross-sectional sample of 234 manufacturing plants.

LITERATURE REVIEW

There is little doubt that information systems (IS) affect all sections and functions of a company and, therefore, IS should also have an impact on quality management. In this context, Weston (1993) claimed that quality management and other related management interventions such as JIT and BPR, rely heavily on IS which act as a feedback mechanism, facilitating communication, and the implementation of advanced tools, systems and modelling techniques. The literature is supportive of this view and contains numerous examples about how IS might be used to support quality management efforts (e.g., Ayers, 1993; Berkley & Gupta, 1994; Cortada, 1995; Zadrozny & Ferrazzi, 1992), what is the role of IS in a quality management system (e.g., Pearson & Hagmann, 1996; Sobkowiak & LeBleu, 1996), and how specific IS applications impact various aspects of quality management (e.g., Aiken *et al.*, 1996; Counsell, 1997; Goodman & Darr, 1996; Kaplan, 1996; Khalil, 1996; Kock & McQueen, 1997; Miller, 1996). Forza (1995a) developed a reference model to link quality management practices, information systems and quality performance through empirical research. However, using his own model and associated measures, Forza (1995a) did not succeed in empirically establishing a link between quality management practices and IS, and only the use of IS in the quality assurance aspect of quality management was explored. Forza (1995b) argued that the contribution of IS should be further investigated by developing adequate measures especially with reference to its use. Torkzadeh and Doll (1999) devised and applied a construct to measure the perceived impact of IS on work, which relates to only one of the

quality management dimensions. More recently Dewhurst *et al.* (2003) conducted a multiple case study to identify what quality management areas were being influenced by the use of IS. Dewhurst *et al.* (2003) found evidence of intensive use of IS to facilitate the deployment of top management support, customer relationships, supplier relationships, workforce management, employee attitudes and behaviour, product design process, process flow management, and quality data and reporting. However, most of these studies failed to address the effect on performance, and rely on case evidence which compromises their generalizability.

Several studies have also reported the possible existence of moderators in the relationship between information systems and performance. Parthasarthy & Sethi (1993) reported on this issue and found that flexibility strategies, quality and cost leadership, and manufacturing strategies had a significant moderating effect. Powell & Dent-Micalef (1997) argue that if information systems investments *per se* do not provide distinctive advantages, then firms must use them to leverage or exploit firm specific, intangible resources such as organizational leadership, culture, and business processes. The same authors suggested the need to analyse the advantages arising from merging information systems with other resources. In this context several authors have argued that information systems can act as an “enabler” that makes possible the enactment of quality programs and other initiatives that rely on the generation, manipulation, and dissemination of vast amounts of information (Dewhurst *et al.*, 2003; Sriram & Stump, 2004). However, the amount of research analysing the interaction between information systems and quality management practices is very limited. Previous research has focused on how IS might be used to support quality management efforts (e.g., Ayers, 1993; Berkley & Gupta, 1994; Cortada, 1995; Zadrozny & Ferrazzi, 1992), what is the role of IS in a quality management system (e.g., Pearson & Hagmann, 1996; Sobkowiak & LeBleu, 1996), and how specific IS applications impact various aspects of quality management (e.g., Aiken *et al.*, 1996; Counsell, 1997; Goodman & Darr, 1996; Kaplan, 1996; Khalil, 1996; Kock & McQueen, 1997; Miller, 1996). Therefore, there is a clear need for empirical investigations that assess the interaction between information systems and quality management practices at a more operational level.

HYPOTHESES

The resource-based view (Barney, 1986; 1991; Peteraf, 1993) argues that to confer competitive advantage an organization should acquiring or developing resources and/or capabilities that contribute positively to performance, are not possessed by all competing firms, and are difficult to imitate or duplicate (Barney, 1986). These resources and capabilities can either be acquired in factor markets and/or developed inside the firm.

In its treatment of IS-based advantages, the resource-based view has emphasized sustainability protected by resource embeddedness, i.e., resource complementarity and co-specialization. Complementarity represents an enhancement of resource value, and arises when a resource produces greater returns in the presence of another resource than it does alone, e.g., an EDI systems that only marginally improves performance under

ordinary conditions, but produces sustainable advantages when combined with pre-existing supplier quality management. Complementary resources are co-specialized if one resource has little or no value without the other (Clemons & Row, 1991). Under the resource view, a complementary interaction typically enhances the value for both (or all) complementary resources, although the causality may be ambiguous (Barney, 1991). For example, EDI can be used to place orders, send product specifications, design details, etc., along with confirmation of invoices and payments (Jonscher, 1994). An EDI system by itself would be a commodity resource, yet it may combine with supplier and customer trust developed as a result of quality management activities (supplier relationships and customer relationships) to produce an embedded, mutually reinforcing, advantage-producing resource bundle. Teague *et al.* (1997) outlined how suppliers can be involved earlier in the design process by the use of IS. In some cases, companies can access the inventory systems of their suppliers and place orders automatically and there can also be access to production scheduling systems. EDI systems have been traditionally expensive to implement, however with the development of the internet an ever increasing number of companies are using EDI systems based on the internet technology, benefiting from its lower implementation and operating costs.

Additional, information systems such as enterprise resource planning systems, manufacturing resource planning systems, and the internet allow a firm to connect not only different functions within a firm but also among the firm's supply chain partners (i.e., suppliers, distributors, and third party logistics providers), enabling the partners to share information such as order status, product schedules, and sales records, to integrate major supply chain processes and to plan production, logistics and marketing promotions (Overby & Min, 2001). However, for these information systems to be effective, complementary resources such as trust, open communication, and cooperation are needed and quality management can help to cement their development through closer relationships with customers and suppliers (Martinez-Lorente *et al.*, 2000). Thus, the interaction between information systems and quality management could result in idiosyncratic capabilities which could lead the organization to better competitive operational performance.

Closely related to the resourced-based view is the knowledge-based view of the firm. From a resourced-based view perspective, knowledge creation can be seen as part of the process to develop organizational resources and capabilities that are difficult to imitate by competitors. In this context, some authors have stressed the importance of knowledge creation through quality management (Linderman *et al.*, 2004). Information systems, have a key role to play in this knowledge creation process as a key facilitator of organizational memory and the ability to capture and integrate explicit knowledge by making it easy to codify, communicate, assimilate, store, and retrieve (Anand *et al.*, 1998; Rockart & Short, 1989). Examples of the utility of knowledge codification through information systems are provided by Leidner and Elam (1995) and Lado and Zhan (1998). Thus, the knowledge-based view also provides a rationale for the linkage of information systems and quality management in generating organizational capabilities which could lead to competitive operational performance.

Based on the above discussion, we would expect that certain information systems do combine with quality management to explain significant competitive operational performance variance.

H1: Interaction between computer manufacturing information systems and quality management will be positively related to operational performance.

H2: Interaction between electronic data interchange and quality management will be positively related to operational performance.

H3: Interaction between enterprise systems and quality management will be positively related to operational performance.

H4: Interaction between Network and Internet information systems and quality management will be positively related to operational performance.

H5: Interaction between decision support systems and quality management will be positively related to operational performance.

The argument in favour of the direct effect of individual information systems hinges on the assumption that since elements of information systems, EDI for instance, are embedded with efficacy-enhancing properties such as automatic reordering and speedier and more accurate analyses and information flows (Hill, 2000) performance gains would automatically accrue simply from making investments in information systems. We also control for implementation of quality management activities. Past research suggests that implementation of quality management activities help to improve operational performance (Ahire & O'Shaughnessy, 1998; Curkovic *et al.*, 2000; Dow *et al.*, 1999; Wilson & Collier, 2000).

The next section describes the research methodology employed to test the research hypotheses, which is then followed by a discussion of the results and conclusions, which summarise the findings and implications for academics and practitioners.

4. RESEARCH METHODOLOGY

Sample and data collection

The study utilized a cross-sectional mail survey of a sample of Spanish manufacturing companies drawn from "Fomento de la Produccion" company directory. 1949 respondents were selected from a list of 3000 companies. The title of the specific respondent sought was primarily Quality Manager or Quality Director.

The questionnaire was developed in Spanish and was pretested with quality managers, from a sample of 14 large Spanish manufacturers (Dewhurst *et al.*, 2003). These executives were asked to review the questionnaire for structure, readability, ambiguity, and completeness. The final survey instrument incorporated feedback received from these executives, which enhanced the clarity of the instruments. Appendix 1 provides detailed information pertaining to this survey.

In an effort to increase the response rate, a modified version of Dillman's (1978) total design method was followed. Survey questionnaires were sent to respondents via first-class mail; each survey included a cover letter and postage-paid return envelope. Two weeks after the initial mailing, reminder postcards were sent to all potential respondents. For those who did not respond a second wave of surveys, cover letters, and postage-paid return envelopes were mailed approximately 6 weeks after the initial mailing. In total, 442 completed surveys resulting in a response rate of 22.7% which is comparable to similar studies in the literature (e.g., Frohlich & Dixon, 2001; Small & Yasin, 1997).

To test for non-response bias, we compared the responses of early and late waves of returned surveys based on the assumption that the opinions of late respondents are representative of the opinions of non-respondents (Armstrong & Overton, 1977). We performed *t*-tests comparing early and late respondents on key demographic variables, namely number of employees and sales volume. We found no significant differences between early and late respondents. This suggests that nonresponse would not likely bias the findings. We used Harman's one-factor test to address the issue of common method variance. If that were a serious problem, we would expect a single factor to emerge from a factor analysis or one general factor to account for most of the covariance in the independent variables (Podsakoff & Organ, 1986). We performed factor analysis on items related to the predictor variables. No general factor was apparent in the unrotated factor structure. Therefore, no common method variance problem was detected.

The final sample consisted of quality managers (70.5%) whilst other major respondents were quality department representatives (10.5%) and plant directors (3.4%). Some 60% of the companies in the sample were made up of Spanish-owned firms, 21% of other European Union countries, and 19% from non-EU countries.

Measures

We measured five types of information technologies: computer manufacturing systems (CMS); electronic data interchange (EDI), network/internet technologies (NWK), knowledge / decision support systems (KDSS), enterprise planning systems (EPS), and The measure of computer manufacturing systems (CMS) contains seven items (see Appendix for details) pertaining to the use of computer aided manufacturing systems (CAM), computer numerically control machines, robots, electronic systems of product identification, electronic systems of quality control and flexible manufacturing systems (Cronbach's alpha = 0.80). The measure of EDI contains two items pertaining to the implementation of EDI systems with suppliers and customers (Cronbach's alpha = 0.79). The measure of network technologies (NWK) pertain to the level of usage of local area network and internet based technologies (Cronbach's alpha = 0.62). Knowledge/decision support systems contains four items pertaining to the use of knowledge management systems, decision support information systems, groupware decision support systems, and advanced statistical tools (Cronbach's alpha = 0.67). The enterprise planning systems measures consists of three items measuring the extent of use of enterprise resource planning systems, material resource planning systems (MRP), and forecasting software (Cronbach's alpha = 0.82).

The measure of total quality management was consisted of six items related to the adoption of quality management practices in human resource management, process flow management, product design process, supplier relationships, customer relationships, and information analysis (Cronbach's alpha = 0.80).

Operational performance was used as the dependent variable in this study. The measure of operational performance captures the firm's production cost, on-time delivery, volume-flexibility, cycle time, and product quality relative to competition (Cronbach's alpha = 0.65). These performance dimensions are also consistent with previous measures of operational performance in the literature (Ferdows & De Meyer, 1990; Miller & Roth, 1994; Schroeder *et al.*, 2002). By making operational performance measures relative to the competition we tried to eliminate the industry effect by which some industries tend to perform better than others in particular performance areas. As it is often difficult to obtain objective data on operational issues (Narasimhan & Das, 2001) we relied on senior executives' perceptions of their companies' operational performance, which have also been adopted by other researchers (e.g., Germain *et al.*, 2001).

Analytical procedures

The measures used for this study are presented in the Appendix. All multi-item measures are based on 5-point scales. In order to assess construct validity of the information systems and quality management constructs, each scale was subjected into a principal components factor analysis with varimax rotation and appropriate factor solutions were obtained. All scales were one-dimensional with eigenvalues greater than 1.0 and factor loadings in excess of 0.40 for each scale item. Next we calculated index measures for each one of the constructs in the study. This was done by averaging the scores provided by the respondent across the relevant items within a construct.

Table 1 reports descriptive statistics and correlations between the five information technology constructs, quality management, and operational performance constructs. The correlation analysis shows that all information technology constructs correlate significantly with quality management, indicating that as the level of information systems usage increases so does the level of quality management practices. The analysis provides other interesting results. All information technology constructs (computer manufacturing systems, EDI, knowledge/decision support systems, network and enterprise systems) showed significant correlations with operational performance. These results indicate that firms that are highly competitive in cost, delivery, flexibility, and cycle time, show higher levels of usage of EDI, knowledge/decision support systems, computer manufacturing systems, network/internet systems and enterprise systems.

The next step in the analysis was to perform a multiple regression analysis in an effort to identify the hypothesized effect of the interaction or synergy between the individual information technology constructs and quality management on operational performance. Estimates were obtained by ordinary least squares regression.

Table 1. Correlations and descriptive statistics

	Mean	Standard deviation	Cronbach's Alpha	1	2	3	4	5	6	7
1. Quality management	2.842	1.181	0.79	1						
2. EDI systems	2.421	0.939	0.77	0.234**	1					
3. Enterprise systems	3.343	0.885	0.82	0.334**	0.263**	1				
4. Computer manufacturing systems	2.481	0.833	0.80	0.359**	0.346**	0.569**	1			
5. Networks/internet systems	2.389	1.406	0.62	0.327**	0.396**	0.456**	0.443**	1		
6. Knowledge/decision support systems	3.8385	0.532	0.67	0.366**	0.359**	0.528**	0.520**	0.569**	1	
7. Operational Performance	3.002	1.100	0.65	0.199**	0.170**	0.109*	0.131**	0.180**	0.231**	0.214**

Notes: ** $p < 0.01$; * $p < 0.05$; (two-tailed)

RESULTS

The results of the test of the first hypothesis are contained in Table 2. The interaction term between computer manufacturing systems and quality management was positively and significantly related to operational performance (production costs, on-time delivery, flexibility, cycle time, and product quality) ($p < 0.01$), thus, providing support for hypothesis 1.

Table 2. OLS estimates of computer manufacturing systems and quality management

<i>Predictor variables</i>	Operational Performance ($N = 420$)	Significance
Intercept	3.708**	0.000
Quality management (QM)	-0.089	0.338
Manufacturing systems (MS)	-0.035	0.613
MS \times QM	0.021**	0.000
Adjusted R^2	0.040	
Overall F	18.378**	0.000

Notes: ** $p < 0.01$ (two-tailed); $p < 0.05$ *

Table 3. OLS estimates of electronic data interchange and quality management

<i>Predictor variables</i>	Operational Performance ($N = 420$)	Significance
Intercept	3.3676**	0.000
Quality management (QM)	-0.011	0.911
Electronic data interchange (EDI)	0.041	0.498
EDI \times QM	0.022**	0.000
Adjusted R^2	0.052	
Overall F	24.067**	0.000

Notes: ** $p < 0.01$ (two-tailed); $p < 0.05$ *

Table 4. OLS estimates of enterprise systems and quality management

<i>Predictor variables</i>	Operational Performance ($N = 420$)	Significance
Intercept	3.708**	0.000
Quality management (QM)	0.098	0.290
Enterprise systems (ES)	-0.063	0.349
ES \times QM	0.018**	0.000
Adjusted R^2	0.039	
Overall F	17.831**	0.000

Notes: ** $p < 0.01$ (two-tailed); $p < 0.05$ *

Table 5. OLS estimates of network/internet systems and quality management

<i>Predictor variables</i>	Operational Performance ($N = 420$)	Significance
Intercept	3.676**	0.000
Quality management (QM)	-0.011	0.931
Network/Internet systems (NWK)	0.078	0.190
NWK \times QM	0.019**	0.000
Overall F	20.745**	0.000
Adjusted R^2	0.045	

Notes: ** $p < 0.01$ (two-tailed); $p < 0.05$ *

Table 6. OLS estimates of knowledge/decision support systems (KDSS) systems and quality management

<i>Predictor variables</i>	Operational Performance ($N = 420$)	Significance
Intercept	3.672**	0.000
Quality management (QM)	-0.077	0.454
Knowledge / Decision support systems (KDSS)	0.123 [†]	0.057
KDSS \times QM	0.026**	0.000
Adjusted R^2	0.057	
Overall F	26.370**	0.000

Notes: ** $p < 0.01$ (two-tailed); $p < 0.05$ *; [†] $p < 0.10$

Table 3 considers the effect of electronic data interchange usage on operational performance. Table 4 shows a positive and significant coefficient for the interaction between EDI and quality management ($p < 0.01$). Thus, hypothesis 2 was accepted.

The effect of the interaction between enterprise systems and quality management practices on operational performance is reported in Table 4. According to the results the main effect of the interaction term between ES and quality management on operational performance was positive and significant ($p < 0.05$), thus, providing support for hypothesis 3.

Table 5 presents the results related to the effect usage of network/internet systems and quality management on operational performance. Table 5 shows a positive and significant coefficient for the interaction between network/internet systems and quality management ($p < 0.01$). Thus, hypothesis 4 was also accepted.

Table 6 contains the results of the test of the fifth hypothesis, revealing that the interaction between knowledge/decision support systems (KDSS) and quality management practices on operational performance is positive and statistically significant; thus, providing support for hypothesis 5.

DISCUSSION

The results from this study provide evidence to support the need for integration of information technology with quality management. This is noteworthy because, although there is descriptive and theoretical support for this relationship, there has been little prior empirical investigation. This study indicates that organizations implement information technologies and quality management simultaneously, providing evidence of the pursuit of cumulative capabilities. In doing so, they achieve a competitive advantage that is difficult to imitate. In addition, integrating information technology goals with quality management goals enhances development of a foundation for achieving other strategic goals as cumulative capabilities. These findings are in concurrence with the work of Flynn and Flynn (2005), who found that there was a direct relationship between cumulative capabilities and superior performance in the global environment.

The results of this study indicate that organizations with joint implementation of information technologies (i.e., computer manufacturing systems, electronic data interchange, enterprise systems, network/internet systems, and knowledge / decision support systems) and quality management achieve better operational performance in terms of production costs, on-time delivery, volume flexibility, cycle time, and quality. Thus, the productivity gains, cost reductions, and improved decision making associated with the use of information technologies and the reduced variances associated with the use of quality management translate into improved operational performance.

The regression analysis results indicated that when computer manufacturing systems, electronic data interchange, enterprise systems, network/internet systems, and knowledge / decision support systems are implemented along with quality management, the interaction between the two produces a synergistic effect providing these organizations with greater operational performance than competitors. These results suggest that the joint implementation of information technologies and quality management creates specifically proprietary processes and capabilities that lead to the development of valuable resources that in turn lead to higher competitive performance. Consistent with the resource-based view of the firm (RBV), our proposition is that information technologies (computer manufacturing systems, electronic data interchange, enterprise systems, network/internet systems and knowledge / decision support systems) and quality management interact allowing a manufacturing firms to learn and create privately held knowledge that is idiosyncratic and difficult for competitors to imitate. The findings also provide support to the notion that knowledge generation through quality management has an effect on performance (Linderman et al., 2004).

The results of our research allowed us to further validate the notion that quality management and information technology complement each other and that the effect of their combination on performance is superior to the implementation of each one separately. While there is some empirical research that suggests that quality management and information systems are complementaries (Dewhurst *et al.*, 2003; Forza, 1995a), our results extend these findings by examining the effect their interaction on operational performance. The results of this study also support the argument that the emphasis on technology alone cannot singularly ensure high performance (Zahra & Covin, 1993) but it is the fusion of people, business,

and technology resources, with the “management difference” (i.e., quality management) producing the critical distinctive advantage (Keen, 1993).

CONCLUSIONS

This study contributes and extends a growing research stream documenting the role of information systems and its interaction with other management, precisely with quality management practices. Specifically, we investigated the interaction between information systems and quality management and the effect on measures of a firm’s competitive operational performance. Strategy researchers have documented how dynamic capabilities can generate sustainable competitive advantage insofar as they are valuable, rare, and hard to copy (Barney, 1991). The findings of significant positive relationship between the interaction among specific information systems (knowledge / decision support systems and electronic data interchange) and competitive operational performance (production costs and volume flexibility respectively) constitute a significant contribution to, and extension of, the literature in information systems and quality management.

Some IS proponents argue that the effect of information systems on performance might be mediated by some variable, and it has been argued that quality management might be one of them. Based on this premise, this paper investigates the extent to which information systems and quality management practices interact to foster operational capabilities. Using the resource-based view of the firm and data collected from 420 manufacturing firms we test whether firms can gain performance advantages by accumulating and combining information systems and quality management practices by generating economically valuable, relatively scarce, and imperfectly imitable organizational routines and capabilities. In addition to reinforcing previous research documenting the importance of information systems and quality management for mutual benefits, this investigation also documents how the interaction between information systems and quality management contribute to enhanced operational (i.e., production costs and flexibility). From a practical perspective, this study shows that such information systems as computer manufacturing systems, electronic data interchange, enterprise systems, network/internet systems and knowledge / decision support systems interact with quality management practices contributing directly to the firm’s operational performance enhancing the firm’s competitive position in production costs, on-time delivery, volume flexibility, cycle time, and quality.

At this point, it is important to acknowledge important limitations of our study that might provide opportunities for future research. Though the constructs developed in this study exhibit acceptable reliability for the purposes at hand, future research should refine them and consider adding new indicators that more fully tap the constructs, specially the internet, knowledge/decision support systems constructs. Second, inferences in this study are based on cross-sectional data, making causal claims difficult. We were also unable to assess performance effects over time, and believe that a longitudinal database with strong measures of relevant variables should be developed to assess the issues of the interaction between information systems and quality management practices and the effect on performance. Finally, information systems are also a vitally important strategic partner in fostering other important organizational capabilities such as supply management capabilities, which may generate durable strategic advantage. Therefore future research should focus at including supply chain management elements. Despite these limitations, this study paves the way for researchers and managers to more fully capitalize

on the potential of the integration between information systems and quality management to foster a firm's operational competitive capabilities.

APPENDIX

Survey indicators

To what extent do you use : (1 for no use at all, and 5 for intensive use)

- csm1 *Computer manufacturing systems ($\alpha= 0.80$)*
 csm2 Computer aided manufacturing (CAM)
 csm3 Numeric control machines with computer control
 csm4 Robots
 csm5 Electronic systems of product identification
 csm6 Electronic systems of quality control
 csm7 Flexible manufacturing systems (FMS)
 Electronic data interchange (EDI) ($\alpha= 0.77$)
 is4 Electronic data interchange with customers/clients
 is5 Electronic data interchange with suppliers
 Enterprise systems (EPS) ($\alpha= 0.82$)
 es1 Manufacturing Requirements Planning
 es2 Enterprise Resource Planning
 es3 Forecasting software
 Network and Internet systems ($\alpha= 0.62$)
 nis1 Intranet
 nis2 E-mail
 nis3 Local area networks
 nis4 *Wide area networks*
 Knowledge/Decision support systems($\alpha= 0.67$)
 kdss1 Decision support systems
 kdss2 Intelligent Knowledge Based Systems
 kdss3 Groupware systems
 kdss4 Statistical analysis systems

To what extent does your company use quality management principles in : (1 for no use at all and 5 for intensive use)

- Quality management ($\alpha= 0.80$)*
 qm1 Information management
 qm2 Workforce management
 qm3 Supplier relationship management
 qm4 Customers relationship management
 qm5 New product design
 qm6 Process flow management

Please indicate how do the following measures at your plant compare to industry competition?: (1 no competitive and 5 highly competitive)

	<i>Operational Performance</i> ($\alpha = 0.65$)
op1	Production costs per unit
op2	On-time delivery to customers
op3	Flexibility to change production volume
op4	Cycle time (between the reception of raw materials and completion of finished product)
op5	Rate of defective units

REFERENCES

- Adam, E. E. J., Corbett, L. M., Flores, B. E., Harrison, N. J., Lee, T. S., Rho, B. H., Ribera, J., Samson, D., & Westbrook, R. (1997). An international study of quality improvement approach and firm performance. *International Journal of Operations and Production Management*, 17(9), 842-873.
- Ahire, S. L., & O'Shaughnessy, K. C. (1998). The role of top management commitment in quality management: an empirical analysis of the auto parts industry. *International Journal of Quality Science*, 3(1), 5-37.
- Aiken, M., Hasan, B., & Vanjani, M. (1996). Total Quality Management: A GDSS Approach. *Information Systems Management*, 13(1), 73-75.
- Anand, V., Manz, C. C., & Glick, W. H. (1998). An organizational memory approach to information management. *Academy of Management Review*, 23(4), 796-809.
- Armstrong, J., & Overton, T. (1977). Estimating nonresponse bias in mail surveys. *Journal of Marketing Research*, 14(3), 396-402.
- Ayers, J. B. (1993). TQM and information technology: Partners for profit. *Information Strategy: The Executive's Journal*, 9(3), 26-31.
- Bailey, J. E., & Pearson, S. W. (1983). Development of a Tool for Measuring and Analysing Computer User Satisfaction. *Management Science*, 29(5), 530-545.
- Bakos, J. Y. 1987. Dependent Variables for the Study of Firm and Industry-Level Impacts of Information Technology. Paper presented at the 8th Annual International Conference on Information Sciences.
- Barney, J. (1986). Strategic factor markets: expectation, luck, and business strategy. *Management Science*, 32(10), 1231-1241.
- Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, 17(1), 99-120.
- Berkley, B. J., & Gupta, A. (1994). Improving Service Quality with Information Technology. *International Journal of Information Management*, 14(2), 109-121.
- Bessen, J. (2002). Technology Adoption Costs and Productivity Growth: The Transition to Information Technology. *Review of Economic Dynamics*, 5(2), 443-469.
- Bharadwaj, A. S., Bharadwaj, S. G., & Konsynski, B. R. (1999). Information technology effects on firm performance as measured by Tobin's q. *Management Science*, 45(7), 1008-1024.
- Boyer, K., Leong, G. K., Ward, P., & Krajewski, L. (1997). Unlocking the potential of advanced manufacturing technologies. *Journal of Operations Management*, 15(4), 331-347.
- Brynjolfsson, E., & Hitt, L. (1996). Paradox lost? Evidence on the returns to information systems spending. *Management Science*, 42(4), 541-558.
- Byrd, T. A., & Marshall, T. E. (1997). Relating Information Technology investment to Organisational performance: a causal model. *Omega*, 25(1), 43-56.

- Choi, T., & Eboch, K. (1998). The TQM paradox: relations among TQM practices, plant performance, and customer satisfaction. *Journal of Operations Management*, 17(1), 59-75.
- Clemons, E., & Row, M. (1991). Information power and the control of the distribution channel. *MIS Quarterly* 64-67.
- Cortada, J. W. (1995). *TQM for Information Systems Management: Quality Practices for Continuous Improvement*. New York: McGraw-Hill.
- Counsell, J. (1997). Using Technology to Involve the Workforce. *Total Quality Management*, 8(2 & 3), 5126-25129.
- Curkovic, S., Vickery, S., & Droge, C. (2000). Quality-related elements: their impact on quality performance and firm performance. *Decision Sciences*, 31(4), 885-905.
- Das, A., Handfield, R. B., Calantone, R. J., & Ghosh, S. (2000). A contingent view of quality management—the impact of international competition on quality. *Decision Sciences*, 31(3), 649-690.
- Devaraj, S., & Kohli, R. (2000). Information technology payoff in the healthcare industry: A longitudinal study. *Journal of Management Information Systems*, 16(4), 41-67.
- Devaraj, S., & Kohli, R. (2003). Performance impacts of information technology: Is actual usage the missing link? *Management Science*, 49(3), 273-289.
- Dewan, L., & Kraemer, K. L. (2000). Information technology and productivity: evidence from country-level data. *Management Science*, 46(4), 548-562.
- Dewan, S., & Min, C. (1997). The substitution of information technology for other factors of production: a firm-level analysis. *Management Science*, 43(2), 1660-1675.
- Dewhurst, F. W., Martinez-Lorente, A. R., & Sánchez-Rodríguez, C. (2003). An initial assessment of the influence of IT on TQM: a multiple case study. *International Journal of Operations and Production Management*, 23(4), 348-374.
- Dillman, D. (1978). *Mail and Telephone Surveys: The Total Design Method*. New York: John Wiley.
- Doll, W. J., & Vonderembse, M. A. (1987). Forging a Partnership to Achieve Competitive Advantage: The CIM Challenge. *MIS Quarterly*, 11(2), 205-221.
- Douglas, T. J., & Judge, W. Q. J. (2001). Total quality management implementation and competitive advantage: the role of structural control and exploration. *Academy of Management Journal*, 44(1), 158-169.
- Dow, D., Samson, D., & Ford, S. (1999). Exploding the myth: do all quality management practices contribute to superior quality performance? *Production and Operations Management*, 8(1), 1-27.
- Ferdows, K., & De Meyer, A. (1990). Lasting improvements in manufacturing performance: in search of a new theory. *Journal of Operations Management*, 9(2), 168-184.
- Flynn, B., Schroeder, R., & Sakakibara, S. (1995). The impact of quality management practices on performance and competitive advantage. *Decision Sciences*, 26(5), 659-691.
- Flynn, B. B., & Flynn, E. J. (2005). Synergies between supply chain management and quality management: emergin implications. *International Journal of Production Research*, 43(16), 3421-3436.
- Forza, C. (1995a). The Impact of Information Systems on Quality Performance: An Empirical Study. *International Journal of Operations and Production Management*, 15(6), 9-83.
- Forza, C. (1995b). Quality Information Systems and Quality Management: A Reference Model and Associated Measures for Empirical Research. *Industrial Management and Data Systems*, 95(2), 6-14.
- Forza, C., & Filippini, R. (1998). TQM impact on quality conformance and customer satisfaction: a causal model. *International Journal of Production Economics*, 55(1), 1-20.

- Frohlich, M. T., & Dixon, J. R. (2001). A taxonomy of manufacturing strategies revisited. *Journal of Operations Management*, 5(19), 541-558.
- Germain, R., Droge, C., & Christensen, W. (2001). The mediating role of operations knowledge in the relationship of context with performance. *Journal of Operations Management*, 19(4), 453-469.
- Goodman, P. S., & Darr, E. D. (1996). Exchanging Best Practices through Computer-Aided Systems. *Academy of Management Executive*, 10(2), 7-19.
- Handfield, R. B., & Pagell, M. D. (1995). An analysis of the diffusion of flexible manufacturing systems. *International Journal of Production Economics*, 39(3), 243-254.
- Hendricks, K. B., & Singhal, V. R. (1996). Quality awards and the market value of the firm: An empirical investigation. *Management Science*, 42(3), 415-436.
- Hendricks, K. B., & Singhal, V. R. (2001a). Firm characteristics, total quality management and financial performance. *Journal of Operations Management*, 19(3), 269-285.
- Hendricks, K. B., & Singhal, V. R. (2001b). The long-run stock price performance of firms with effective TQM programs. *Management Science*, 47(3), 359-368.
- Hill, C. A. (2000). Information technology and supply chain management; a study of the food industry. *Hospital Material Management Quarterly*, 22(1), 53-58.
- Jonscher, C. (1994). An economic study of the information technology. New York: Oxford University Press.
- Kagan, A. (1994). Information technology seen as key to productivity. *Chemical Week*, 155(2), 20-22.
- Kaplan, C. (1996). Technology to Ease Team-Based Quality Assessments. *National Productivity Review*, 15(3), 65-82.
- Kaynak, K. (2003). The relationship between total quality management practices and their effects on firm performance. *Journal of Operations Management*, 21(4), 205- 217.
- Keen, P. (1993). Information technology and the management difference: a fussion map. *IBM Systems Journal*, 32 17-39.
- Kelley, M. R. (1994). Productivity and information technology: the elusive connection. *Management Science*, 40(1), 1406-1425.
- Khalil, O. E. M. (1996). Innovative Work Environments: The Role of Information Technology and Systems. *SAM Advanced Management Journal*, 61(3), 32-36.
- Kock, N. F. J., & McQueen, R. J. (1997). Using Groupware in Quality Management Programs. *Information Systems management*, 14(2), 56-62.
- Kotha, S., & Swamidass, P. M. (2000). Strategy, advanced manufacturing technology and performance: empirical evidence from U.S. manufacturing firms. *Journal of Operations Management*, 18(3), 257-277.
- Lado, A. A., & Zhang, M. J. (1998). Expert systems, knowledge development and utilization, and sustained competitive advantage: a resource-based model. *Journal of Management*, 24(4), 489-509.
- Leidner, D. E., & Elam, J. J. (1995). The impact of executive information systems on organizational design, intelligence, and decision making. *Orgarnazion Science*, 6(6), 445-461.
- Linderman, K., Schroeder, R., Zaheer, S., Liedtke, C., & Choo, A. S. (2004). Integrating quality management practices with knowledge creation processes. *Journal of Operations Management*, 22(6), 589-607.
- Loveman, G. W. 1994. An assessment of the productivity impact of information technologies. In T. J. Allen & S. Morton (Eds.), Information technology and the corporation of the 1990's: 84-110. New York: Oxford University Press.
- Lucas, H. C. (1981). The key to successful information systems. New York: Columbia University Press.

- Mahmood, M. A., & Mann, G. J. (1993). Measuring the organizational impact of information technology investment: An exploratory study. *Journal of Management Information Systems*, 10(1), 97-122.
- Martinez-Lorente, A. R., Dewhurst, F. W., & Gallego-Rodriguez, A. (2000). Relating TQM, marketing and business performance: an exploratory study. *International Journal of Production Research*, 38(14), 3227-3246.
- Menon, N. M., Lee, B., & Eldenburg, L. (2000). Productivity of information systems in the healthcare industry. *Information Systems Research*, 11(1), 83-92.
- Miller, H. (1996). The Multiple Dimensions of Information Quality. *Information Systems Management*, 13(2), 79-82.
- Miller, J. G., & Roth, A. V. (1994). A taxonomy of manufacturing strategies. *Management Science*, 40(3), 285-304.
- Narasimhan, R., & Das, A. (2001). The impact of purchasing integration and practices on manufacturing performance. *Journal of Operations Management*, 19(5), 593-609.
- Overby, J. W., & Min, S. (2001). International supply chain management in an Internet environment. *International Marketing Review*, 18(4), 392-420.
- Parthasarthy, R., & Sethi, S. P. (1993). Relating strategy and structure to flexible automation: A test of fit and performance implications. *Strategic Management Journal*, 14(7), 529-540.
- Pearson, J. M., & Hagmann, C. (1996). Status Report on Quality Assurance Methods. *Information Systems Management*, 13(1), 52-57.
- Peteraf, M. A. (1993). The cornerstones of competitive advantage: a resource-based view. *Strategic Management Journal*, 14(3), 179-192.
- Podsakoff, P. M., & Organ, D. W. (1986). Self-reports in organizational research: problems and prospects. *Journal of Management*, 12(4), 531-544.
- Powell, T. (1995). Total quality management as competitive advantage: a review and empirical study. *Strategic Management Journal*, 16(1), 15-37.
- Powell, T. C., & Dent-Micalef, A. (1997). Information technology as competitive advantage: the role of human, business, and technology resources. *Strategic Management Journal*, 18(5), 375-405.
- Premkumar, G., & Roberts, M. (1998). Adoption of new information technologies in rural small business. *Omega*, 27(4), 467-484.
- Rockart, J. F., & Short, J. E. (1989). IT in the 1990s: managing organizational interdependencies. *Sloan Management Review*, 30(2), 17-33.
- Rogers, D. S., Daugherty, P. J., & Ellinger, A. E. (1996). The Relationship between Information Technology and Warehousing Performance. *Logistics and Transportation Review*, 32(4), 409-421.
- Samson, D., & Terziovski, M. (1999). The relationship between total quality management practices and operational performance. *Journal of Operations Management*, 17(4), 393-409.
- Schroeder, R., Bates, K. A., & Junttila, M. A. (2002). A resource-based view of manufacturing strategy and the relationship to manufacturing performance. *Strategic Management Journal*, 23(2), 105 - 117.
- Small, M. H., & Yasin, M. M. (1997). Advanced manufacturing technology: Implementation policy and performance. *Journal of Operations Management*, 15(4), 349-371.
- Sobkowiak, R. T., & LeBleu, R. E. (1996). Repositioning HR Information Systems: Empowering Employees through Information. *Information Systems Management*, 13(1), 62-64.
- Sohal, A., Moss, S., & Ng, L. (2000). Using information technology productively: Practices and factors that enhance the success of IT. *International Journal of Technology Management*, 20(3-4), 340-353.

- Sriram, V., & Stump, R. L. (2004). Information technology investments in purchasing: An empirical investigation of communications, relationship and performance outcomes. *Omega*, 32(1), 41-55.
- Strassmann, P. A. (1997). *The squandered computer: evaluating the business alignment of information technologies*. New Canaan, Connecticut: The Information Economics Press.
- Swamidass, P. M., & Kotha, S. (1998). Explaining manufacturing technology use, firm size and performance using a multidimensional view of technology. *Journal of Operations Management*, 17(1), 23-37.
- Teague, P. E., Baker, D. J., Puttre, M., & Fitzgerald, K. R. (1997). Suppliers: The competitive edge in design. *Purchasing*, 122(7), 32S35-32S23.
- Torkzadeh, G., & Doll, W. J. (1999). The development of a tool for measuring perceived impact of information technology on work. *Omega*, 27(3), 327-339.
- Weston, F. C. J. (1993). Weighting 'soft' and 'hard' benefits of information technology. *Manufacturing Systems*, 11(7), 120-121.
- Willcocks, L. P., & Lester, S. (1997). In search of information technology productivity: Assessment issues. *Journal of the Operational Research Society*, 48(11), 1082-1094.
- Wilson, D. D., & Collier, D. A. (2000). An empirical investigation of the Malcolm Baldrige National Quality award causal model. *Decision Sciences*, 31(2), 361-390.
- Zadrozny, M. A., & Ferrazzi, K. E. (1992). Building a technology base for TQM. *Chief Information Officer Journal*, 5(2), 16-21.
- Zahra, S., & Covin, J. (1993). Business strategy, technology policy, and firm performance. *Strategic Management Journal*, 14(6), 451-478.