IT use in supporting TQM initiatives: an empirical investigation

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Structured abstract:

Purpose
To provide insights into current IT and TQM theory and practice on operational and quality performance, in particular the use of IT in supporting TQM policies and practices.

Design/methodology/approach
Hypotheses derived from the key features of TQM and IT presented by previous authors are tested using Structural Equation Modelling through field research on a sample of 234 manufacturing companies in Spain.

Findings
The results indicate that the sampled firms make considerable use of IT to support their TQM initiatives and that overall such efforts generate significant positive gains on operational and quality performance, the few exceptions to this are noted and discussed.

Research limitations/implications
The limitations of the survey include: single key informant, only cross-sectional and limited performance measures. A longitudinal/cross-cultural study including other performance measures (e.g. percentage defect rates, number of customer claims) would add to further understanding.

Practical implications
A survey of IT in support of TQM initiatives on operational and quality performance in manufacturing suggests how firms and other organisations should focus their IT investments to improve performance.

Originality/value
Both Information Technology and Total Quality Management have had, and continue to have, a significant impact on most organizations. Although each paradigm has been widely researched there is little empirical research on the relationship between the two and how they both relate to business performance.

Keywords:
Information Technology, Total Quality Management, performance, empirical study, Structural Equation Modelling

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Introduction

The effects of IT on business performance have been frequently studied and reported, for example by Devaraj and Kohli (2003) and Sriram and Stump (2004). Similarly there have been many studies into the effects of TQM implementation on performance, for example Douglas and Judge (2001) and Kaynak (2003). Weston (1993) claimed that management interventions such as Total Quality Management (TQM) rely heavily on IT, which act as a feedback mechanism and facilitate communication and the implementation of advanced tools, systems and modelling techniques and many authors, for example Kock and McQueen (1997) and Miller (1996), have considered how specific IT applications might impact on TQM. However, few authors have provided convincing evidence of the effects of IT on TQM and business performance. Perhaps the only exception is the study by Forza (1995b) in which he developed a reference model to link TQM practices, information systems and quality performance through empirical research. However, Forza (1995a) did not succeed in empirically establishing a link between TQM practices and IT, and only the use of IT in the quality assurance aspect of TQM was explored. Consequently, Forza (1995a and 1995b) argued that the contribution of IT to TQM should be further investigated by developing adequate measures especially with reference to its use.

A first attempt at further investigation was undertaken by Torkzadeh and Doll (1999) who only reported on the perceived impact of IT on work, which is not the most recognised of several TQM dimensions that have appeared in the literature, see for example Martinez-Lorente et al. (2000). More recently, Dewhurst et al. (2003) investigated the influence of IT use on several key TQM dimensions through a multiple case study of 14 companies and proposed a framework linking: company characteristics (e.g. size); extent of use of different categories of IT; extent of application of key dimensions of TQM; impact of use of each IT category on each TQM dimension; and the effects of each IT category and each TQM dimension on business performance. This paper presents a detailed analysis of a survey instrument designed to test the framework of Dewhurst et al. (2003) and reports on:

- validation of the questionnaire survey measurement constructs;
- correlations between IT, TQM and performance constructs;
- testing of structural equation models to link the constructs;
- implications of the finding for academics and practitioners

The design and content analysis of the questionnaire constructs can be found in Dewhurst et al. (2003), which also contains a draft version of the questionnaire in an appendix. Further details of the questionnaire and a more general analysis of the results can be found in Martinez-Lorente et al. (2004).

In the next section we briefly revisit the previous literature from which the key measures of the survey and the structural equation models and their hypotheses were derived. A third section briefly describes the survey and reports on the validation of the constructs whilst a fourth section presents the results from an analysis of the survey and the hypothesis testing of the structural equation models. In the final section we present conclusions, discuss the implications for management, report on the limitations of the study and consider the way forward for future research.

Linking IT, TQM and performance

It is frequently argued that IT investments are a very important factor in increasing productivity and reducing costs (e.g. Bessen, 2002; Kotha and Swamidass, 2000; Torkzadeh and Doll, 1999). Evidence of positive and significant returns from IT investment can be found in Bharadwaj et al. (1999), Byrd and Marshall (1997), Brynjolfsson and Hitt (1996), Dewan and Kraemer (2000), Kelley (1997), Rogers et al. (1996) and Sohal et al. (2000). Other firm level studies by Menon et al. (2000) and Devaraj and Kohli (2000) found evidence of positive effects of IT interventions in hospitals. However some studies showed contradictory results (e.g. Swamidass and Kotha, 1998; Willcocks and Lester, 1997) and some failed to find a significant increases in financial performance or competitive advantage (e.g. Powell and Dent-Micalef, 1997; Strassmann, 1997). Some authors have argued that the effects of IT may not be fully reflected in firm-level financial outcomes (Strassmann, 1997), but rather manifested at a more operational level such as shorter cycle time and increased customer satisfaction (e.g. Handfield and Pagell, 1995). Consequently it would be expected that IT implementation would have a positive impact on operational and quality performance.

Several writers have attempted to define the key dimensions that constitute TQM and Martinez-Lorente et al (2000) rationalised these into the key dimensions shown in Table 1. Consequently, any study into the use of IT to support TQM should focus on each of these dimensions.

<Insert Table 1>

Sousa and Voss (2002) suggest that TQM is expected to be positively related with company performance and a positive impact of IT on TQM dimensions should then result in a positive impact on company performance. We now consider each TQM dimension and suggest hypotheses to link IT, TQM and operational and quality performance.

Top management leadership is one of the major determinants of successful TQM implementation and refers to the commitment of top management in applying and stimulating the TQM approach across the organization, accepting responsibility for products and services and providing the necessary leadership to motivate all employees (Martinez-Lorente et al., 2000). As reported by Dewhurst et al. (2003) IT can be used to: support the leadership role of senior management; facilitate the dissemination of TQM values; and manage information on quality, which in turn facilitates TQM application and consequently promotes the benefits of TQM. Samson and Terziovski (1999) reported that top management leadership has a significant and positive impact on operational performance. Ahire and O´Shaughnessy (1998) found that firms with top management leadership produce higher quality products than those with low top management commitment and Dow et al. (1999) found that shared TQM vision has a positive impact on quality outcomes. Therefore, we propose the following hypothesis:

H1: IT to support top management leadership has a positive impact on operational performance (H1a) and quality performance (H1b).

Customer relationships are clearly identified in the literature as a critical component of TQM. Quelch and Klein (1996) argued that IT enables organisations to reach customers who are geographically remote and a study by Stone et al. (1996) indicated that customers will increasingly seek to manage the relationship themselves, using new technologies (e.g. Internet and Electronic Data Interchange). Dewhurst et al. (2003) also reported evidence about IT use to facilitate customer surveys, perform sophisticated analyses of consumer needs, expectations and behaviour, and for targeting specific consumers and products. Samson and Terziovski (1999) reported that customer focus has a significant and positive impact on operational performance whilst Ahire and O´Shaughnessy (1998) and Dow et al. (1999) also found that customer focus has a positive impact on quality outcomes. Therefore, we propose a second hypothesis:

H2: IT to support customer relations has a positive impact on operational performance (H2a) and quality performance (H2b).

Supplier quality management is concerned with the selection of suppliers based on quality rather than price and the establishment of long-term, cooperative relationships to help suppliers to improve the quality of their materials and/or services. The literature contains numerous examples of how IT can be used to support supplier relationships such as improving communication links. For example, EDI can be used to place orders, send product specifications, design details, etc., along with confirmation of invoices and paying for suppliers (Jonscher, 1994) and the Internet can be used to identify new sources of supply. Teague et al. (1997) outline how suppliers can be involved earlier in the design process by the use of IT. In some cases, companies can access the inventory systems of their suppliers and place orders automatically and also access their production scheduling systems. Kaynak (2003) found a positive effect of supplier quality management on inventory management performance whilst Ahire and O´Shaughnessy (1998) reported that supplier quality management is a significant predictor of product quality. Therefore, we propose a third hypothesis:

H3: IT to support supplier relationships has a positive impact on operational performance (H3a) and quality performance (H3b).

Workforce management is clearly identified as a critical component of TQM (Martinez-Lorente et al., 2000). Several authors have reported that IT can support human resource practices by facilitating teamwork and more effective communications among employees and with managers (Dewhurst et al., 2003). Other common uses of IT in the area of human resources practices include training, evaluation, and employee recognition. Samson and Terziovski (1999) reported that workforce management, has a significant and positive impact on operational performance. Ahire and O´Shaughnessy (1998) found that empowerment emerges as significant predictors of product quality and Dow et al. (1999)

found that employee commitment has a positive impact on quality outcomes. Therefore, we propose a fourth hypothesis:

H4: IT to support workforce management has a positive impact on operational performance (H4a) and quality performance (H4b).

Product design refers to the design of quality into products and services (Handfield et al., 1999) and Quality function deployment (QFD), failure mode and effect analysis (FMEA), design of experiments, and concurrent engineering are common examples of quality product design process tools. Additionally, quality-oriented organizations rely on concurrent engineering which requires the interaction among several departments in an organization, most often production, marketing and R&D. Several authors have indicated that IT could be employed to facilitate the adoption of quality process design tools. For example, Mezgar et al. (1997) pointed out that IT is useful in design of experiments and Rangaswamy and Lilien (1997) stated that IT is useful in QFD. Hameri and Nihtila (1997) reported a case study in which design projects involved numerous teams from various locations and web-based applications in new-product development provided an effective media for communicating and disseminating information. Flynn et al. (1995) and later Kaynak (2003) found a positive impact of product design on quality performance. Based on the previous hypotheses we therefore propose a fifth:

H5: IT to support product design process has a positive impact on operational performance (H5a) and quality performance (H5b).

Process management entails taking a preventive approach to quality improvement such as designing fool-proof processes, self-inspection through clear work instructions, and the use of statistical and non-statistical improvement instruments (Martinez-Lorente et al., 2000). IT investments have been widely used in process flow management. For example, SPC can be facilitated by the introduction of IT, through the automated measurement of product and process parameters and the registration and processing of data (Gong et al., 1997). IT can also assist in maintenance through the use of automated systems to detect the need for machine maintenance and diagnose what needs to be done (Dilger, 1997). Wilson and Collier (2000) found that process design and process flow management result in positive impacts on financial performance. Both Flynn et al. (1995) and Kaynak (2003) found a positive effect of process management on quality performance. This leads us to propose a sixth hypothesis:

H6: IT to support process flow management has a positive impact on operational performance (H6a) and quality performance (H6b).

Quality data and reporting is concerned with the availability and visibility of information relating to scrap, rework and the cost of quality throughout the organization (Martinez-Lorente et al., 2000). TQM organizations make use of IT to support data collection efforts such as measurement of quality costs, facilitating other common quality-related tasks such as collection information about production processes, employees, customers, suppliers, and providing updated information about quality performance (Dewhurst et al., 2003). Wilson and Collier (2000) found that quality data and reporting result in positive impacts on financial performance whilst Flynn et al. (1995) reported that statistical control/feedback has a positive effect on quality performance. This leads to our final hypothesis:

H7: IT to support quality data and reporting has a positive impact on operational performance (H7a) and quality performance (H7b).

Figure 1 shows the proposed general theoretical model for these hypotheses. In the next sections we report on the testing of these hypotheses.

<Take in Figure 1>

The empirical study

The sampling frame consisted of 1,949 senior quality managers who were selected from the 3000 largest manufacturing companies in Spain (Fomento de la Produccion, 2001). Quality managers were determined as the most appropriate respondents because they were considered to be most familiar with the quality management practices and performance outcomes of their organisation.

Following comments on a draft questionnaire (see Dewhurst et al, 2003) the questionnaire was refined and then submitted to academics in Spain and the UK and was also piloted on sample of 10 companies. Based on the responses from the pre and pilot tests the questionnaire was further refined before being mailed

The survey was administered in three mailings following a modified version of Dillman's (1978) Total Design for survey research. In the first mailing, a cover letter explaining the purpose of the study and a survey questionnaire along with a postage-paid envelope were sent to all members in the sample frame. A letter encouraging non-respondents to participate in the research was sent three weeks later. Six weeks after the initial mailing, a second survey and cover letter were sent to the remaining non-respondents. The resulting sample was made up 442 firms which resulted in an initial response rate of 22.7% and comparable to similar studies in the literature (e.g. Frohlich and Dixon, 2001). Of those 442 respondents, 52.9% of companies (n = 234) identified themselves as implementing TQM, yielding a definitive 12% response rate.

Armstrong and Overton's (1977) approach was used to assess non-response bias, which consisted of comparing early with late respondents (i.e. first and second mailing). The last wave of surveys received was considered to be the representative of non-respondents. No significant differences were found between early and late respondents on all variables, which include sales volume and number of employees. These results suggested that non-response bias was not a concern for the study.

The majority of the questionnaires (70.5%) were answered by quality managers whilst other respondents included quality department representatives (10.5%) and plant directors (3.4%). An analysis of variance (Anova) showed that respondents' perceptions among different groups were not significantly different for 61 of the 67 items considered. Indeed only six cases were found in which quality department members perceived a more optimistic situation than others (e.g. quality managers, operations managers, production managers and plant directors). Some 60% of the companies in the sample were made up of Spanish firms, 21% of other European Union countries and 19% from non-EU countries.

The questionnaire comprised 67 items: 28 measured IT usage, 28 measured the use of IT to support TQM, 4 measured operational performance, and 5 measured quality performance.

The measurement of IT usage was based on previous studies (e.g. Bakos, 1987; Boyer et al., 1997; Premkumar and Roberts, 1998; Swamidass and Kotha, 1998) and respondents were asked to report their level of utilization using a five-point Likert scale (1 = no use, 5 = intensive use). These were classified into six broad categories according to their purpose: administrative IT (ITADMN), communications-related IT (ITCOMM), decision support IT (ITDEC), production planning IT (ITPLAN), product design IT (ITDESIGN), and production control IT (ITPDCTRL) as shown in Table 2.

<Take in Table 2>

To measure the use of IT in support of TQM, respondents were asked to indicate the extent to which the use of IT supported each TQM element as shown in Table 3, using a five-point Likert scale, where 1 represented "nothing at all" and 5 represented "greatly". The level of operational and quality performance were measured by asking respondents to report the comparative position of their firm with respect to competitors using a five-point Likert scale, where 1 represented "not competitive at all" and 5 represented "very competitive" as shown in Table 4.

<Take in Table 3>

<Take in Table 4>

Previous measures of operational performance by Schroeder et al. (2002), which included measurements of production costs, conformance quality, on-time delivery, cycle time, and flexibility were used. However, the conformance quality indicator was excluded from our operational performance construct because it was included it as part of the quality performance construct. As product quality and customer satisfaction constitute two key TQM objectives (Forza and Filippini, 1998); defective rates, product quality, plant quality performance, quality in the relationships with customers, and customer satisfaction were also measured.

The research model shown in Figure 2 was derived from the general theoretical model in Figure 1 and portrays the relationships corresponding to hypothesis H1. Similar research models were also developed for the remaining hypotheses by just changing the IT to support top management leadership construct for the corresponding IT-related construct in each hypothesis.

<Take in Figure 2 >

Analysis

A set of Confirmatory Factor Analyses (CFAs) was undertaken to address the validity and reliability of the seven constructs pertaining to the utilization of IT to support TQM (ITTML, ITCR, ITSR, ITWFM, ITPD, ITPFM, and ITQDR), as well as the operational and quality performance constructs. The construct structure could not be individually confirmed for IT support process flow management (ITPFM) because the measurement model was just identified with three items (degrees of freedom, DF = 0). Therefore, in this case a two-construct structure was estimated; that is, IT support process flow management (ITPFM) and operational performance were confirmed together as a pair. Tables 3 and 4 show the constructs and their respective scale items. As recommended by many researchers (e.g. Hair et al., 1995), multiple fit criteria were employed to evaluate the measurement models. As can be seen in Tables 3 and 4, the chi-square statistic in each CFA was non-significant ($p > 0.05$) indicating that the covariance structure implied by the model does not significantly differ from the covariance structure determined from the sample data, thus, indicating a good fit. In addition, other fit indices are presented in Tables 3 and 4, which also indicated an acceptable fit of the measurement models to the data. For instance, the RMSEA, and RMR for each CFA were below the recommended maximum of 0.10 (Chau, 1997), and the AGFI and the GFI were above the 0.80 and 0.90 respective minimum recommended values (Chau, 1997).

We did not conduct a full CFA that included exogenous and endogenous latent variables for two reasons. First, we were not interested in the associations amongst the exogenous variables (i.e. IT to support quality management latent variables) making it unnecessary to conduct a full CFA. Second, the sample size was too small to perform a full CFA. Several authors suggest that a minimum sample size of ten observations for each measurement variable is required for multivariate analyses to ensure adequate statistical power (Hair et al., 1995; Tanaka, 1987); this would prescribe a minimum sample size of approximately four hundred for the proposed model (39 measurement variables). Our sample size (234 respondents) was insufficient to ensure adequate statistical power for such a model.

Convergent validity addresses whether set of alternative measures accurately represents the construct of interest (Churchill, 1979) and was assessed by reviewing the level of significance for the factor loadings. If all the individual factor loadings for each item were significant, then the indicators were effectively measuring the same construct (Anderson and Gerbing, 1988). As can be seen from Tables 3 and 4 the coefficients for all indicators were large and significant (t-values > 2.00; $p < 0.05$).

Scale reliability provides a measure of the internal homogeneity of the items comprising a scale (Churchill, 1979) and was calculated, as in Hair et al. (1995), by:

$$\frac{\left(\sum \textbf{factor loading}\right)^2}{\left(\sum \textbf{factor loading}\right)^2 + \left(\sum \textbf{error variances}\right)}$$

All constructs displayed composite reliabilities in excess of the generally accepted 0.70 value for non exploratory studies and well above the 0.60 recommended value for exploratory studies (Churchill, 1979)(see Tables 3 and 4).

Discriminant validity among the latent variables and their associated measurement variables can be assessed by fixing (i.e. constraining) the correlation between pairs of constructs to 1.0, re-estimating the modified model, and measuring the change in the chi-square statistic (Segars and Grover, 1993). The condition of discriminant validity is met if the difference of the chi-square statistics between the constrained and standard models is significant (1 d.f.). The chi-square difference tests indicated that discriminant validity exists among all the uses of IT to support TQM constructs and between the operational and quality performance constructs ($p < 0.05$).

The hypotheses presented in the second section were tested using Structural Equation Modelling (SEM). The overall fit for the estimated research models (illustrated in Figures 1 and 2) are shown in Table 5. As recommended by many researchers, multiple fit criteria (RMSEA, RMR, CFI, GFI, and AGFI) were assessed to rule out measuring biases inherent to using a single fit index (Hair et al., 1995). The indices indicated a good fit between the data and the proposed models. The χ^2/DF ratio and RMS were below the recommended maximum of 3.00 and 0.10; the RMSEA was below the 0.10 minimum acceptable level and NNFI, CFI, and GFI were equal to or above the recommended acceptable 0.90 level (Chau, 1997).

<Take in Table 5>

The hypotheses tests were based on the direct effects between constructs. Table 6 shows the results from the estimation of the research models corresponding to each hypothesis, which were tested at the significance level $p < 0.05$, two tailed (t-value > 1.96).

<Take in Table 6>

Results

The results of the section of the survey relating to IT use within manufacturing are summarised in Table 2. The support of administration (ITADMN) was the most widely and consistently reported use of IT. Although communication (ITCOMM) was the second most popular, it was dominated by e-mail whilst the use of other items varied widely. The use of IT in production planning (ITPLAN) was also significant but also varied widely and this was followed by IT for product design (ITDESIGN) with even higher levels of variance between respondents. IT for decision support (ITDEC) and production control (ITPDCTRL) overall were below the median. However, ITDEC was adversely affected by the low response to Intelligence Knowledge Based Systems (IKBS) whilst ITDPCTRL was mainly influenced by the use of computers in shop-floor control.

The results of the section of the survey relating to IT use in support of TQM are summarised in Table 3. The majority of responses were above the scale median of 3, indicating that IT plays a key role in supporting TQM. Some measures were significantly above the scale median, i.e. communication with customers (itcr5); improving ordering and communication with suppliers (itsr2 and itsr3); and supporting data collection, maintenance and analysis (itqdr2, itqdr3 and itqdr4). These results are consistent with the recent literature, for example, Carr and Smeltzer (2002) and Ellram and Zsidisin (2002) in relation to supplier relationships. These suggest that the highly significant use of e-mail is not restricted for internal use but also plays a key role in communications with customers and suppliers. However, a few measures were below the scale median and the majority of these were related to product design (itpd1, itpd2 and itpd3) indicating that TQM firms in the sample make limited use of IT to support new product quality design tools such as QFD and FMEA. A possible explanation of this result could be that several responding firms were manufacturing units of multi-nationals which undertake product design elsewhere.

Five of the seven SEM hypothesis tests were fully supported as shown in Table 7. The use of IT to support top management leadership (H1) was highly related to operational and quality performance and this result is consistent with earlier anecdotal evidence by Dewhurst et al. (2003) who found that firms with TQM programs used IT to facilitate the dissemination of TQM values. IT use in support of customer relations (H2) had a positive impact on operational and quality performance and again is consistent with previous literature (Dewhurst et al., 2003; Quelch and Klein, 1996). Hypothesis H3 was also supported, in particular the use of IT to support ordering, communication with suppliers, financial transactions with suppliers, and identification of new suppliers had a positive effect on quality and operational performance, and these results are also consistent with recent literature suggesting that automated ordering processes such as EDI, Intranets, Extranets improve buyer performance (Sriram and Stump, 2004). Workforce management is another key element of TQM and the results indicated that firms make considerable use of IT to support workforce management activities (H4). Specifically, these beneficial effects on operational and quality performance result from the utilisation of IT to help employees to share task-related information, facilitate teamwork, provide training about quality management issues, and facilitate the evaluation of employees on quality improvement. Firms in the sample made extensive use of IT to collect and disseminate quality information and of particular note is the use of IT to maintain quality information systems (e.g. documents); in decision support and statistical tools; and to collect data from individuals (employees, customers and suppliers) and processes (work/production processes). The results of the structural equations analysis indicated that IT use to support quality data and reporting improves both operational and quality performance (H7).

However, two of the seven SEM hypothesis tests were only partially supported. IT use to support product design significantly improves quality performance (H5b) but not operational performance (H5a). Specifically, firms that employ IT to facilitate the exchange of new design information between departments and execute product design tools such as design of experiments, FMEA, and QFD have significant improvements in quality in comparison their competitors. Similarly, the results suggest that firms who use IT to manage their production processes obtain higher quality than their competitors (H6a) but do not experience better operational results (H6b) such as lower unit production cost, better delivery, flexibility, and reduced cycle times. These two results are consistent with the lack of evidence from previous studies for any relationship between product design or process management and operational performance despite the evidence linking process design and process flow management to financial performance Wilson and Collier (2000).

Conclusions

This study has examined the use of IT to support TQM initiatives and their contribution to operational and quality performance in the manufacturing sector of Spain and provides a step towards understanding how IT and TQM jointly add value to manufacturing firms. Since organizations use a variety of approaches and practices to remain competitive, identifying practices that positively impact on performance allows organizations to more effectively manage their scarce resources.

The relative strength and significance of the structural equation model coefficients in Table 6 are instructive in understanding the positive effects of the use of IT in TQM on performance. Five of the seven uses of IT to support TQM factors were found to be significantly and positively related to operational performance. This suggests that managers who focus on improving operational performance measures (i.e. reduced unit production cost, faster delivery, improved flexibility, and reduced cycle time) should invest in IT to support management leadership, customer focus, supplier relations, workforce management and information collection/storage and reporting. This is not to say that TQM firms should not invest in the other two factors (IT to support product design, and IT to support process flow management) but rather to note that in our study these weaker factors did not significantly distinguish the high from the low performers. With respect to quality performance, all of the TQM-oriented IT factors were found to be significantly and positively related. Consequently if a management focus is on quality performance (product quality and customer satisfaction) then firms should direct their IT investment to all seven key TQM initiatives.

The results confirm the importance of the interaction between TQM and IT (Weston, 1993), and shed light on the support mechanisms between IT and TQM activities. Indeed these results are not unique to TQM firms in manufacturing and could also be applied to organisations that want to maximize the return of their IT investments. The results suggest that organizations should link their IT investments to support specific quality-oriented initiatives. For example, if the focus is on workforce management, then organisations should investment in the use of IT to help employees to share task-related information, facilitate teamwork and provide training about quality management issues.

The study exposes a number of opportunities and areas for future research. For example, the lack of a significant relationship between the use of IT to support the product design process and process flow management represents an opportunity for future research. The use of a single key informant could be seen as a potential limitation of the study and future research could consider collecting information from several individuals in the organization. The research reported here is only cross-sectional and future research could be longitudinal, as in Bharadwaj et al. (1999), to account for: (a) any lags between IT and TQM practices and changes in performance and (b) to take into account the rapid changes and acceptances of IT. It would also be interesting to replicate such research with other measures of operational and quality performance (e.g. percentage defect rates, number of customer claims, etc). Furthermore, cultural issues might influence how organizations respond, which could be addressed through cross-cultural surveys and contribute significantly to our understanding of international differences. Finally, although the constructs were defined as precisely as possible by drawing on relevant literature and statistically validated, they can realistically only be thought of as proxies for an underlying latent phenomenon that is itself not fully measurable.

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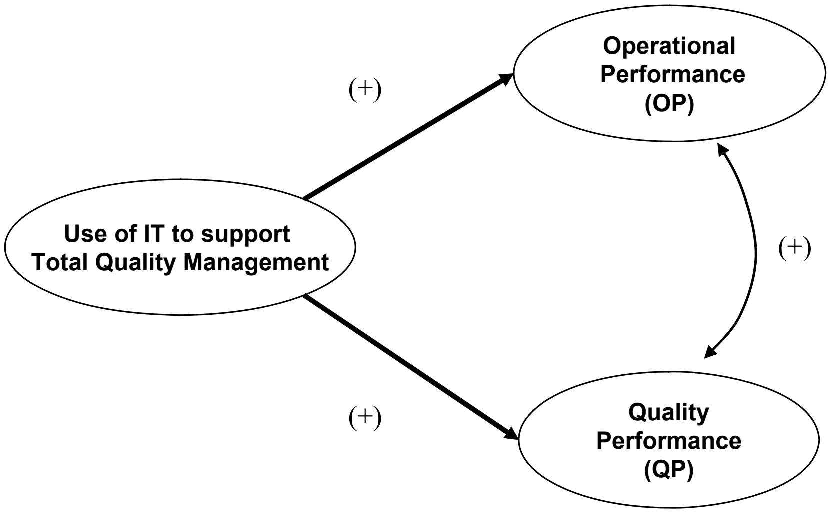

Figure 1. The general theoretical model

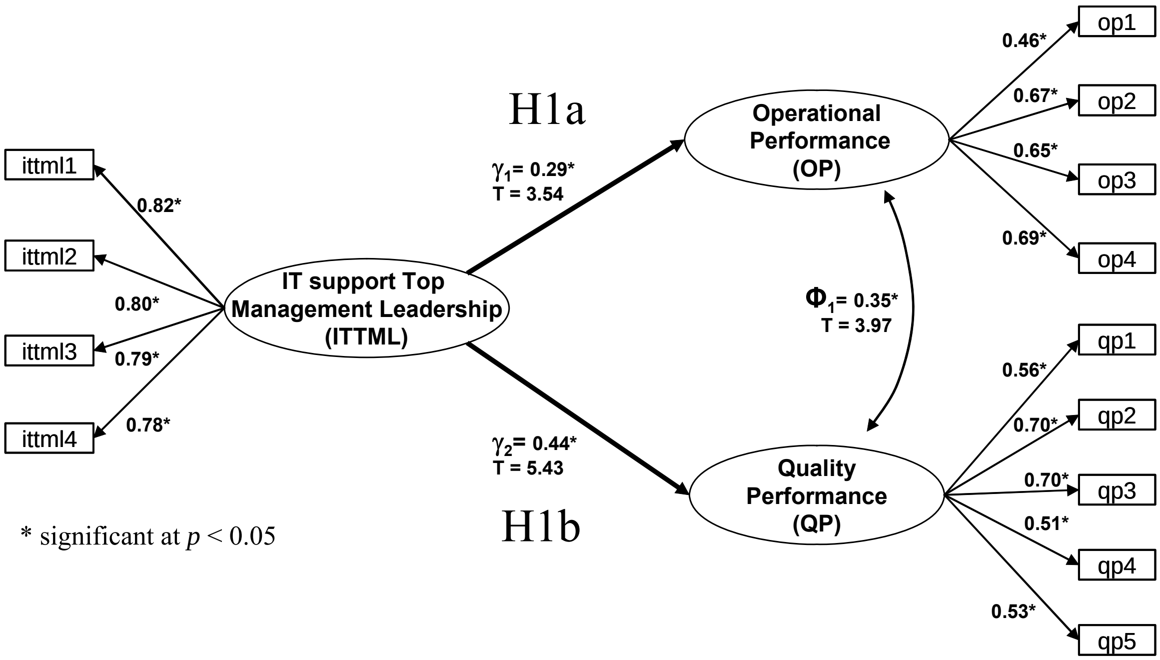

Figure 2. Model parameter estimates associated with hypothesis H1

TQM dimensions	Description
Top management leadership	Top management commitment is one of the major determinants of successful TQM implementation. Top management has to be the first in applying and stimulating the TQM approach, and they have to accept the maximum responsibility for the product and service offering. Top management also has to provide the necessary leadership to motivate all employees.
Customer relationships	The needs of customers and consumers and their satisfaction have always to be in the mind of all employees. It is necessary to identify these needs and their level of satisfaction.
Supplier relationships	Quality is a more important factor than price in selecting suppliers. Long-term relationship with suppliers has to be established and the company has to collaborate with suppliers to help improve the quality of products/services.
Workforce management	Workforce management has to be guided by the principles of: training, empowerment of workers and teamwork. Adequate plans of personnel recruitment and training have to be implemented and workers need the necessary skills to participate in the improvement process.
Product design process	All departments have to participate in the design process and work together to achieve a design that satisfies the requirements of the customer, according to the technical, technological and cost constraints of the company.
Process flow management	Housekeeping along the lines of the 5S concept. Statistical and non-statistical improvement instruments should be applied as appropriate. Processes need to be mistake proof. Self-inspection undertaken using clear work instructions. The process has to be maintained under statistical control.
Quality data and reporting	Quality information has to be readily available and the information should be part of the visible management system. Records about quality indicators have to be kept, including scrap, rework and cost of quality.

Table 1. TQM key dimensions from Martinez-Lorente et al. (2000)

IT usage category **To what extent does your company use the following IT?** **(1-no use at all to 5- intensive use)**	**Mean**	**SD**
Administrative (ITADMN)		
Invoicing systems	4.77	0.470
Payroll systems	4.73	0.588
Data bases	4.59	0.683
Stock control systems	4.45	0.869
Cost accounting systems	4.36	0.865
Communication (ITCOMM)		
e-mail	4.60	0.707
Company intranet (internal web)	3.95	1.230
Advertising by a company web page	3.32	1.378
Electronic data interchange (EDI) with customers/clients	3.25	1.206
Electronic data interchange (EDI) with suppliers	3.16	1.167
Inter company networks	2.99	1.469
Group working with electronic information interchange	2.82	1.228
Decision support (ITDEC)		
Data analysis techniques	3.19	1.173
Decision support systems (DSS)	3.05	1.169
Forecasting software	2.99	1.301
Intelligent Knowledge Based Systems (IKBS)	2.00	1.139
Planning (ITPLAN)		
Manufacturing Requirements Planning (MRP)	3.54	1.354
Computer Aided Production Planning (CAPP)	3.28	1.386
Enterprise Resource Planning (ERP) for example SAP	3.00	1.390
Product design (ITDESIGN)		
Computer Aided Design (CAD)	3.48	1.449
Computer Aided Engineering (CAE)	3.00	1.400
Computer Aided Manufacturing (CAM)	2.81	1.524
Production control (ITPDCTRL)		
Computers for controlling the factory floor	3.50	1.310
Numeric control machines with computer control (CNC)	2.82	1.566
Electronic systems of quality control	2.73	1.321
Flexible manufacturing systems (FMS)	2.47	1.326
Electronic systems of product identification	2.42	1.393
Robots	2.33	1.400

Table 2. IT use based on Bakos (1987) and others.

Code	Construct /Item To what extent does you company use IT for the following? (1-not at all to 5-intensively)	Mean	SD	Std Loads
ITTML	*IT to support Top Management Leadership* (Reliability = 0.87)			
ittml1	Make the commitment to TQM visible to staff and employees	3.00	1.081	0.81
ittml2	Communicate TQM values to employees	3.12	1.036	0.79
ittml3	Facilitate communication between top management and employees	3.27	0.992	0.81
ittml4	Encourage employee involvement to improve work processes	3.06	1.028	0.78
χ^2 = 0.00 p-value= 1.00 DF = 1 RMSEA= 0.00 RMR = 0.00 CFI = 1.00 GFI = 1.00 AGFI = 1.00				
ITCR	*IT to support Customer Relationships* (Reliability = 0.83)			
itcr1	Identify customers	3.05	1.023	0.36
itcr2	Identify customer needs	3.30	0.952	0.62
itcr3	Analyze customer surveys	3.30	1.141	0.91
itcr4	Measure customer satisfaction	3.46	1.069	0.86
itcr5	Improve communications between you and the customer	3.86	0.845	0.67
χ^2 = 5.87 p-value= 0.12 DF = 3 RMSEA= 0.06 RMR = 0.02 CFI = 0.99 GFI = 0.99 AGFI = 0.95				
ITSR	*IT to support Supplier Relationships* (Reliability = 0.78)			
itsr1	Identify suppliers	3.11	0.976	0.53
itsr2	Improve ordering	3.80	0.860	0.77
itsr3	Improve communications between you and your suppliers	3.73	0.838	0.77
itsr4	Improve financial transactions between you and your suppliers	3.66	0.963	0.68
χ^2 = 7.03 p-value= 0.13 DF = 4 RMSEA= 0.06 RMR = 0.03 CFI = 0.99 GFI = 0.99 AGFI = 0.95				
ITWFM	*IT to support Workforce Management* (Reliability = 0.81)			
itwfm1	Team working	3.29	0.922	0.80
itwfm2	Enabled staff to share task-related information	3.52	0.930	0.69
itwfm3	Training of staff on quality issues	3.23	0.970	0.65
itwfm4	Staff evaluation in quality improvement programmes	2.87	1.004	0.73
χ^2 = 2.38 p-value= 0.12 DF = 1 RMSEA= 0.08 RMR = 0.01 CFI = 1.00 GFI = 1.00 AGFI = 0.95				
ITPD	*IT to support Product Design* (Reliability = 0.81)			
itpd1	Design of experiments	2.16	1.123	0.72
itpd2	Failure mode and effect analysis (FMEA)	2.67	1.271	0.73
itpd3	Quality function deployment (QFD)	2.43	1.180	0.88
itpd4	The exchange of new design information between departments	3.10	1.234	0.54
χ^2 = 0.02 p-value= 0.89 DF = 1 RMSEA= 0.00 RMR = 0.00 CFI = 1.00 GFI = 1.00 AGFI = 1.00				
ITPFM	*IT to support Process Flow Management* (Reliability = 0.78)*			
itpfm1	Detect the need for machine maintenance	3.18	1.029	0.70
itpfm2	Check product adjust to design	3.21	1.047	0.81
itpfm3	Application of SPC	3.46	1.023	0.44
χ^2 = 11.98 p-value= 0.44 DF = 12 RMSEA= 0.00 RMR = 0.05 CFI = 1.00 GFI = 0.99 AGFI = 0.97				
ITQDR	*IT to support Quality Data and Report* (Reliability = 0.82)			
itqdr1	Collect data about employees, customers and suppliers	3.55	0.906	0.47
itqdr2	Collect data about work/production processes	3.72	0.939	0.49
itqdr3	Maintain quality information systems (e.g. documents)	3.94	0.825	0.55
itqdr4	Provide DSS, statistical tools, diagrams	3.91	0.874	0.61
itqdr5	Provide timely information to staff for decision-making	3.50	0.892	0.90
itqdr6	Provide relevant information to staff that meets their needs	3.30	0.881	0.87
χ^2 = 11.31 p-value= 0.08 DF = 6 RMSEA= 0.06 RMR = 0.03 CFI = 0.99 GFI = 0.98 AGFI = 0.94				

Table 3 Items measuring the use of IT supporting TQM

Code	Construct /Item How does your company compare to all your competitors on the following measures? (1-not at all to 5-highly)	Mean	SD	Std Loads
OP	*Operational Performance* (Reliability = 0.71)			
op1	Production cost per unit	3.97	0.811	0.46
op2	Fast delivery to customers	3.94	0.850	0.67
op3	Flexibility to change volume	3.93	0.753	0.68
op4	Cycle time	3.89	0.821	0.66
χ^2 = 0.03 p-value= 0.87 DF = 1 RMSEA= 0.00 RMR = 0.00 CFI = 1.00		GFI = 1.00		AGFI = 1.00
QP	*Quality Performance* (Reliability = 0.72)			
qp1	Defective rates	3.75	0.822	0.50
qp2	Product quality	3.89	0.671	0.80
qp3	Customer relations	3.72	0.718	0.65
qp4	Customer satisfaction in the last three years	4.08	0.733	0.47
qp5	Plant quality performance in the last 3 years (Reverse coded)	3.34	0.903	0.48
χ^2 = 4.96 p-value= 0.08 DF = 2 RMSEA= 0.08 RMR = 0.03 CFI = 0.99		GFI = 0.99		AGFI = 0.93

Table 4 Items measuring operational and quality performance

	Research model associated to hypothesis:						
	H1	**H2**	**H3**	**H4**	**H5**	**H6**	**H7**
Chi-Square	105.71	126.68	111.65	95.77	87.34	78.93	117.89
Degrees of freedom	57	68	58	57	57	47	80
p- value	0.000	0.000	0.000	0.001	0.006	0.002	0.004
χ^2/DF	1.85	1.86	1.92	1.71	1.53	1.68	1.47
RMSEA	0.061	0.061	0.063	0.054	0.048	0.054	0.045
NNFI	0.94	0.92	0.90	0.94	0.95	0.92	0.95
GFI	0.94	0.93	0.93	0.94	0.95	0.95	0.94
AGFI	0.90	0.89	0.89	0.91	0.91	0.91	0.90

Table 5. Model fit indices

	IT usage construct items						Hypothesis test parameters						Operational Performance construct items				Quality Performance construct items				
Hypothesis	**1**	**2**	**3**	**4**	**5**	**6**	γ_a	T_a	γ_b	T_b	Φ	T	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**5**
H1	0.82*	0.80*	0.79*	0.78*			0.29*	3.54	0.44*	3.07	0.35*	3.97	0.46*	0.67*	0.65*	0.69*	0.56*	0.70*	0.70*	0.51*	0.53*
H2	0.36*	0.63*	0.89*	0.88*	0.66*		0.17*	2.16	0.27*	3.51	0.42*	3.97	0.46*	0.67*	0.66*	0.69*	0.54*	0.80*	0.68*	0.51*	0.51*
H3	0.52*	0.78*	0.77*	0.68*			0.18*	2.15	0.29*	3.51	0.42*	4.39	0.45*	0.67*	0.66*	0.70*	0.55*	0.79*	0.69*	0.51*	0.52*
H4	0.79*	0.69*	0.66*	0.74*			0.30*	3.48	0.49*	5.92	0.33*	3.82	0.46*	0.67*	0.65*	0.69*	0.56*	0.78*	0.69*	0.52*	0.53*
H5	0.71*	0.72*	0.89*	0.54*			0.02	0.28	0.19*	2.45	0.46*	4.66	0.45*	0.68*	0.66*	0.69*	0.53*	0.80*	0.69*	0.50*	0.51*
H6	0.69*	0.82*	0.43*				0.11	1.30	0.33*	3.87	0.43*	4.50	0.45*	0.68*	0.66*	0.69*	0.55*	0.80*	0.68*	0.50*	0.52*
H7	0.47*	0.49*	0.55*	0.61*	0.89*	0.88*	0.29*	3.52	0.44*	5.63	0.35*	3.99	0.46*	0.68*	0.65*	0.69*	0.55*	0.78*	0.69*	0.52*	0.53*

* denotes significant at $p<0.05$

Table 6. Parameter estimates for hypothesis tests

Hypothesis	Description	Results (at 0.05 level)
H1	The use of IT to support top management leadership (ITTML) has a positive and significant impact on both operational performance (H1a) and quality performance (H1b).	Fully Supported
H2	The use of IT to support customer relations (ITCR) has a positive and significant impact on operational performance (H2a) and quality performance (H2b).	Fully Supported
H3	The use of IT to support supplier relations (ITSR) has a positive and significant impact on operational performance (H3a) and quality performance (H3b).	Fully Supported
H4	The use of IT to support workforce management (ITWFM) has a positive and significant impact on operational performance (H4a) and quality performance (H4b).	Fully Supported
H5	The use of IT to support the product design process (ITPD) has a positive and significant impact on and quality performance (H5b) but although the path relating ITSR and operational performance was positive it was not significant (*p* > 0.10).	(H5a) not supported but (H5b) supported
H6	The use of IT to support the product flow management (ITPFM) has a positive and significant impact on quality performance (H6b) but although the path relating ITPFM and operational performance was positive it was not significant (*p* > 0.10).	(H6a) not supported but (H6b) supported
H7	The use of IT to support quality data and reporting (ITQDR) has a positive and significant impact on operational performance (H7a) and quality performance (H7b)	Fully Supported

Table 7. Summary of hypotheses testing