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Paul P. Tallon
Boston College, paul.tallon@bc.edu

Kenneth L. Kraemer
University of California at Irvine, kkraemer@uci.edu

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THE DEVELOPMENT AND APPLICATION OF A PROCESS-ORIENTED "THERMOMETER" OF IT BUSINESS VALUE

Paul P. Tallon
Wallace E. Carroll School of Management
Boston College
paul.tallon@bc.edu

Kenneth L. Kraemer
Paul Merage School of Business
University of California, Irvine

ABSTRACT

The issue of whether firms are receiving an adequate return on their investment in information technology (IT) continues to pervade managerial decision making. While productivity and other financial metrics are established hallmarks of IT investment evaluation, research has called for broader and richer metrics that can take into account the diversity of IT impacts. In this paper, we extend previous instrument development research to develop and test a process-oriented *thermometer* of IT business value using survey data based on executives' perceptions of IT impacts at multiple points along the value chain. Consistent with earlier research, we find that our process measures are sensitive to differences in industry, firm size, and business strategy. Through additional analysis of post-implementation reviews of IT impacts in four firms, we find consistency of within-firm perceptual measures among teams of senior executives, highlighting the potential for our thermometer to gauge the level of IT impacts within a single firm. We conclude that process-oriented perceptual measures can offer new and useful insights into IT impacts, complementing what we already know from firm-level objective metrics.

Keywords: Organizational Impacts of IT, IT Business Value, Process Orientation, Executive Perceptions, Perceptual Measures, Value Chain, Value Disciplines

I. INTRODUCTION

Despite a significant increase in the volume of research into the business impacts of information technology (IT), executives continue to voice frustration at the lack of metrics to assess IT business value, denoting the contribution of IT to firm performance [Jeffrey 2003]. As firms pursue greater efficiency and effectiveness from IT, leveraging the vast sums spent on IT in recent years, the challenge of determining the locus and adequacy of IT impacts has been further complicated by next generation investment in areas such as e-commerce, knowledge management, and marketing analytics.

Even as researchers continue to debunk the productivity paradox [Barua et al. 1995; Brynjolfsson and Hitt 1996; Dewan and Min 1997; Rai et al. 1997; Sircar et al. 2000], laying claim instead to a variety of direct and indirect impacts from IT, business and information systems (IS) executives have been unable to use this to infer the existence or adequacy of IT impacts within their own firms [Barua and Mukhopadhyay 2000]. Executives' concern has been further heightened by the recent *IT Doesn't Matter* debate which has led to a renewed interest in proving the value of IT [Carr 2003]. While many firms have adopted some rudimentary analysis (e.g., NPV, ROI or payback) for large-scale IT initiatives, the complex task of identifying and computing IT impacts means that fewer than 30% of firms use post-implementation reviews to identify the true extent of IT impacts. Yet, without such validation and confirmation, there will likely remain some lingering doubt as to whether IT is truly delivering on its promise.

It is in this context that the lack of suitable IT business value metrics becomes apparent. Although productivity may be a quintessential yardstick for IT business value, and as such has been a cornerstone of IT business value research for over a decade, researchers have echoed the call of practitioners in seeking a broader, more inclusive interpretation of IT business value that surpasses unidimensional measures such as productivity, sales or profitability to consider the first order impacts of IT [Barua et al. 1995; Barua and Mukhopadhyay 2000; Brynjolfsson and Hitt 1998]. In response to this call, we extend earlier research by developing a multidimensional model or *thermometer* of IT business value that tracks a variety of impacts from IT across myriad processes and activities within the value chain.

The conceptual design of the value chain and its interlinking chain of business processes provides a useful vehicle for tackling the measurement of IT business value. Processes represent an "ordering of work activities across time and place, with a beginning, an end, and clearly identified inputs and outputs" [Davenport 1993]. Evaluating how IT influences the performance of these activities by, for example, computing the time saved in performing an activity or the quality of the output produced by an activity generates insights into where value is being created in the value chain, or potentially where value is being destroyed if inter-process linkages are considered.[1] The challenge of measuring IT impacts at the activity or process-level is, as other process-level researchers have noted, a complex undertaking in that activities are not only vast in number, but are also highly idiosyncratic across firms or industry sectors [Barua et al. 1995; Barua and Mukhopadhyay 2000]. Our approach to measuring IT business value at the process-level is neither to undertake a census of all impacts across all activities nor to concentrate on how one or more technologies may have impacted a particular process [Mukhopadhyay et al. 1997; Srinivasan et al. 1994]. Instead, we argue that an approach directed at evaluating IT impacts in activities of strategic importance can yield insights that surpass what firm-level objective or financial criteria alone can provide, but without being overwhelmed by the enormity of having to exhaustively assess all impacts across all activities.[2]

The design of a process-oriented instrument to evaluate IT impacts is significant for two reasons. First, as academics refocus their efforts on understanding how IT creates firm value using first-order impacts at the process-level [Barua et al. 1995], there is a sense that research should be guided by a framework that is sensitive to the locus of impacts from IT. Second, a renewed emphasis within firms on evaluating IT impacts has created an opportunity for researchers to reach out to practitioners with robust models and new ways of thinking that allow firms to better critique the performance impacts of IT, especially in light of the lack of process-level objective

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[1] The interconnected design of the value chain means that weaknesses in one part of the value chain could create problems further downstream. For example, supply chain bottlenecks in inbound logistics could lead to lengthy delays in production and a reduction in customer satisfaction if order delivery times in outbound logistics suffer.

[2] By definition, objective measures are based on quantifiable data. While these measures can refer to firm-level performance measures such as sales or net income, they can also refer to specific process measures. For example, in terms of customer relations at a brokerage firm, objective measures could include such things as number of accounts opened, growth in assets under management, or number of client queries answered within 24 hours.

metrics. We refer to the ensuing process-oriented instrument as a *thermometer* of IT business value because of its measurement abilities. Just as a standard thermometer detects changes in temperature, an IT business value thermometer should be sensitive to variations in IT impacts. Since exogenous factors such as industry, firm size or business strategy can contribute to the heterogeneity of IT impacts between firms, an IT business value thermometer should also be sensitive to these variables.[3]

Developing an IT business value thermometer is not without its challenges, however. Perhaps the most difficult challenge to evaluating IT impacts at the process-level (even within those processes that are considered of strategic importance) is the availability of objective data coupled with firms' unwillingness to release or share process-level data with IS researchers for confidentiality reasons [Barua and Mukhopadhyay 2000]. As an alternative, we consider perceptual measures. By designing measures that encompass quantitative (hard) and qualitative (soft) IT impacts, perceptual measures can overcome management's hesitancy to share data and, more importantly, embrace intangible impacts that are often regarded as impervious to measurement. Indeed, much of the frustration voiced by researchers and practitioners in the past arises from a perceived inability to accurately assess the qualitative or intangible IT impacts. Despite this, many practitioners may still have an instinctive sense for how IT is impacting areas such as customer loyalty, employee morale or retention, quality, and knowledge creation, even if there are no objective metrics to definitively substantiate their heart-felt beliefs [Seddon et al. 2002; Tallon et al. 2000; Watson 1990].

While concern for bias, subjectivity, and error has meant that perceptual measures are not without their detractors [Chan 2000; Mezias and Starbuck 2003; Starbuck and Mezias 1996], perceptions can still play a key role in identifying and measuring IT impacts. Sensemaking theory argues that in a complex or uncertain environment, one in which individuals notice information from diverse sources, perceptions are a necessary way for individuals to understand and make sense of the past [Weick 1995]. If objective data exist, perceptions may be iteratively refined and improved but, equally, a lack of objective data does not prevent executives from perceiving or arriving at what they see as a plausible interpretation of the reality underlying IT impacts [Starbuck and Milliken 1988; Weick 1995]. For this reason, the creation of a thermometer of IT business value need not be based on objective criteria alone or on measures that we can somehow objectively verify. In a world where "perception is reality", it is meaningful and valuable to discover what executives are thinking about IT impacts. Even if these perceptions are an imperfect mirror of reality, we can still gain insights that objective measures alone cannot provide. Therefore, our contribution to the extant IS literature is not just in terms of instrument development, but in showing how this instrument can extend or enhance decision making around IT impacts within firms. We caution, however, that while an IT business value thermometer can pinpoint areas where IT impacts are deficient, it cannot at the same time resolve those weaknesses. The raison d'être of this thermometer is to provide insights into the locus and adequacy of impacts from IT and while it can signal positive or negative deviations from a desired or benchmark level of IT value, it remains the sole responsibility of IS and business management to interpret these signals and to initiate remedial action where necessary.

In the next section, we review the extant literature on IT business value to provide an overview of the different types of IT impact measures. We then give a theoretical outline for a process thermometer by mapping process-level IT impacts from the literature to processes within the value chain. We then use this outline to develop a set of process-oriented measures of IT impacts

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[3] While many variables, including TQM, business process reengineering, flexible work practices, are instrumental in the search for increased value from IT (Bresnahan et al. 2002; Brynjolfsson and Hitt 2000), exogenous factors are especially important in order that the thermometer be properly *calibrated*. The value of a thermometer to an end-user (practitioner or academic) assumes an understanding of what constitutes a "normal" level of value. This determination, we argue, will depend on industry, firm size and business strategy.

and explore how these impacts can be identified through executives' perceptions. We then review the survey and data used to test and validate our measures, and review how the thermometer was used as part of a post-implementation review in four large firms. Lastly, we review the broader limitations and implications of our research and offer a general conclusion.

II. THEORETICAL BACKGROUND

Reviews of the IS literature on IT impacts by Dehning and Richardson (2002), Kohli and Devaraj (2003) and Melville et al. (2004) reveal a variety of measures such as value added, revenues, profit, costs, and productivity. By design, these measures entail a firm level focus on IT impacts, a fact that has added to the often contradictory results on IT impacts seen in the extant literature [Barua and Mukhopadhyay 2000]. In the top panel of Table 1, we offer a summary of these objective or firm-level financial measures as a way to further motivate our use of process-level measures and perceptual process-level measures in particular.

As noted in Table 1, there is significant diversity in the range of measures considered in prior research. Measures tend to be either market-based reflecting a change in market capitalization due to an increase in IT spending, accounting-based involving ratios such as ROA, ROE or margin, or output-based as a way to assess the impact of IT on labor, capital or multi-factor productivity. Even in studies where several of these measures are used, there is still a concern for whether practitioners think in terms of such aggregate measures when making an IT investment, or whether they instead look to more specific or micro measures as a way to focus on the unique goals of each IT investment. For example, while a firm making an investment in CRM might expect to realize a positive impact on profit margin, market share or ROA, a more likely objective is that the system will be used to identify unique customer needs, reduce customer turnover, and secure more profitable deals with the benefit of knowing what individual customers want. In due course, these intermediate measures will likely pass through or be aggregated up to the firm-level and be reflected in firm-level financial metrics but in the near term, managers may prefer to focus on metrics that make most sense.

In response, IS researchers have advocated first-order or intermediate impacts at the process-level [Bakos 1987; Barua et al. 1995; Crowston and Treacy 1986; Kauffman and Weill 1989; Ragowsky et al. 2000]. As reported in Table 1, where researchers have devised intermediate measures, it has most often been in the context of an evaluation of specific technologies such as POS, JIT or EDI [Banker et al. 1991; Mukhopadhyay et al. 1997; Ray et al. 2004; Srinivasan et al. 1994], or measures that while process-level are still limited by the availability of suitable objective or financial data. Barua et al. (1995), for example, investigated inventory turnover, capacity utilization, relative quality, relative price, and rate of new product introduction; while in a healthcare setting, Devaraj and Kohli (2000) use patient satisfaction and mortality rates. Indeed, in a later healthcare study, Kohli (2004) notes that IT impacts are "more likely to be detected at the process level than at the firm level". Finally, Mukhopadhyay et al. (1997) consider quality as an intermediate measure of performance in a study of mail processing at the U.S. postal service while in an evaluation of Chrysler's automotive manufacturing and production processes, Srinivasan et al. (1994) use shipment discrepancies as an intermediate performance measure.

While these studies are illustrative of what process-oriented measures have been used in the past, they also indicate the challenge of generality. Quite simply, process-level measures from a medical setting cannot easily transfer to an automotive or general services setting and yet in firm-level studies, industry or firm-level idiosyncrasies do not limit the use of productivity, ROA, sales or other financial measures. The net effect is that while there is a consensus among researchers that process research is necessary and important to understanding IT impacts, the objective metrics created by the extant process literature are expressly designed to fit a unique set of circumstances and firms and so lack relevance in other contexts.

Table 1. IT Business Value Measures

Measures	References
Objective / Financial Measures	
Market Measures	
Tobin's question	Bharadwaj et al. (1999)
Market Capitalization	Dos Santos et al. (1993); Hitt and Brynjolfsson (1996); Im et al. (2001); Tam (1998)
Profitability	
Return on Assets (ROA)	Barua et al. (1995); Floyd and Wooldridge (1990); Hitt & Brynjolfsson (1996); Li and Ye (1999); Rai et al. (1996, 1997); Tam (1998)
Return on Equity (ROE)	Hitt and Brynjolfsson (1996); Rai et al. (1996, 1997); Tam (1998)
Profit Margin (ROS)	Byrd and Marshall (1997); Li and Ye (1999); Kettinger et al. (1994)
Costs	
Coordination costs	Shin (1997)
Labor and SG&A	Bharadwaj (2000); Mitra and Chaya (1996)
Productivity / Output	
Revenues	Brynjolfsson and Hitt (1995); Dewan and Min (1997); Hitt and Brynjolfsson (1996)
Value-added	Bresnahan et al. (2000); Brynjolfsson and Hitt (2000); Kudyba and Diwan (2002)
Process Measures (compiled from objective criteria)	
Food service sales	Banker et al. (1991)
Inventory turnover	Barua et al. (1995)
Mortality rates	Devaraj and Kohli (2000)
Mail sorting (quality)	Mukhopadhyay et al. (1997)
Shipment discrepancies	Srinivasan et al. (1994)
Perceptual Measures	
Profit, sales, cash flow	Bergeron and Raymond (1995); Chan et al. (1997); Venkatraman (1989)
Productivity gains	Grover et al. (1998)
Customer service quality	Ray et al. (2004)
Product development	Ravichandran and Lertwongsatien (2005)
IS Effectiveness	Delone and McLean (1992); Ragowsky et al. (2000)
Competitive advantage	Sethi and King (1994): instrument development paper (N=185)
	Dimensions: primary activity efficiency, support activity efficiency, resource management functionality, resource acquisition functionality, threat, preemptiveness, synergy
Strategic variables	Mahmood and Soon (1991): instrument development paper (N=31)
	Dimensions: buyers and consumers, competitive rivalry, suppliers, search and switching costs, market, products and services, pricing, economics of production, internal organizational efficiency, inter-firm efficiency

A GENERAL THEORY OF PROCESS MEASUREMENT

As a step towards creating a general theory to facilitate measurement of IT impacts at the process-level, Barua and Mukhopadhyay (2000) outline a “generalized business value complementarity model” in which IT impacts are first identified as intermediate performance measures such as customer service, time to market, mass customization, new products, and inventory turnover. The nature of the complementaries that give rise to such outcome measures is revealed in how IT interacts with, or is integrated into, business processes. The theory behind this model argues that IT resources create value through use and application in supporting business activities and the goals of the enterprise. This view parallels previous research that suggested that impacts from IT ought to be evaluated with reference to the goals for which IT is deployed in the first instance [Crowston and Treacy 1986; Berger 1988; Kauffman and Kriebel 1988].

A weakness in the model proposed by Barua and Mukhopadhyay (2000) is that it fails to offer a generalized framework of business processes around which complementary IT impact measures could be assessed. However, in earlier research that did not expressly use a complementarities approach, Mooney et al. (1995) proposed a general framework categorizing IT impacts according to whether they fall under an operational process (marketing and intelligence processes, production processes, design and development processes, procurement and logistics processes, and product and service delivery processes) or a management process (information handling processes, communication processes, coordination processes, knowledge processes, and control processes). Combining the IT business value complementarities model outlined by Barua and Mukhopadhyay (2000) with the process framework outlined in Mooney et al. (1995) is a useful first step towards developing a general process-level model of IT business value. However, a key issue is whether this will translate to a meaningful and comprehensive process-oriented model. If the processes listed in Mooney et al. (1995) are incomplete, then despite the complementarities approach advocated by Barua and Mukhopadhyay (2000), our model could potentially overlook some key aspects of IT value.

To address this issue, we turned to the generic value chain which Porter (1985) argues is based on a “theory of the firm”. The value chain reveals a structured map of the processes in a firm. To the extent that the processes identified in Mooney et al. (1995) can be mapped to the value chain, we can feel more confident that the processes and measures encapsulated in our thermometer are sufficient to span the firm, identifying the most pertinent impacts from IT. In Table 2, we show the various areas of the generic value chain into which the processes identified in Mooney et al. (1995) can be mapped. The result of this mapping allows us to propose a more refined set of process headings than Mooney et al. (1995), namely: process planning & support, supplier relations (inbound logistics), production and operations, product and service enhancement, sales and marketing support, and customer relations (outbound logistics).

We also noted that there were still a number of activities that the generic value chain and Mooney et al. (1995) had not identified, but that still needed to be included in a process model in order for it to be as comprehensive and persuasive as possible. Prior research by Sethi and King (1994) identifies a series of IT impacts that are closely tied to the notion of competitive rivalry as embodied in the *Competitive Forces Model* (Porter 1980). For example, these impacts reflect uses of IT in activities that serve to establish barriers to entry and exit, or that are linked to the development of substitute products and services, activities that may not be covered already in the generic value chain. Accordingly, we added a final (seventh) process heading called *competitive dynamics* to capture any ancillary activities associated with competitive rivalry.

Table 2. IT Business Value Process Mapping

Mooney et al. (1995)	Generic Value Chain (Porter 1985)	Proposes Process Headings for inclusion in this Study
Operational Processes	Primary Activities	
Procurement & Logistics	Inbound Logistics	Supplier Relations
Production	Operations	Production & Operations
Marketing and Intelligence	Marketing and Sales	Sales & Marketing Support
–	Service	Customer Relations
Product / service delivery	Outbound Logistics	
Management Processes	Secondary Activities	
Information Handling		
Communications	Firm Infrastructure	Process Planning & Support
Coordination	HR Management	
Knowledge	Procurement	
Control		
Design & Development	Technology development	Product & Service Enhancement
–	–	Competitive Dynamics

Note: Mooney et al. (1995) consider design and development under the heading of operational processes while Porter (1985) regards technology development (which includes R&D) as a secondary activity.

RESEARCH MODEL: CONSTRUCTING THE THERMOMETER

With these general *buckets* representing processes or activities, our next challenge was to explore critical measures of IT impacts in each area. As noted earlier, our goal was not to produce an exhaustive listing of all IT impacts, but rather to capture impacts that have some sense of commonality across firms or industries and are representative of the distinct nature of IT impacts in different processes. To obtain these impacts, we first conducted a general review of the IS literature to identify studies where IT impacts were reviewed either conceptually or empirically. A representative cross-sample of these studies is shown in Table 3 on a process-by-process basis. Once again, while this table does not give an exhaustive listing of all IT impacts, it nonetheless conveys a general sense of the wide diversity of IT impacts as noted in the literature over the past decade.

From this review, we created a list of keywords to motivate our choice of measures in each area. For instance, we identified product quality, transaction costs, lead times, cooperation, and coordination as key aspects of supplier relations or inbound logistics that IT might conceivably impact, while in customer relations, we identified delivery times, after sales support, and responsiveness to customer needs. Equally, while these keywords are not exhaustive of all possible IT impacts in a particular process, they are illustrative of what the literature sees as the primary areas that IT has impacted. Across the processes identified in Table 3, our challenge was then to build specific measures around each keyword. We also recognized that the text of each item needed to refer to activities, events or outcomes that are visible to executives. If we designed measures of IT impacts that executives might not understand, the scope for perceptual bias would increase as executives resort to guess-work to infer what IT impacts might look like. We were equally mindful that the design of the generic value chain may seem rigid or highly structured with defined inter-process links. Accordingly, we sought to create measures that would work equally well where a firm's configuration of processes more closely resembles a value shop employing unordered or functionally independent processes or a value network where processes are dynamically linked [Stabell and Fjeldstad 1998]. To the extent possible, our measures also needed to address the most common forms of inter-process linkages, consistent with the design of the value chain.

Table 3. Classifying Process-level IT Impacts

Planning & Support:
Enhance decision making outcomes [Galbraith 1977]
Improve organizational communication and coordination [Gurbaxani and Whang 1991; Malone 1987]
Facilitate the design of new and improved business processes [Broadbent et al. 1999]
Supplier Relations [Inbound Logistics]:
Coordinate supplier linkages in order to reduce search costs [Bakos 1991; McFarlan 1984]
Facilitate closer ties with suppliers through EDI [Srinivasan et al. 1994]
Enable closer monitoring of quality and improved delivery techniques [Kraemer et al. 2000]
Production & Operations:
Enhance manufacturing techniques through computer-aided design [Kelley 1994]
Create economies of scale through improvements in the production process [Porter 1985]
Increase labor productivity through automation [Harris and Katz 1991a; Rai et al. 1996]
Product & Service Enhancement:
Facilitate the development of new products and services [Brooke 1991; Parsons 1983]
Enable products and services to be differentiated in a different ways [Bakos and Treacy 1986]
Improve product and service quality [Barua et al. 1995]
Sales & Marketing Support:
Enable a corporation to identify and serve new market segments [Pine et al. 1995]
Track market trends and responses to marketing programs [Porter and Millar 1985]
Monitor the effectiveness of pricing strategies [Beath and Ives 1986]
Customer Relations [Outbound Logistics]:
Establish, sustain and improve relationships with customers [Ives and Learmonth 1984]
Offer improved levels of customer service [Ives and Mason 1990; Ray et al. 2004]
Improve customer responsiveness [Kraemer et al. 2000; Ray et al. 2004]
Competitive Dynamics:
Alter the competitive dynamics of an industry [Bakos and Treacy 1986; McFarlan 1984]
Improve competitiveness by enhancing product choice, selection, cost [Porter and Millar 1985]
Facilitate the introduction of substitute products [Porter 1985]

References are illustrative of the various types of impacts collected under each process heading.

In building our IT business value measures around executives' perceptions, we were able to adapt previous instrument development research by Mahmood and Soon (1991) and Sethi and King (1994) who developed perceptual measures of the extent to which IT contributes to competitive advantage. Although their measures were not built around a process model of the firm, we could still associate several of their measures with various keywords used in Table 3, allowing us to fold some of their measures directly into our thermometer. With the inclusion of additional items to reflect IT impacts that they had not considered, we developed a list of 44 items to assess the impact of IT on different activities within the value chain (all items appear in the appendix). The text of each item was sufficiently general as to accommodate services and manufacturing firms. We also sought to employ a scale that would reflect realized impacts rather than expected impacts, while we also wanted to avoid giving respondents the option of using the mid-point on a Likert scale; not using an odd-number scale would allow respondents to label their firm as something other than average. Through pilot testing with executives in 30 firms, we selected a ten-point Likert scale, anchored on "weak realized impacts" and "strong realized impacts". The list of items was preceded by the following question: "To what extent does IT contribute to the performance of your firm along each of the following dimensions? Please restrict your appraisal to realized, not expected impacts."

MAKING THE CASE FOR PERCEPTUAL MEASURES

While perceptual measures form the core of our business value thermometer, we are not implying that perceptions are in any way superior to, or should replace, objective measures. It is our contention that perceptions complement and reinforce objective measures while conceding that perceptions can detect IT impacts that might otherwise be excluded from, or subsumed within, more aggregate firm-level measures. While previous research shows that IT leads to greater sales and profits, both classic objective measures of IT impacts [Dehning and Richardson 2002; Kohli and Devaraj 2003], perceptual measures could offer rich and potentially useful insights by identifying the impacts of IT on certain activities in the value chain. Where objective measures cast doubt on the extent of impacts from IT (reminiscent of the productivity paradox) it may be useful to dissect such measures to find whether lackluster performance is somehow attributable to failures or deficiencies within certain areas of the value chain.

In this way, objective and perceptual measures complement and add value to each another. Some research on perceptual measures has appeared in the literature where, for example, executives have been asked to perceptually rate their firm performance relative to competitors using financial measures such as cash flow, profit, and profit margins [Bergeron and Raymond 1995; Chan et al. 1997; Venkatraman 1989] (refer to Table 1). Researchers have also used perceptual measures to examine IT use and the effectiveness of the IS function [Delone and McLean 1992; Ragowsky et al. 2000]. Broadbent and Weill (1993) posit a link between managerial perceptions of the role of IT infrastructure, the perceived value of that infrastructure, and managers' IT investment biases. Research has also found that a CEO's perceptions and attitudes towards IT and the degree of importance they attribute to IT are associated with a firm's progressive use of IT [Busch et al. 1991; Jarvenpaa and Ives 1991]. Grover et al. (1998) also used perceptual data from managers to assess the link between diffusion, process change, and productivity gains for eleven different technologies. These studies indicate a pattern of researchers using managerial perceptions in different areas of research, and so there is a base of support for using perceptions to assess IT impacts. Finally, researchers argue that executives' seniority enables them to serve as knowledgeable informants in a qualitative appraisal of IT impacts inside their own firms [Delone and McLean 1992; Dess and Robinson 1984]. Indeed, Barua and Mukhopadhyay (2000)[4] suggest that executives may already "know from intuition and daily experience" how much value IT is providing to their firms. Turning this intuition into a formal set of measures is ultimately what our IT business value thermometer hopes to achieve. Notwithstanding the appeal of perceptual measures as a way to explore IT impacts, IS researchers remain skeptical of whether perceptions are completely accurate and truthful, and so it is important to understand how perceptions are formed and through this gain a deeper appreciation for perceptual bias and distortion, whether deliberate or unintentional [Chan 2000; Mezias and Starbuck 2003; Starbuck and Mezias 1996].

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[4] Even in the absence of objective data, business and IT executives are not blind to the performance of IT. For example, a CIO at a mid-western bank we visited remarked, "We only recently moved to include IT as part of our balanced scorecard initiative, but don't for a minute assume that [our business unit VPs] didn't know whether IT was doing what it was supposed to be do. The budget for IT projects comes out of their pockets and they're responsible for making it work. When they can't open accounts quickly enough, or customer data are unavailable, they're not afraid to bang on my door. They've always had a sense for whether IT is performing or not. The balanced scorecard has sharpened their awareness but perceptions are still important."

In offering an opinion on the performance impacts of IT, an executive is likely to weigh personal experience and reports received from peers and subordinates [Starbuck 1985]. Perceptions emerge from a complex cognitive/sensemaking process where information from multiple sources is integrated and filtered against a set of prior expectations [Weick 1995]. Of course, there is always a question of whether expectations are reasonable and so psychology research has used Brunswik's lens model [Brunswik 1955] to note that unrealistic expectations become more realistic over time as either confirming or disconfirming signals prompts the individual to rethink their prior views. Thus, while the majority of firms might not conduct a formal post-implementation review of IT spending, executives' may still have a gut sense for how much impact IT has had on their financial performance [Bannister and Remenyi 2000; Tallon and Kraemer 2006; Watson 1990].

Despite concern that the subjective nature of perceptions imposes a high degree of bias or error, perceptual measures of firm performance have been found to correlate with objective measures. For example, Venkatraman and Ramanujam (1987) confirm that, "perceptual data from senior managers, which tend to strongly correlate with [objective measures], can be employed as acceptable operationalizations of [firm performance]". Miller et al. (1997) also find that executives' ability to accurately recall and report on past events, a common criticism of perceptual reporting, is not as subject to error as once thought. Maule and Hodgkinson (2003) question whether perceptions are biased, arguing instead that, "the cognitive strategies underlying managerial perceptions may well be functional in an everyday context". In reviewing the association between IT, firm strategy, and firm performance, Floyd and Wooldridge (1990) determine that qualitative insights obtained in interviews with CEOs were consistent with results from a regression analysis. While it is natural to question the accuracy of executives' perceptions, these studies indicate that perceptions are sufficiently valid and credible to convey a realistic sense of the reality behind IT impacts.

MEASURES OF FIRM-LEVEL HETEROGENEITY (CONTROL VARIABLES)

To the extent that IS research finds that IT impacts reflect idiosyncratic firm-level characteristics such as firm size [Harris and Katz 1991b; Mason and Ragowsky 2002; Mitra and Chaya 1996; Rai et al. 1996], industry [Brynjolfsson and Hitt 1996; Dewan and Min 1997; Kohli and Devaraj 2003] or strategy [Bresnahan et al. 2002; Keen 1991; Quinn and Baily 1994], a critical test of our measures is that they also be sensitive to these items. Variables such as size and industry are routinely employed as controls in firm-level empirical analysis in order to control for potential scale and industry effects. In the same way, differences in strategy can play a role in the measurement of IT impacts as IT resources are concentrated in processes that are critical to a business strategy. Consequently, the primary locus of IT impacts in the value chain may closely align with a firm's business strategy [Treacy and Wiersema 1995].

While the literature identifies several typologies for classifying business strategy such as Porter's (1985) generic strategies (cost leadership, differentiation and niche) or the prospector, defender, analyzer and reactor typology of Miles and Snow (1978), we focus on a third approach that uses value disciplines to show how a firm creates value for its customers [Treacy and Wiersema 1995]. What is appealing about this approach is its complementarity with our focus on IT impacts at the process-level. As seen in Table 4, each value discipline focuses on distinct processes in the value chain and espouses a different role for IT. As such, Treacy and Wiersema (1995) suggest that operational excellent firms "deliver a combination of quality, price and ease of purchase that no one else in their market can match. They are not product or service innovators, nor do they cultivate one-to-one relationships with their customers; their proposition … is guaranteed low price and/or hassle-free service". This strategy is noticeably different from a product leadership firm that "consistently strives to provide its market with leading-edge products or new applications of existing products or services", while a customer intimate firm knows "the people it sells to and the products and services they need. [These] companies don't deliver what the market wants but what a specific customer wants. [They] don't pursue transactions, they cultivate relationships".

Table 4. Overview of Value Disciplines

	Operational Excellence	Customer Intimacy	Product Leadership
Value Discipline	Best total cost	Best total solution	Best product
Examples	Dell, Costco, Jetblue	Merrill Lynch, Capital One	Intel, 3M, Sony
Core Processes	Supplier Relations, Production and Operations	Customer Relations, Sales and Marketing Support	Product and Service Enhancement
Role of IT	Pursue automation and supply chain integration	Offer personalization and mass customization	Support the design of new product offerings

Adapted from Treacy and Wiersema (1995), Weill and Broadbent (1998, p. 134), Weill and Ross (2004, p. 160).

In order to measure a firm's value disciplines, we opted for a simple approach in which we asked respondents to allocate 100 points across the three value disciplines, assigning higher points to disciplines that their firm tends to pursue most. This allowed respondents to signal an unambiguous preference for one of the three disciplines (e.g., 50-25-25), or they could change their allocation to reflect a more mixed focus (e.g., 40-40-20 or 33-34-33). In our pilot testing, we noted that firms tended to have a dominant value discipline (e.g., 80-10-10) rather than evenly pursuing all value disciplines at the same time. As respondents would unlikely be familiar with the terminology behind value disciplines, as part of our survey design, we added a short description of each value discipline (as shown in the appendix) in order to address any definitional confusion that respondents might have in responding to the survey. The description used in each case was also pilot tested with 30 firms in order to remove any ambiguity.

Table 5. Characteristics of the Sample (N=257)

Variable	Frequency	Percent
Revenues (1998)		
Less than $500 million	9	3.5
$500 million to $1 billion	40	15.6
$1 billion to $5 billion	102	39.7
$5 billion to $10 billion	45	17.5
More than $10 billion	61	23.7
Industry Group*		
Paper & Packaging	24	9.3
Computers & Electronics	23	8.9
Chemicals & Metals	11	4.3
Finance, Insurance & Real Estate	65	25.3
Utilities (electric and gas)	37	14.4
Telecommunications	28	10.9
Business & Professional Services	18	7.0
Wholesale & Retail Trade	15	5.8
Other services	36	14.1
Respondents		
CEO, COO, CFO, or EVP	56	21.8
CIO, or IT Director	51	19.8
Sr. Vice President / Vice President	143	55.6
Other	7	2.8

* Industries can be grouped by manufacturing (N=58) and services (N=199).

III. DATA COLLECTION AND ANALYSIS

The data used for this study was collected as part of the Intercorporate Measurement Program, a multi-year project conducted by the Center for Research on Information Technology and Organizations at the University of California, Irvine and CSC Index, the consulting division of Computer Sciences Corporation (CSC). Data from this program has been used in prior empirical research [Gurbaxani et al. 2000]. The sample frame consisted of CSC's North American clients, many of whom are ranked in the Fortune 500. Survey packets were mailed to the CIO of each firm with the request that the CIO forward the survey to a senior business executive. To protect the confidentiality of their responses, business executives were asked to mail their completed survey directly to us rather than returning it through the office of the CIO.

Over a two year period (1997-1998), complete responses were received from 257 firms (average 1998 revenues: $10.8 billion); characteristics of the sample appear in Table 5. Over 50% of respondents were vice presidents of functional areas, while a further 22% identified themselves as a CEO, COO, CFO or EVP. A comparison of our sample with the Fortune 500 firms on sales, net income, and total assets did not yield any significant differences; there were also no differences in survey responses received in each year or between responses received at the beginning and end of our data collection process.

INSTRUMENT VALIDATION

We began by using exploratory factor analysis with varimax rotation in SPSS to assess the dimensionality of our survey data. As reported in Table 6, using the eigenvalue rule, a seven-factor structure emerged explaining 77.7% of the total variance. All survey items factored under their process headings as noted in the survey instrument in the appendix. The significance of this result is that IT impacts can be classified according to the process where they occur. So, rather than talking about each individual IT impact (in this case 44 separate IT impacts), we can instead group IT impacts according to where they materialize within the value chain.

The next step in instrument validation involved subjecting the factor structure in Table 6 to tests for discriminant and convergent validity. In order to determine if the factors are distinct, discriminant validity asks if the indicators of a particular factor load higher on that factor than on competing factors, while convergent validity investigates whether the indicators of a factor correlate higher among themselves than with indicators of a different factor. In order for the seven-factor structure to be declared valid, the shared variance (squared multiple correlation) between each factor-pair should be less than the variance extracted for each factor, which in turn should exceed a suggested minimum of 0.50 [Fornell and Larcker 1981]. We used EQS 5.7b, a widely used structural modeling package, to perform all such validity tests.

As reported in Table 7, variance extracted exceeds 0.50 while the shared variance for each factor-pair is less than their respective variance extracted, thereby verifying that discriminant and convergent validity are present. Finally, we identified reliability using Cronbach's Alpha. In each case, reliability was found to comfortably exceed a minimum of 0.80 [Nunnally 1978].

Notwithstanding the fact that exploratory factor analysis had uncovered a seven-factor structure that was fully consistent with our expectations, we also undertook a confirmatory factor analysis within EQS. The goal of this exercise was to model the correlations between factor pairs and to test if a second order factor, reflecting all first order factors, was an appropriate way to model the relationships between the entire set of 44 items and their respective factor headings. This extra step has no impact on the overall interpretation of our results other than to highlight the efficacy of measuring IT impacts within a firm through multiple process-level measures. Testing for a second order factor is not the same as combining or aggregating all individual process items into a single firm-wide measure; it simply tests whether first order factors share variance through a higher order factor. Since the higher order factor is never directly observable, it means that to get a sense for how IT is impacting overall firm performance, one must first assess what impact IT is having on the different first order factors.

Table 6. Factor Loadings (N=257)

Survey Items	Sales / Mkting Support	Planning / Support	Supplier Relations	Prod./Serv. Enhance.	Customer Relations	Prod. & Ops.	Compet. Dynamics
SM8	**0.842**	0.084	0.211	0.164	0.078	0.149	0.158
SM7	**0.837**	0.109	0.230	0.132	0.098	0.144	0.171
SM6	**0.819**	0.174	0.206	0.205	0.146	0.076	0.210
SM9	**0.785**	0.078	0.291	0.228	0.036	0.170	0.258
SM1	**0.782**	0.258	0.139	0.226	0.182	0.116	0.068
SM4	**0.765**	0.215	0.206	0.259	0.120	0.138	0.166
SM5	**0.758**	0.273	0.153	0.211	0.204	0.107	0.139
SM3	**0.716**	0.330	0.150	0.091	0.155	0.130	0.136
SM2	**0.706**	0.255	0.184	0.223	0.187	0.257	0.165
PS2	0.108	**0.801**	0.093	0.173	0.195	0.080	0.028
PS1	0.302	**0.742**	0.109	0.240	0.176	0.051	0.098
PS4	0.213	**0.730**	0.190	0.232	0.146	0.155	0.105
PS5	0.178	**0.717**	0.176	0.149	0.187	0.224	0.218
PS3	0.216	**0.685**	0.272	0.113	0.028	0.067	0.275
PS6	0.180	**0.667**	0.121	0.103	0.143	0.123	0.063
PS7	0.154	**0.588**	0.098	0.051	0.356	0.335	0.190
SR4	0.237	0.164	**0.847**	0.130	0.175	0.101	0.185
SR5	0.213	0.166	**0.826**	0.161	0.165	0.063	0.181
SR3	0.208	0.170	**0.809**	0.210	0.173	0.119	0.116
SR2	0.303	0.148	**0.801**	0.205	0.223	0.129	0.089
SR1	0.273	0.156	**0.790**	0.143	0.239	0.137	0.066
SR6	0.210	0.314	**0.585**	0.032	0.198	0.257	0.088
PSE3	0.278	0.192	0.172	**0.830**	0.192	0.186	0.173
PSE1	0.285	0.197	0.158	**0.814**	0.192	0.184	0.175
PSE2	0.296	0.220	0.176	**0.811**	0.211	0.164	0.148
PSE6	0.243	0.161	0.232	**0.732**	0.112	0.334	0.088
PSE5	0.245	0.209	0.209	**0.584**	0.200	0.229	0.394
PSE7	0.398	0.264	0.153	**0.532**	0.099	0.411	0.124
PSE4	0.274	0.234	0.179	**0.502**	0.239	0.406	0.265
CR1	0.086	0.222	0.296	0.153	**0.753**	0.191	0.044
CR2	0.105	0.345	0.216	0.188	**0.739**	0.195	0.137
CR5	0.194	0.123	0.327	0.273	**0.709**	0.075	0.228
CR4	0.376	0.303	0.091	0.196	**0.579**	0.093	0.246
CR3	0.234	0.373	0.195	0.091	**0.555**	0.307	0.246
CR6	0.148	0.081	0.239	0.254	**0.523**	0.096	0.309
CR7	0.263	0.316	0.170	0.026	**0.478**	0.116	0.258
PO2	0.148	0.203	0.142	0.318	0.174	**0.781**	0.192
PO1	0.198	0.232	0.095	0.360	0.188	**0.741**	0.164
PO3	0.240	0.077	0.245	0.236	0.105	**0.716**	0.126
PO4	0.241	0.305	0.111	0.149	0.221	**0.692**	0.254
CD3	0.258	0.171	0.179	0.152	0.219	0.209	**0.769**
CD1	0.264	0.247	0.129	0.233	0.245	0.141	**0.757**
CD4	0.304	0.199	0.210	0.143	0.221	0.181	**0.748**
CD2	0.299	0.182	0.137	0.284	0.181	0.244	**0.712**
Eigenvalue	22.166	2.924	2.579	2.293	1.725	1.324	1.192
% Variance	50.4%	6.6%	5.9%	5.2%	3.9%	3.0%	2.7%

Factor loadings greater than 0.40 are highlighted in bold

Table 7. Validity and Reliability

Dimensions of IT Bus. Value	Reliability	1.	2.	3.	4.	5.	6.	7.
1. Planning & Support	0.913	**0.61**						
2. Supplier Relations	0.949	0.30	**0.77**					
3. Production & Operations	0.912	0.37	0.23	**0.72**				
4. Product & Service Enhance.	0.954	0.34	0.28	0.44	**0.74**			
5. Sales & Marketing Support	0.966	0.35	0.37	0.31	0.40	**0.76**		
6. Customer Relations	0.908	0.54	0.43	0.40	0.39	0.35	**0.59**	
7. Competitive Dynamics	0.938	0.37	0.29	0.40	0.38	0.42	0.49	**0.79**

Diagonal elements denote variance extracted; off-diagonal elements denote shared variance.

First, allowing all factors to correlate freely, we obtained fit statistics indicating a well-fit model: X^2/d.o.f. = 2.26; CFI = 0.879 (d.o.f. = 881). We next replaced all paths signifying inter-factor correlations with a second-order factor. The fit of this second-order model is equally good: X^2/d.o.f. = 2.26; CFI = 0.877 (d.o.f. = 895). Second-order factor loadings or path estimates ranged in size from 0.71 to 0.86 and were significant at p<0.001. This result shows that future use of our items in more extensive nomological testing could model process-level IT business value as a second-order factor that is reflectively measured by seven first order factors which, in turn, are measured by 44 survey items.

VALUE DISCIPLINES: DISCRIMINANT ANALYSIS

Of the three control variables used to assess the sensitivity of our thermometer (size, industry, and strategy), additional analysis was needed to translate our value discipline measures into a dummy variable representing one of three possible strategies. In order to classify firms as operationally excellent, customer intimate or product leaders, we used the following three rules on the data provided by each respondent:

Allocation rules:

1. If a value discipline receives 50 or more points, label the firm as such;
2. If the value discipline with the greatest allocation is at least 10 points more than the second highest allocation, then label the firm using the highest allocation;
3. There is no dominant value discipline – label the firm as *mixed*.

Using rule 1, 197 firms were classified as operational excellence (OE), customer intimacy (CI) or product leadership (PL), while 47 were classified under rule 2, while 13 were classified under rule 3. The final classification totals were: 135 (OE), 77 (CI), 32 (PL) and 13 (*mixed*). Average allocation percentages for all groups appear in Table 8. As expected, a one-way analysis of variance finds significant differences (p<0.001) between the four groups on the percentages allocated to each value discipline.

As the above stated rules are somewhat arbitrary, we performed a discriminant analysis to determine if our classifications were accurate. While this accurately predicted 82.1% of our classifications, as noted in Table 8, the discriminant analysis also reclassified a significant number of firms as *mixed*. To address this, we reviewed our classification rules (in particular, increasing the 10-point gap in rule 2), but observed relatively little change in our assignment totals. Therefore, in order to maintain the integrity of our three focal groups, we opted to exclude the 13 firms in this *mixed* category (representing 5% of our sample) from the remainder of our analysis. Therefore, the applicable sample size for the remainder of our analysis is N=244.

Table 8. Value Disciplines – Discriminant Analysis

	Allocation Percentages (%)			Predicted Group Membership				
	OE	CI	PL	OE	CI	PL	Mixed	Total
Operational Excellence (OE)	**59.6**	27.4	13.0	118	10	0	7	135
Customer Intimacy (CI)	26.2	**53.6**	20.2	2	58	0	17	77
Product Leadership (PL)	25.2	24.3	**50.5**	0	0	23	9	32
Mixed	35.0	31.4	33.6	0	0	1	12	13
			Totals	120	68	24	45	257
			Predicted correctly (%)	87.4	75.3	71.9	92.3	

SENSITIVITY TO FIRM-LEVEL HETEROGENEITY

Having validated the design of the IT business value thermometer using factor analysis, reliability, and validity tests, and having classified each participant firm according to its primary value discipline, our next step was to assess if our items were sensitive to firm-level heterogeneity based on industry, firm size, and strategy. If our thermometer is to accurately determine IT impacts, it must be sensitive to differences in these factors: industry (manufacturing vs. services), firm size (small vs. large), and strategy (OE, CI vs. PL). Considering the high rate of reliability in our items with Cronbach's Alpha ranging from 0.908 to 0.966, we created a single aggregate measure in each process as the average of all impact measures in that process; this reduced the complexity of our thermometer from 44 items down to 7 process-level averages.[5]

As a first test of sensitivity to firm-level heterogeneity, we performed a series of one-way analysis of variance (ANOVA) tests for each of our seven process-oriented averages. In examining the results of these tests in Table 9, we note that, except supplier relations, there are no significant differences in IT impacts by value discipline. However, we find that the primary locus of IT impacts for operationally excellent firms lies in production and operations, while customer intimate firms see the greatest impacts in the area of production and operations and customer relations. In addition, product leadership firms had higher IT impacts in the area of product and service enhancement than other value disciplines, although this was not their primary locus of value. This result is consistent with Treacy and Wiersema (1995) who argue that product leaders need to look beyond product development so they can, "avoid the embarrassing 'oops!' of discovering too late that engineering's design can't be manufactured, that the product can't be serviced, or that it's not what the customers want". In this way, product leaders are advised to focus not just on product and service enhancement, but on activities that are closely linked to their innovation-intensive activities.

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[5] Mindful of the distrust often associated with perceptual measures, we have taken a number of steps to show that our survey instrument measures the benefits derived from IT investments. While measurement error cannot be avoided entirely, the critical issue in creating "trust" in such an instrument is to rule out systematic error from perceptual bias. Accordingly, in a parallel study, we find that executives' perceptions of process-oriented IT impacts are highly correlated with key financial measures of IT business value based on productivity, sales, net income, and market share [Tallon and Kraemer 2006]. While perceptual measures remain open to distortion, our research indicates that, on balance, perceptions tend to reflect the economic realities underlying IT impacts and so ought not to be discounted or declared inadmissible purely because of their non-financial or qualitative nature.

Table 9. Sensitivity Tests (ANOVA) for Firm-level Heterogeneity

	Process Planning	Supplier Relations	Product & Ops.	Prod. & Srv. Enh.	Sales / Mkting.	Customer Relations	Competitive Dynamics
Aver. for all Firms	6.09	4.65	5.67	4.92	4.33	5.61	4.92
Value Discipline							
Op. Excellence	5.97	4.43	5.68	4.94	4.17	5.51	4.81
Cust. Intimacy	6.30	4.82	5.82	4.84	4.63	5.83	5.11
Prod. Leadership	6.10	5.19	5.33	5.03	4.28	5.48	4.95
F (sig.)	1.007 ns	3.395 *	0.764 ns	0.131 ns	1.600 ns	0.957 ns	0.583 ns
Industry							
Manufacturing	6.18	4.81	5.58	4.89	4.34	5.70	4.17
Services	6.06	5.70	4.93	4.33	5.58	5.13	5.14
F (sig.)	0.202 ns	0.624 ns	0.175 ns	0.011 ns	0.001 ns	0.230 ns	10.656 ***
Size (revenues)							
Small (< $3B)	6.05	4.28	5.58	4.68	4.12	5.29	4.64
Large (> $3B)	6.13	5.01	5.77	5.15	4.55	5.92	5.20
F (sig.)	0.145 ns	12.510 ***	0.685 ns	3.786 *	3.51 *	8.539 **	5.011 *

ns: not significant * p<0.1 ** p<0.01 *** p<0.001

With the exception of competitive dynamics, we find that there were no significant differences between manufacturing and services firms. Other researchers have equally failed to find differences in IT impacts across manufacturing sub-sectors [Mason and Ragowsky 2002]. However, in terms of differences between small and large firms (having split the sample by median sales), we found statistically significant differences indicating that large firms report higher IT business value across the value chain than small firms. While we did not have data on IT spending, prior research has shown that large firms tend to spend more on IT as a percentage of sales than small firms [Lee and Bose 2002; Mitra and Chaya 1996], while IT spending, in turn, is a known predictor of firm performance [Byrd and Marshall 1997; Rai et al. 1997; Sircar et al. 2000]. While our sample includes both manufacturing and services firms, it is interesting to note that our results as to firm size contradict prior sector-specific research by Mason and Ragowsky (2002) who find that in manufacturing firms, size (based on sales) has a negative effect on perceptions of impacts from using supplier-oriented IT, and Harris and Katz (1991b) who identify that small firms in the life insurance sector realize disproportionately higher value from IT than their larger counterparts.

As a second test, we tested a multivariate model to determine if interaction effects (two-way and three-way) between industry, size and business strategy were able to predict IT business value. As seen in Table 10, significant main effects are largely absent for value disciplines and industry, echoing a lack of significance for these variables in our earlier ANOVA test in Table 9. Table 10 also shows that there are significant main effects for firm size in four processes: supplier relations, sales and marketing, customer relations, and competitive dynamics, echoing similar significant ANOVA results in these areas in Table 9. What is interesting though is the pattern of results in Table 10 for two-way effects between size and value discipline and between industry and value discipline (the only process where these two-way effects are insignificant is competitive dynamics)

Table 10. Main and Interaction Effects (F Statistics)

	Process Planning	Supplier Relations	Product & Ops.	Prod. & Srv. Enhance.	Sales & Mkting.	Customer Relations	Competitive Dynamics
Intercept	1279.8 ***	741.6 ***	753.0 ***	598.6 ***	525.7 ***	965.2 ***	517.2 ***
<u>Main effects</u>							
Value discipline	0.371 ns	0.612 ns	1.076 ns	4.012 *	0.369 ns	0.070 ns	0.171 ns
Industry	0.127 ns	0.000 ns	0.009 ns	0.050 ns	1.059 ns	0.207 ns	7.849 **
Company size	0.723 ns	3.028 *	1.551 ns	1.308 ns	7.738 **	4.472 *	2.979 *
<u>Interaction effects</u>							
ind. x size	1.385 ns	2.676 ns	0.042 ns	0.188 ns	0.007 ns	0.008 ns	0.851 ns
ind. x value disc.	2.750 *	4.769 **	4.057 *	6.566 ***	6.367 ***	2.596 *	1.461 ns
size x value disc.	2.906 *	4.606 **	7.321 ***	6.009 **	10.807 ***	3.184 *	1.911 ns
ind. x size x v. disc.	0.296 ns	1.363 ns	0.864 ns	1.645 ns	0.770 ns	0.680 ns	1.395 ns
Corrected model	1.758 *	3.492 ***	2.194 *	2.593 **	3.567 ***	2.129 *	2.490 **
Model R^2	0.08	0.14	0.09	0.11	0.15	0.09	0.11

ns: not significant * p<0.1 ** p<0.01 *** p<0.001

Interpreting these two-way effects is important. For example, while IT impacts are numerically similar in manufacturing and service firms (main effects are essentially insignificant across the value chain as seen in Table 10), two-way effects show that IT impacts in services firms that are pursuing customer intimacy are very different from IT impacts in manufacturing firms that are pursuing operational excellence.

To highlight this distinction, we reviewed plots showing each interaction effect. For each process, these plots show that executives in manufacturing firms perceive less IT impacts than service firms where customer intimacy or product leadership is their value discipline, but in the case of operational excellence, manufacturing firms perceive higher IT impacts than service firms. We reveal in Figures 1 and 2, plots for customer relations, and production and operations, reflecting the processes with the highest levels of IT business value. Plots for other processes reveal similar interaction effects, as noted in Table 11 where we report descriptive data for all two-way interaction effects.

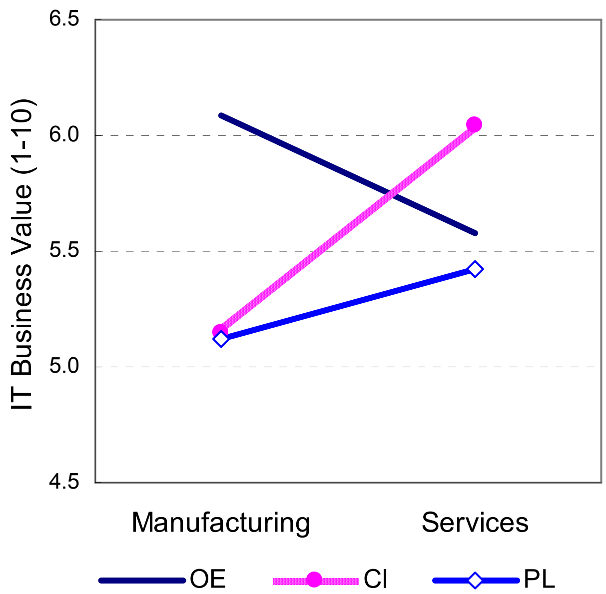

Figure 1. Production and Operations

While there are several possible explanations for these interaction effects, in view of the capital intensive nature of manufacturing firms, one can appreciate why operationally excellent firms have higher impacts across the value chain, as reported in Table 11. In contrast, service firms are more effective at using IT to pursue customer intimacy and product leadership. Given the complexities of mass customization in a manufacturing setting, it is not unusual to see that IT impacts are lower here than in a services setting.

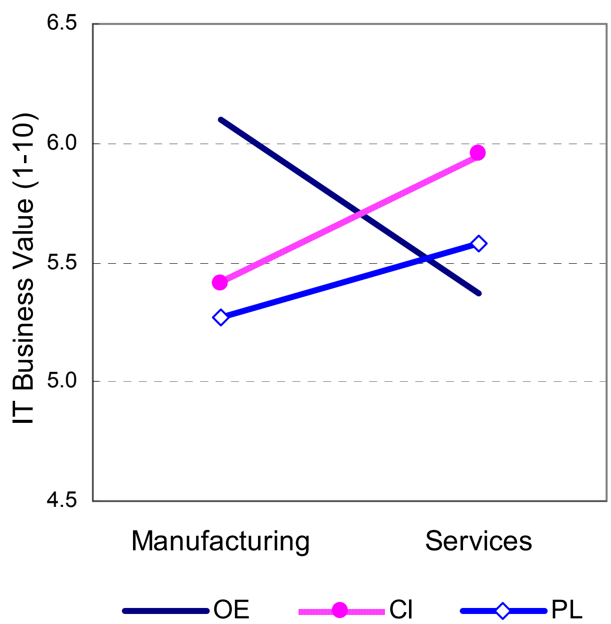

Figure 2. Customer Relations

Table 11. IT Business Value and Two-way Interaction Effects

Business Processes		Industry x Value Discipline				Size x Value Discipline		
		OE	CI	PL		OE	CI	PL
Process Planning	Mfg.	6.51	5.73	6.19	Large	6.19	5.87	6.25
	Services	5.85	6.48	6.06	Small	5.71	6.54	5.82
Supplier Relations	Mfg.	5.16	4.44	4.62	Large	4.85	4.90	5.74
	Services	4.26	4.94	5.44	Small	3.93	4.77	4.12
Production & Ops.	Mfg.	6.09	5.15	5.12	Large	5.96	5.26	5.81
	Services	5.58	6.04	5.42	Small	5.34	6.14	4.41
Prod. & Serv. Enhan.	Mfg.	5.69	3.95	4.70	Large	5.32	4.47	5.48
	Services	4.77	5.13	5.18	Small	4.49	5.05	4.17
Sales & Marketing	Mfg.	4.84	3.97	3.77	Large	4.44	4.38	5.17
	Services	4.02	4.85	4.52	Small	3.87	4.78	2.59
Customer Relations	Mfg.	6.10	5.41	5.27	Large	5.96	5.85	5.88
	Services	5.37	5.96	5.58	Small	4.98	5.81	4.73
Compet. Dynamics.	Mfg.	4.59	3.91	3.62	Large	5.02	5.33	5.63
	Services	4.86	5.50	5.56	Small	4.55	4.98	3.66

Table 10 also shows the presence of interaction effects between firm size and value disciplines. In reviewing plots of these interaction effects – plots for production and operations and customer relations are shown in Figures 3 and 4 – it was found that small firms reported less IT business value throughout the value chain, except where they were pursuing customer intimacy. This suggests that smaller firms are able to gain value from IT if pursuing a strategy of customer intimacy because of their ability to get close to the customer and to provide a greater degree of personalization. In contrast, the impersonal atmosphere often projected by large firms makes it difficult to gain significant value from IT if the firm is considering customer intimacy. However, when large firms pursue operational excellence or product leadership, IT can deliver greater value via economies of scale.

The net result of these interaction effects is to reinforce the notion that not all firms are created equal when it comes to gaining value from IT while it also shows that the different process measures in our thermometer can distinguish between firms based on their operating characteristics. Consistent with earlier research by Mason and Ragowsky (2002) and Ragowsky et al. (2000), we find that perceptions of IT impacts are shaped by firms' operating characteristics (size, industry, and firm strategy), and so these factors must not be overlooked in interpreting data for a given firm.

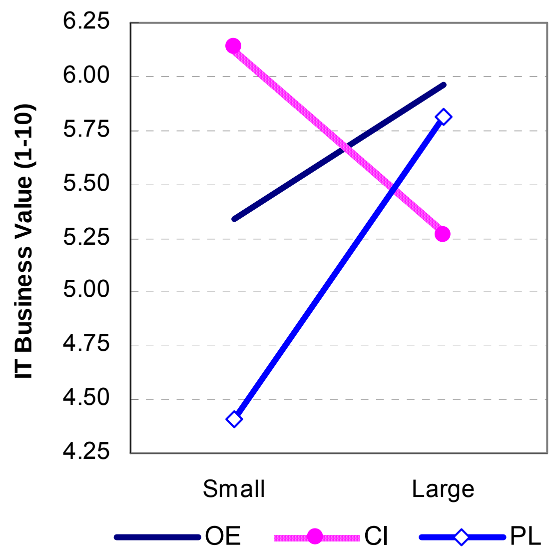

Figure 3. Production and Operations

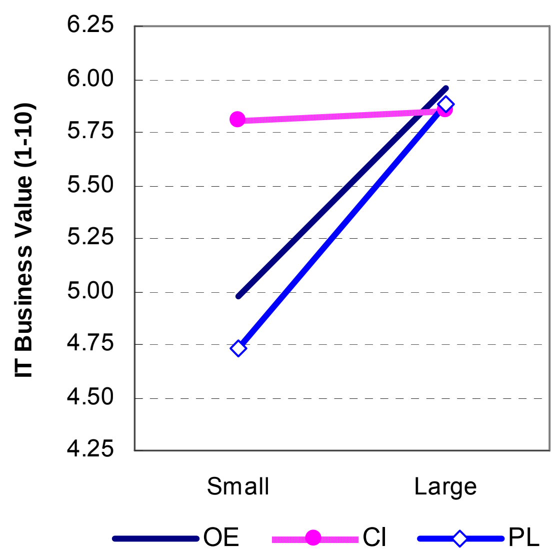

Figure 4: Customer Relations

APPLYING THE THERMOMETER IN A MULTI-FIRM STUDY

As a community of researchers, we embrace the need to validate our measures and so a great deal of effort is necessarily spent on testing for reliability and validity. While a subsequent step might involve embedding these measures in a nomological network of substantive variables in order to test a theory or a set of hypotheses – something which we have undertaken in a parallel study[6] – a key motivating factor in this study was a desire to create a set of business value metrics that could be used either by executives or by IS researchers involved in case study analyses of IT impacts. As such, testing a nomological net, while useful, will still not confirm to academics or practitioners whether these measures are truly useful.

Using a perception-based survey instrument that has been validated across a large sample to draw inferences about the state of IT impacts in a given firm is fraught with danger because of the potential for respondent bias [Podsakoff and Organ 1986]. As argued previously, perceptions emerge from a complex sensemaking process that is not entirely free from bias and distortion [Weick 1995]. If executives in the same firm perceive IT impacts in different ways, confidence in our measures would be eroded to the point that we would be challenged to say what we were measuring. If perceptual measures are consistent with economic reality in firms, we should expect consistency in how executives notice, interpret, and report on IT impacts. Hence, in order to build trust and confidence in our measures, we felt it was appropriate to obtain perceptual data from multiple executives in the same firm and to test these data for consistency.

In working with CSC on a later round of surveys, we randomly selected three Fortune 200 firms (labeled Paper Inc., Electronics Inc., and Logistics Inc.) and a large privately-held travel services firm (Travel Services, Inc.) to whom we could send multiple surveys. With the assistance of each firm's CIO, we negotiated access to the senior executive committee in each firm whose members were at SVP level or higher. We then mailed a copy of the survey instrument to each committee member with an invitation that they return the completed survey directly to us. From an initial mailing, we received 57 surveys (50% response rate). A sample of ten non-respondents cited time constraints or insufficient tenure with their firm as their main reason for not responding. Two of Paper Inc.'s respondents came from unrelated subsidiaries, while one respondent in each of the remaining firms was not a member of the senior executive committee. Removing these individuals from our sample led to a sample size of 52 respondents in four firms.

Inter-rater reliability among the executives in each firm was assessed as an intra-class correlation coefficient with two-way mixed effects [Shrout and Fleiss 1979]. While the number of survey items (44) is fixed, respondents are randomly selected in each firm. Inter-rater reliability measures were applied in three ways: first, to all IT business value items in each business process; second, to all IT business value items simultaneously; and third, to the three items used to ascertain each firms' business strategy.

As reported in Table 12, regarding IT business value at the process-level, inter-rater reliability is significant in all but three processes (89% or 25 of 28 process measures are significant). With this level of support, we can conclude that senior executives in each firm tend to agree with each other on how much value IT is generating at various points within the value chain. We further identified significant inter-rater reliability in each firm when all IT business value items were taken together. There was also significant agreement among executives as to the composition of their firm's business strategy. Overall, these results show that perceptual bias or distortion is not as much of an impediment to the use of perceptual measures as researchers in other disciplines have reported [Mezias and Starbuck 2003; Starbuck and Mezias 1996].

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[6] Research by Tallon et al. (2000) that uses a subset of the 44 process-level perceptual items in this study offers some evidence of nomological validity. In their study, they found that the level and locus of process-level payoffs from IT were closely aligned with firms' strategic intent for IT, and that the use of post-implementation reviews was an important predictor of subsequent payoffs from IT investment. Other research undertaken using these items in 2000 (N=63), and 2003 (N=241) confirm that the survey items remain valid and reliable over time.

Table 12. Inter-rater Reliability Correlations

	Paper Inc. N=23	Logistics Inc. N=10	Electronics Inc. N=8	Travel Services Inc. N=11
IT Business Value				
Process Plan. & Support	0.849 ***	0.533 *	0.589 *	0.749 **
Supplier Relations	0.422 ns	0.614 *	0.732 **	0.704 **
Production & Operations	0.840 ***	0.626 *	0.715 **	0.416 ns
Product / Serv. Enhance.	0.668 **	0.724 **	0.346 ns	0.708 **
Sales & Mkting Support	0.783 ***	0.678 **	0.510 *	0.627 **
Customer Relations	0.864 ***	0.732 **	0.621 **	0.581 *
Competitive Dynamics	0.709 *	0.857 ***	0.722 **	0.668 *
All processes (44 items)	0.887 ***	0.800 ***	0.628 **	0.621 ***
Business Strategy				
Value Disciplines	0.965 ***	0.945 ***	0.803 **	0.860 **

ns: not significant * $p<0.1$ ** $p<0.01$ *** $p<0.001$

IV. DISCUSSION AND IMPLICATIONS

Notwithstanding the conceptual appeal of using a process approach to study IT impacts, there is a significant lack of process-level research in the IS literature when compared with firm-level studies that use production function economics or financial measures of performance [Barua and Mukhopadhyay 2000; Kohli 2004; Melville et al. 2004]. The reason for this shortfall is important as it underscores the difficulty facing future IS researchers in this domain. Process-level data are proprietary and unpublished in any public forum, unlike financial accounting data which are available for publicly traded firms. If process data are collected through a balanced scorecard approach, for example, these data are routinely protected from competitors and seldom shared with academics for research purposes. The process-level studies reported in Table 1 of this paper focused either on processes in specific firms (Chrysler, U.S. Postal Service) or in the case of Barua et al. (1995), used archival MPIT (Management Productivity and Information Technology) data collected by the Strategic Planning Institute during the 1980s, a program that has since been discontinued. Besides data collection challenges, the unique nature of processes likely means that objective metrics vary widely across firms. There are no standard or generally accepted objective process measures in the same way that there is broad consensus on firm-level or financial measures of firm performance as embodied within generally accepted accounting principles (GAAP).

Perceptual measures, we argue, constitute an alternative approach to measuring IT impacts at the process-level and yet perceptions are not a substitute, necessarily, for objective metrics. If perceptual measures are obtained from knowledgeable or informed respondents, perceptions can both complement and supplement objective measures so that even if objective data are lacking or inaccessible, perceptions may still provide critical insights into the level and locus of IT impacts within the firm. As such, we are not suggesting that perceptions should replace objective measures. Both can co-exist and reinforce one another [Chan 2000]. However, the realities of research mean that when objective data are difficult to obtain, researchers can at least turn to perceptions to shed some light on how IT is impacting the firm. The fact that our analysis not only finds that our measures are valid and reliable, but that when used with groups of senior executives in the same firm have the ability to detect consensus ratings of IT impacts. Perceptions are both personal and private, and so there is an ever-present risk of respondent bias. Consensus among executives discounts this widely held view of perceptions [Mezias and Starbuck 2003; Podsakoff and Organ 1986] while indicating the practical merit of our thermometer not only in case study research, but also for practitioners.

Another feature of the IT business value thermometer is its ability to identify whether or not IT is supporting the strategic goals of the firm. Surveys continue to identify strategic alignment or the link between IT and business strategy as one of the top five IT issues facing firms worldwide (CSC 2001). If firms allocate IT resources to processes that are regarded as key to their success, it is reasonable to expect that the primary locus of IT value will be in these processes rather than elsewhere. On the other hand, if strategic processes are starved of IT resources, revealing misalignment between IT and business strategy, it follows that IT impacts will likely be weak, signaling that the firm is incapable of using IT to achieve its strategic goals.

A broader issue stemming from the successful development and application of an instrument that assesses IT impacts across 44 items, grouped under seven distinct processes, is whether we are any closer to definitively measuring IT impacts at the firm level. There is a temptation in multi-item survey research, especially if reliability analysis shows high levels of consistency, to group and average items to produce a single aggregate or composite score. In this research, we did exactly this, reducing our 44 item survey down to seven composite process measures. While it is possible to aggregate these process averages even further into a single firm-wide composite score, it would be dangerous to infer that this is a valid proxy for IT business value at the firm-level. In many respects, IT impacts at the firm-level are, and must remain, focused on financial outcomes (profit, revenues, market growth, costs, etc.). To collapse process-level measures into a single value that is then ascribed to the firm is theoretically unsound since it ignores the fact that complementaries arise at the process-level, not at the firm-level. In the same way that production function analyses in previous research did not try to unravel IT impacts at the process-level [Brynjolfsson and Hitt 1995; Dewan and Min 1997], it would be unwise to scale-up our measures to the firm-level. At the same time, folding these process measures into a second order factor (as reflective indicators) is not the same as inferring that a second order factor is synonymous with IT impacts at the firm level.[7] For researchers wishing to employ our measures in future nomological testing, the use of a second order factor in structural modeling would be an astute way to capture variance across an entire set of dependent variable measures, rather than specifying an independent relationship for each and every process variable outcome.

RESEARCH CONTRIBUTION

This research makes several contributions to the literature on IT impacts. First, we offer a series of theoretical arguments to justify the use of perceptual measures as a complement to objective measures of IT impacts. Second, we use the value chain to develop a theoretical framework that highlights critical activities where IT business value can be evaluated. We subsequently leverage this framework to create a set of 44 measures that capture information on the most critical IT impacts as recognized by the literature in various processes of the value chain. Third, by testing and validating a perception-based instrument, we have illustrated a potentially useful approach to assess the process-level impacts of IT. Fourth, consistent with prior research, we show that exogenous factors such as industry, firm size and business strategy help to explain some of the differences in perceptions of IT impacts. Lastly, we illustrate the robustness of our measures in a series of intra-firm surveys with multiple executives.

LIMITATIONS

Our study is not without its limitations, however. While we sought to make our business value thermometer as comprehensive as possible, we did not exhaust all possible IT impacts. In some ways, this presents an opportunity for other researchers to extend our work by including additional items to reflect a specific industry focus or the use of new workplace technologies. Our collaboration with CSC led us to focus on particularly large firms and so we caution against extrapolating our findings to small or medium size firms. Our attempt to evaluate the accuracy and consistency of our measures as part of an extended survey at four firms is also a limitation.

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[7] We thank an anonymous reviewer for drawing our attention to this aggregation issue.

While it is critical that we found repeated instances of inter-rater reliability, the results from four firms does not provide irrefutable evidence that executives will always agree with each other. Furthermore, we did not formally embed our measures in a nomological net to assess their explanatory ability; this step is clearly important as research moves beyond instrument development to a theoretical evaluation, for example, of how management practices influence IT business value. While consideration of industry, size and value disciplines as a proxy for firm strategy offer some semblance of nomological testing, more extensive theoretical testing is needed before the measures outlined in this study can be included in future research. Rather than using all 44 items in a nomological test, the process orientation of our research may facilitate more detailed testing that focuses on a solitary process.

The argument that an analysis of IT impacts at the process-level affords a more accurate or richer account of IT impacts, and that perceptual measures are a way to unmask these impacts, naturally leads to a discussion of who is the most qualified respondent. Is it preferable to target a broad cohort of managers with responsibility for different processes or to instead target just one senior respondent whose scope of responsibility may involve exposure to multiple processes? The natural response is to consider a tradeoff between data accuracy and data collection effort. Multiple respondents are always preferable and while our use of a single senior executive per firm constitutes a potential weakness, the fact that we found consensus among teams of senior executives in four firms suggests that seniority does not necessarily lead to clouded judgment or inconsistent perceptions of IT business value. Future research could consider this issue in more depth, testing to see if multiple function-level respondents are more accurate in their views on IT impacts than those at more senior levels. Differences between business and IS executives could also be examined in order to assess possible bias based on an innate belief that IS executives will report higher impacts from IT than their business peers.

Finally, the data used in testing our thermometer were collected during the late 1990s. Much has happened in the interim to bring new IT applications to bear on firm performance. We were careful in the design of our thermometer to avoid referencing IT tools or applications that may inadvertently anchor our measures in a particular time period. Thus, we do not refer to case tools, DSS, EIS, ESS or other popular acronyms that may have been in vogue when our research began. The IT impacts measures we developed emphasize how IT has improved the output of an activity rather than invoking a particular form of IT. We must caution, however, that the descriptive data created by our thermometer are time specific. The data in Table 11 could be used for comparative benchmarking purposes, but only after careful consideration of how time and learning effects may have contributed to a general upturn in IT impacts overall. As identified in footnote 8, subsequent research conducted using a subset of the items developed in this study reveals that the factor structure of our thermometer has remained intact over time. Nevertheless, this does not exclude future enhancements or extensions to our items as research seeks to focus on IT impacts within a particular process [Ray et al. 2004] or within a small number of industry sectors [Chan et al. 1997].

V. CONCLUSION

“If you can’t measure it, you can’t manage it,” a comment by Intel Chairman and founder, Andy Grove, echoes a widely held belief that management without metrics is a recipe for disaster [Curley 2003; Jeffrey 2003]. One of our reasons for developing this survey instrument was in response to the growing frustration among executives at the lack of metrics to assess the impact of IT within firms at a time when the strategic value of IT is coming under renewed scrutiny [Carr 2003]. Knowing that firms still struggle with the uncertainty of not being able to say whether their IT investments are delivering what is expected of them, we sought to develop a robust set of measures to aid managers in making this evaluation where, in the past, an absence of frameworks has forced managers to adopt a myopic view of IT evaluation [Irani and Love 2001]. Typically, the goal of a post-implementation review is to identify whether an investment is performing as expected and if not, to provide an explanation for how any shortcomings can be resolved. Reluctance to perform such reviews often hinges on a lack of valid objective data and so executives resort to an evaluation based on instinct and gut-feel [Bannister and Remenyi 2000; Barua and Mukhopadhyay 2000].

Our approach to evaluating IT business value uses executives' perceptions of the impact of IT on process-level activities in the value chain. While research has noted that this is the most appropriate level at which to evaluate IT impacts [Barua et al. 1995; Barua and Mukhopadhyay 2000; Kohli 2004; Wilson 1993], we believe that it is also the more appropriate level for initiating remedial action in the event that IT impacts fail to arise or are somehow seen as inadequate. Whereas most IT evaluation – to the extent that it occurs at all – focuses on individual applications, the process-oriented approach exhibited here extends this assessment to identify if IT as a whole is having a desired effect on business activities. This point explains why we are not advocating the adoption of perceptual measures in lieu of objective measures. Our conclusion is that perceptual measures, if structured around IT impacts at the process-level, can yield richer insights than objective criteria alone, and so our approach does not deny or undermine the use of objective measures in continuing IS research. If objective and perceptual items are considered side-by-side, firms will be better able to identify the locus of IT impacts and to assess whether firm performance has been enhanced.

Our primary goal in this research was to devise a series of measures to assess the impact of IT on critical business activities. For researchers who are active in this area, our findings illustrate the potential usefulness of perceptual measures in a process-level assessment of IT impacts. The adoption of perceptual measures adds a new dimension to reviews of IT impacts that have traditionally focused on economic, financial or accounting-based measures (Barua and Mukhopadhyay 2000; Dehning and Richardson 2002; Kohli and Devaraj 2003; Melville et al. 2004). While objective measures are often seen as restrictive and narrow, perceptual measures have the potential to broaden an evaluation of IT into areas that have been impervious to objective measurement. While research has debunked the IT productivity paradox, fostering new lines of investigation around IT and management practices, firms continue to struggle with IT evaluation, and so we encourage researchers to adopt and improve our measures as a way to enable firms to better assess the contribution of IT to firm performance.

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APPENDIX: SURVEY INSTRUMENT

Section I. Business Strategy and Value Disciplines

What is your firm's primary strategy or operating focus? Please allocate 100% across the following foci.

Strategy/Operating Focus		Percent
Operational excellence (e.g., emphasize efficiency and reliability, end-to-end supply chain optimization)	% =	
Customer Intimacy (e.g., emphasize flexibility and responsiveness, customer service, market-place management)	% =	
Product/service leadership (e.g., emphasize creativity, product development, time-to-market, and market communications)	% =	
Total		100

Section II. Rating of Business Value of Information Technology

To what extent does information technology (IT) contribute to the performance of your firm along each of the following dimensions? Please restrict your appraisal to realized, not expected benefits.

Realized Impact
Weak Average Strong

Does Information Technology…? **1 2 3 4 5 6 7 8 9 10**

Process Planning and Support

PS1 Improve the process and content of decision making
PS2 Improve internal communication within your corporation
PS3 Improve strategic planning
PS4 Provide better coordination among functional areas in your corporation
PS5 Facilitate new processes that constitute a better way of doing business
PS6 Improve coordination among geographically separate units of your corporation
PS7 Facilitate the automation of core business processes

Supplier Relations and Inbound Logistics (SR)

SR1 Reduce transaction costs by making it easier for suppliers to handle orders
SR2 Help to reduce variance in supplier lead times
SR3 Enhance the ability to monitor the quality of products/services from suppliers
SR4 Facilitate the development of close relationships with suppliers
SR5 Help your corporation to gain leverage over its suppliers
SR6 Help your corporation coordinate closely with its suppliers

Production and Operations

PO1 Improve the levels of production or throughput
PO2 Reduce the level of production/service delivery required for economies of scale
PO3 Improve the utilization of machinery
PO4 Improve the productivity of labor through automation

Product and Service Enhancement

PSE1 Reduce the development time for new products/services
PSE2 Reduce the time-to-market for new products/services
PSE3 Reduce the cycle time for development of new products/services
PSE4 Reduce variance and uncertainty in product/service quality
PSE5 Facilitate the tailoring of products/services to individual market segments
PSE6 Reduce the cost of designing new products/services
PSE7 Reduce the production cost of tailoring products/services to market segments

Sales and Marketing Support

SM1 Provide support for identifying market trends through powerful analytical tools

SM2 Assist your corporation in serving new market segments
SM3 Enhance the accuracy of sales forecasts
SM4 Increase your corporation's effectiveness in locating new markets
SM5 Increase your corporation's ability to anticipate customer needs
SM6 Help to track market response to pricing strategies
SM7 Track market response to discounts
SM8 Track market response to promotional or introductory pricing
SM9 Facilitate targeted response to competitor's pricing strategies

Customer Relations and Outbound Logistics

CR1 Enable your corporation to provide administrative support to customers
CR2 Facilitate a higher level of flexibility and responsiveness to customer needs
CR3 Reduce the variance and uncertainty in product/service delivery times
CR4 Facilitate the development of detailed customer databases
CR5 Position customers to rely increasingly on your company's electronic support systems
CR6 Provide on-line access of your corporation's products/services to customers
CR7 Help your corporation coordinate closely with its customers

Competitive Dynamics

CD1 Support your firm in offering a product/service that your competitors cannot immediately match
CD2 Help your company to provide substitutes for your competitors' products/services
CD3 Help delay competitor entry into your firm's product/service areas because of new IT investments
CD4 Capture distribution channels and so increase the cost/difficulty for competitors to enter a new or existing market segment

ABOUT THE AUTHORS

Paul P. Tallon is an Assistant Professor of Information Systems at the Carroll School of Management, Boston College and a Research Associate at the Center for Research on Information Technology & Organizations (CRITO) at the University of California, Irvine. He previously worked as a chartered accountant with PricewaterhouseCoopers (PWC). His research has appeared in, or is forthcoming, in JMIS, Communications of the ACM, CAIS, and the Journal of Global IT Management. His interests include the economic impacts of IT, strategic alignment, and the economics of data management.

Kenneth L. Kraemer is Professor of Management and Computer Science and Director of the Center for Research on Information Technology and Organizations (CRITO) at UC Irvine. His research interests include the socioeconomic implications of IT, national policies for IT production and use, and the contribution of IT to economic development

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