Evaluating business process-integrated information technology investment

In Lee
Department of Information Management and Decision Sciences, College of Business and Technology, Western Illinois University, Macomb, Illinois, USA

Keywords *Information management, Business process re-engineering*

Abstract *Because of increasing competition and limited capital budgets, firms need to carefully assess every information technology (IT) opportunity to ensure that their resources are spent judiciously. Conventional wisdom holds that IT has enormous potential. However, organizations continue to question the benefits of IT in conjunction with new corporate initiatives such as business process re-engineering, e-commerce, and enterprise resource planning. Despite the potential benefits derived from IT investment, traditional capital budgeting models have failed to estimate true IT values due to their inability to measure complex interactions between IT and organizational performance. This paper presents a business process integrated IT evaluation methodology that integrates business strategy, business process design, and supporting IT investment. The evaluation methodology consists of four phases: strategic analysis; business process design; IT configuration; and performance evaluation. The empirical evidence and computational study strongly suggest that measuring cycle time impact on customers' repurchasing decisions is critical in evaluating the potential value of business-process-driven information technology investment.*

1. Introduction

Recent information technology (IT) advances have rapidly changed the ways firms operate their businesses. IT enables firms to redesign business processes, strengthen their customer relationship management, and develop a new business model. Information-intensive business organizations are utilizing IT to create new knowledge, manage existing knowledge, distribute information, and facilitate inter- and intra-organizational collaboration. While IT helps organizations improve productivity, recent e-commerce development has created highly competitive market environments across all industries.

Business process redesign is one area where business strategy and IT have played a crucial role (Davenport, 1993; Davenport and Short, 1990; Grover *et al.*, 1995; Hammer, 1990; Irani *et al.*, 2000). Some firms have reported significant productivity gains by integrating IT into their core business processes. Among successful examples of IT integration with business process redesign are Caterpillar's inventory control systems, Baxter International's stockless inventory system, Ford Motor Company's invoiceless processing, and BankOne's mortgage application process, to name a few. Ford also successfully implemented virtual co-location design information systems to coordinate global concurrent engineering activities and reduced product development time (Bartholomew, 1996). Recently, business process redesign has been further facilitated with enterprise resource planning (ERP) systems and e-commerce applications (Hammer, 2000; Kustermann, 1998). E-commerce has driven process redesign efforts in

Business Process Management Journal
Vol. 10 No. 2, 2004
pp. 214-233

1463-7154
DOI 10.1108/14637150410530271

many organizations with the aim of real time order tracking, record keeping, accounting, invoicing, and customer relationship management.

Numerous success stories indicate that IT may have enormous potential for business process re-engineering (BPR) and financial/strategic benefits. However, organizations continue to question the benefits of IT in conjunction with new corporate initiatives such as e-commerce development and ERP. Empirical studies on the relationship between IT and organizational performance have been widely conducted with only mixed results (Bender, 1986; Brynjolfsson and Hitt, 1996; Floyd and Wooldridge, 1990; Harris and Katz, 1991). Other studies suggest that the benefit an organization gains from IT investments depends on organizational characteristics (Johnasen *et al.*, 1995; Ragowsky and Stern, 1997).

Despite the controversies on the value of IT investment at the industry level, it is evident that while some organizations failed to garner promised benefits from IT investment, other organizations have been successful in IT applications. Many successful IT investment cases indicate that business process design issues should be addressed when IT investments are made. In order to integrate business process design factors into IT investment decisions, we propose a four-phase IT evaluation methodology:

(1) Strategic analysis.

(2) Business process redesign.

(3) IT configuration.

(4) Performance evaluation.

The methodology addresses a fundamental question: are the business process redesign and investment in IT justifiable in terms of organizational performance? Answering this question is difficult yet important for managers, since increasing economic and competitive pressures compel senior management to carefully scrutinize IT capital budgets (Wilder and Hildebrand, 1992). We also present simple mathematical formulas and a simulation approach to reasonably estimate organizational benefits of business process integrated IT investments.

The paper is organized as follows. In Section 2, a brief review of IT evaluation literature is presented. In Section 3, the details of the IT evaluation methodology are discussed. In Section 4, performance of a hypothetical order management system is analyzed using the methodology. In Section 5, empirical evidence of customers' responses to order delivery performance is presented. Finally, this paper concludes by offering some implications of the methodology for business managers.

2. Literature review

Statistics show that IT accounted for over 14 percent of US capital investments in 1993, compared to 8 percent in 1980 (*Fortune*, 1993). Another study estimates that investment in computers has increased tenfold between 1971 and 1990 (Brynjolfsson *et al.*, 1994). More recently, according to IDC (www.idc.com), US corporate investment in e-commerce infrastructure reached $260 billion in 2000. More than 85 percent of investment comes from brick-and-mortar companies. These statistics suggest that IT has become one of the most important cost drivers in business operations, and thus investment in IT requires special attention from management. Large and small, many businesses have realized that they should capitalize on business opportunities through the deployment of IT. For example, in the past decade, e-commerce has revolutionized the ways organizations compete, creating new business opportunities and challenges in almost every industry. Forrester research predicted that worldwide e-commerce – both business-to-business (B2B) and business-to-consumer (B2C) – would hit $6.8 trillion in 2004, capturing 8.6 percent of the world's sales of goods and services (www.forrester.com). Without a timely entry into e-commerce, many traditional brick and mortar companies will eventually go out of business.

Despite the potential benefits of IT investment, traditional capital budgeting models fall short of capturing its true value due to their inability to measure intangible strategic benefits or optimism in projecting financial returns under no investment alternative (Kaplan, 1986). Consequently, many IT investments are based upon "gut feelings" or "intuition", rather than quantifiable criteria (Dos Santos, 1991; Kauffman and Weill, 1989). However, given the significance of IT investments and tight budgetary constraints, it is essential for IT managers to clearly understand whether their investments are financially justifiable, and likely to yield long-term strategic advantages or fail. In the following, we briefly review several studies related to IT evaluation methodologies.

To investigate how organizations make IT investment decisions and how they should, Bacon (1992) conducted a survey of 80 major companies in four countries: the USA, Britain, Australia, and New Zealand. Based on the survey results, he identified and ranked the important decision criteria in IT investments. He found that discounted cash flow (DCF) methods are the most widely used investment criteria for IT projects. Although capital budgeting methods are widely used by managers, they were not recommended by many researchers because of their difficulties in measuring the true value of IT (Cash *et al.*, 1988; Clemons, 1991).

Clemons (1991) pointed out that IT is likely to be essential to the delivery of any new strategic effort in manufacturing, distribution, sales, or service. He argued that part of the problem in justifying IT investment comes from viewing even strategic opportunities to invest in IT as projects, to be judged on their expected value and capital budgeting criteria. He further suggested that managers consider factors such as tangible and intangible benefits and costs of undertaking the program, the risks of proceeding with the program, expected competitive impact, and possible partnership with competitors. Alternatively, the effectiveness index and ranking methods have also been recommended to justify information systems investment (Mahmood and Mann, 1991; Sethi *et al.*, 1993).

Recent research on option theory-based investment stressed that companies must decide how to exploit various investment opportunities most effectively. Dixit and Pindyck (1995) and Dos Santos (1991) suggested that a company with an opportunity for project investment is holding something like a financial option: the company has the right, but not the obligation, to buy an asset before or at a future time of its choosing. They contended that the experience gained from initial investments could prove extremely valuable in the follow-on investments into other projects. However, appropriate IT investment decisions require accurate estimation of certain parameters, such as project risk and time to invest, which are still the most elusive part of the option theory.

While above researchers suggested practitioner-oriented methodologies to predict the IT value before investment, others have focused on the theory building based on empirical data analysis. Contrary to conventional wisdom, most studies found little or no evidence that IT contributes to total output or productivity (Loveman, 1994; Morrison and Berndt, 1990; Roach, 1987). Some researchers attributed inconclusive results to imprecise data, time lag, and mismeasurements (Barua *et al.*, 1995; Brynjolfsson, 1993; Brynsolfsson and Hitt, 1996). Brynjolfsson and Hitt (1998) suggest that the value of IT should be measured not only by cost savings, but also by improvements in quality, customer service, and new product development.

Recently, BPR has received much attention from practitioners and researchers (Davenport, 1993; Davern and Kauffman, 2000; Hammer, 2000; Markus and Benjamin, 1997; Venkatraman, 1994). They argued that BPR's potential benefits can be fully realized by integrating IT with BPR. Devaraj and Kohli (2000) found that IT capital investment combined with BPR improved profitability in the health care industry. A field study suggested the need for a strong integration of IT and business process redesign to improve company-wide productivity (Johnasen *et al.*, 1995). They found that while computer integrated manufacturing (CIM) successfully met operational goals, the technology was still poorly integrated with core business processes such as product development and order fulfillment. As a result, firms created islands of automation with only localized benefits.

3. A business process-integrated IT evaluation methodology

While a large body of researchers have focused on the theoretical contributions of IT evaluation, little attention has been paid to the evaluation methodology that integrates business process and IT. Since IT may fundamentally change the ways in which business organizations interact with internal and external constituents, business strategy and business processes should be considered in the evaluation process. The proposed evaluation methodology consists of four step-by-step phases:

(1) Strategic analysis.

(2) Business process redesign.

(3) IT configuration.

(4) Performance evaluation.

This methodology helps managers estimate the impact of business process design and IT on organizational performance, and helps determine the most appropriate business processes and IT to achieve business strategies. The evaluation process may iterate until the best IT and business process combination is developed. The evaluation procedures are shown in Figure 1. We next describe each phase in detail.

3.1 Strategic analysis

The strategic analysis is concerned with understanding a firm's business environment and internal organization, and developing business strategies to counter competition The starting point of the strategic analysis is identifying major internal/external opportunities and threats from employees, customers, suppliers, competitors, regulatory agencies, and other stakeholders involved. Porter's (1980, 1985) competitive forces and value chain models are helpful in conceptualizing these forces. Current and potential business problems and opportunities are identified from the analysis of competitive forces. Once business opportunities and threats are identified and analyzed, managers should develop business strategies to capitalize on

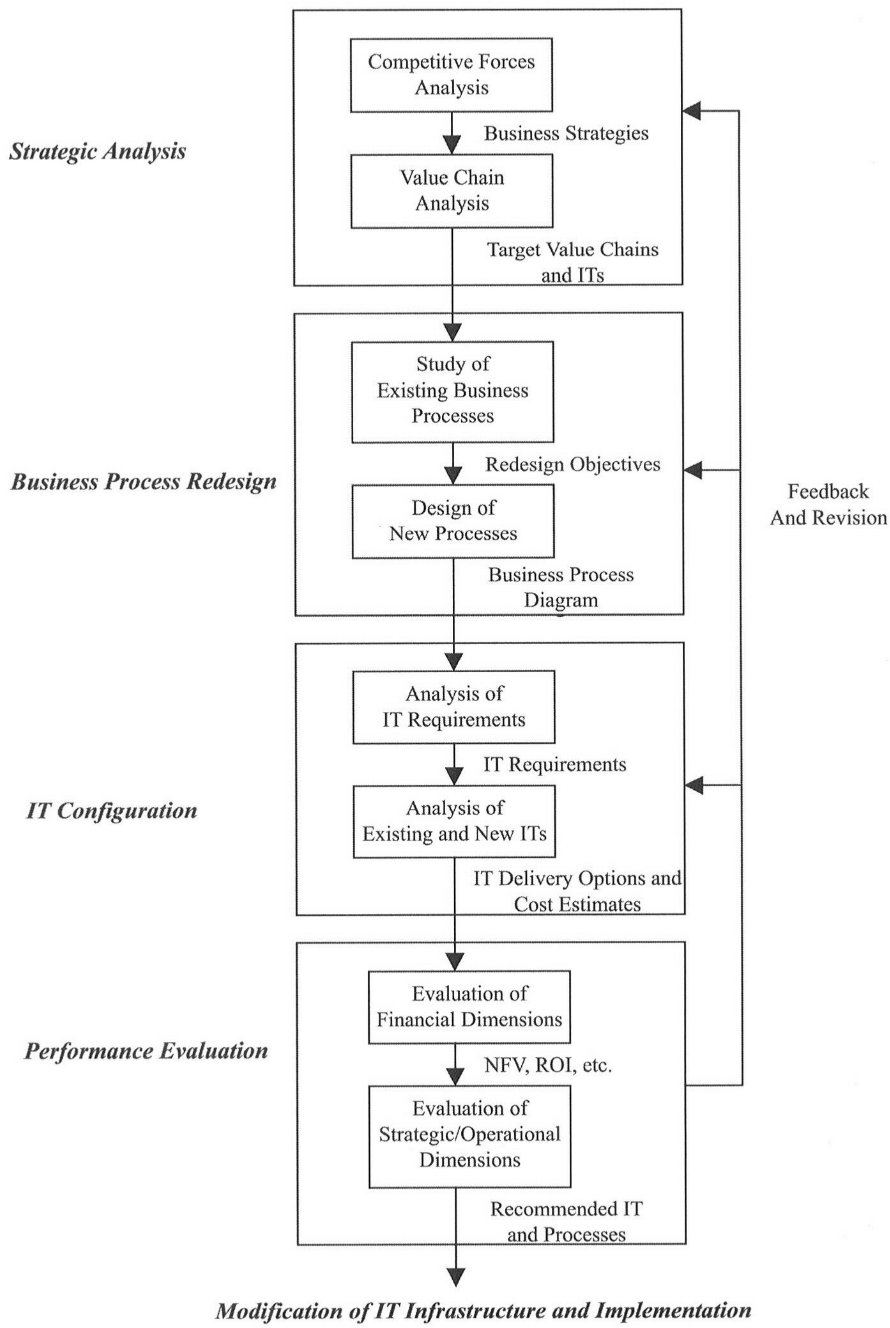

Figure 1.
IT evaluation procedures

opportunities and reduce threats. For example, business strategies can define new products' introduction timings and frequencies to increase revenue.

A value chain analysis identifies the critical activities involved in achieving strategic goals. The value chain analysis also identifies critical information systems supporting the critical value chain activities. Competitors' use of information technologies that support their value chains are identified and analyzed at this stage. A set of IT applications are recommended to gain strategic advantage, especially when their competitors have not employed the IT applications. For the strategic information systems, timing of IT investment is important in order to gain competitive advantage and develop long-term technological competency. The successes of Amazon.com, Yahoo.com, and eBay demonstrate the early IT innovators' advantages in market share and profits. Strategic necessity information technologies are recommended when the majority of competitors have already used the technologies. Finally, along with the identification of critical value chain activities and information systems, business processes that are involved in the activities are identified and analyzed next.

3.2 Business process redesign

In many firms, redesigning key business processes has been a major motivation for new IT investment. Business processes should be designed to achieve specified strategic goals. Business processes convert various organizational inputs into value-added outputs through a set of interrelated activities. Different types of values are generated by different business processes. Since some values are nonfinancial, managers need to investigate how these nonfinancial values contribute to the financial benefits and may derive equivalent financial values. Business process-integrated IT evaluation helps managers make a sound IT investment decision by comparing IT-enabled new business processes with existing business processes.

Business process redesign can be classified into two categories: BPR in physical flow and information flow. BPR in physical flow involves redesign in the transfer of products or services in a physical space. Redesigns of distribution centers and transportation networks are typical examples of BPR in physical flow. On the other hand, BPR in information flow changes the ways in which we create, transform, disseminate, and store information. IT plays a crucial role in achieving BPR in information flow by removing space and time barriers and lowering information processing cost. IT also plays an indirect, yet critical role in achieving BPR in physical flow. For example, electronic data interchange (EDI) is a critical IT application in re-engineering inter-organizational information exchange for electronic orders and invoices. EDI also helps manage the just-in-time materials flow between vendors and manufacturers. Most BPR projects usually address both physical and information flows at the same time.

Three major stages of redesign include the analysis of existing processes, establishment of redesign objectives, and design of new and improved processes. The analysis of existing business processes lead to the establishment of process design objectives (Davenport, 1993). Process design objectives such as cycle time reduction or improved information quality serve as the guidelines for all the IT development activities that follow. Order fulfillment processes are analyzed in terms of the frequency of transaction events, types of processes, speed of processes, and information flow between processes. Product development processes are analyzed in terms of information flow within processes, types of processes, speed of processes, and frequency of information exchange between processes.

In the analysis of BPR, external/internal entities, business events, required processes, and information flows between processes are analyzed. Business processes are classified as either technology-dependent or technology-independent. The processing time and information quality of technology-independent process activities are estimated first. Technology-dependent process activities are identified here, but the processing speed and information quality are estimated in the IT configuration phase since these parameters usually depend on the types of IT chosen. Information flow time between entities and processes are also estimated. The primary tool for the business process design is the business process diagram (BPD). BPD shows the external entities, information flows within and between the systems, and the processes that create, distribute, transform, and store the information. BPD also captures five dimensions of business processes: probability of internal processing events, processing time, frequency of events, information quality, and information flow time.

The following illustrates the use of BPD for the business process redesign. Suppose that an order process redesign is recommended (the BPD for the typical order process is shown in Figure 2). The frequency of periodic internal processing events at each process is derived from the external events triggered by customers. For example, suppose customer orders arrived in an exponential probability distribution of $\mu = 6$ time units. Accordingly, the frequency and processing time of a periodic internal processing event, "review sales order", is estimated.

The proportion of information flow is specified as 1.0 if one and only one process exists next in the information flow route. Otherwise, the proportion of information flow p between processes is $0 < p \leq 1$. There are two possibilities in the subsequent information flows: disjoint and overlapping. If the subsequent information flows are disjoint, the sum of subsequent information flow proportions is always 1.0. For example, if the subsequent events are disjoint, the proportion of information flow between "review sales order" process and "create new customer" process is 0.1, and that of information flow between "process sales order" process and "check customer credit" process is 0.9. If the subsequent information flows are overlapping, the sum of subsequent information flow proportions is more than 1.0. BPD serves as an input into the configuration of IT and the performance evaluation phases.

3.3 IT configuration

IT configuration involves establishing IT requirements, analyzing existing technology, identifying new IT, and measuring its capabilities. In establishing IT requirements, minimum requirements of CPU, software, storage, and telecommunications capacities are estimated based on the business processes' needs. After analyzing the existing IT to see whether it meets the IT requirements for achieving business strategies, new IT options may be considered. Costs of new IT options are broadly classified as hardware, software, telecommunications, maintenance and upgrade, and personnel expenses incurred over the duration of an application life cycle. It is worth noting that a majority of companies which invested in e-commerce applications have reported that upgrade and maintenance costs are much higher than the initial installation costs. Processing

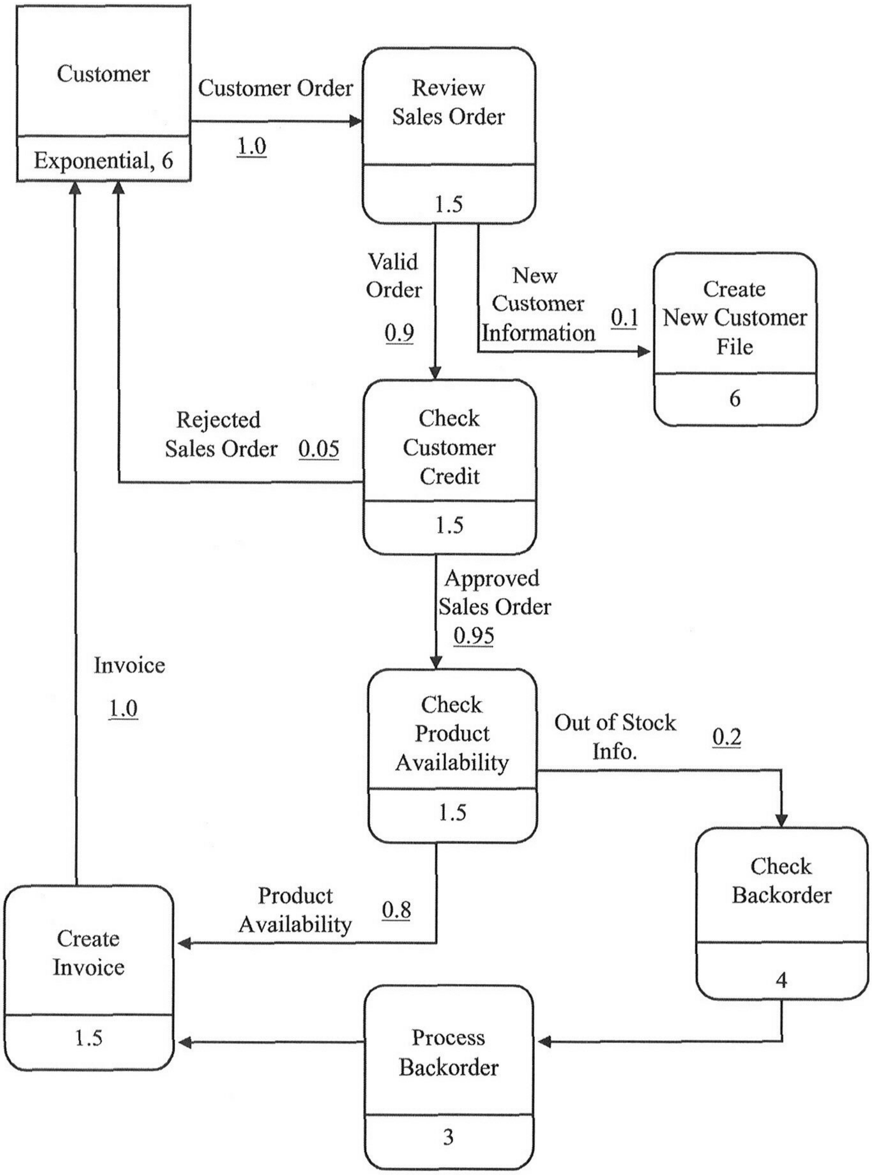

Figure 2.
BPD for the order fulfillment process

time and information quality of technology-dependent processes are also estimated in this phase.

All the remaining costs are estimated in the performance evaluation stage. Managers select new ITs which pass preliminary feasibility tests. Three feasibility tests are suggested: operational, financial, and technical. Feasibility tests are usually iterative and constraints should be incrementally relaxed until a minimum set of alternative technologies is identified. In deciding IT configuration for a specific business process, companies need to consider broad long-term IT architecture issues including industry standards and technology trends in communications, security, multimedia technology, and enterprise integration. In addition, new IT configuration must be structured to support the existing data architecture and integrate seamlessly with the existing information systems including legacy systems. Managers need to consider IT delivery options such as in-house development, off-the-shelf software, application service providers, etc. Major values added by business processes and enabling ITs are summarized in Table I.

3.4 Performance evaluation

Performance evaluation enables managers to compare alternative business processes and IT in terms of organizational performance dimensions There are two broad approaches to performance evaluation: financial and nonfinancial. Financial evaluation is concerned about the bottom line of the organization and is discussed in detail in this section. On the other hand, nonfinancial evaluation consists of two major dimensions: operational and strategic. Operational dimensions are typically quantifiable and include cycle time, defect rates, processing speed, and end-user satisfaction, to name a few. Strategic dimensions are mostly nonquantifiable and include customer satisfaction, service quality, market share, product development capability, etc. In this paper, we focus on the financial evaluation dimensions. We also discuss methodologies that allow us to transform strategic/operational performance into financial performance. The performance evaluation phase provides managers with

Process	Values added	Major IT enablers
Order fulfillment	On-time delivery	EDI, wireless network, order tracking system
	Superior delivery quality	Telecommunications network, computerized distribution management system
	Reduction of order cycle time	Computerized ordering processing system, e-commerce order processing system
	Reduction of product manufacturing time	CIM, CAD, robotics
	Reduction of WIP	Inventory management systems, electronic scheduling system
	Improved invoicing and billing	EDI, electronic funds transfer
	Improved after-sale service	Internet, Extranet, diagnostics
	Reduction of production costs	Equipment management system, CIM
Product development	Increase of market share	Market intelligence systems, technology forecasting systems
	Increase of new product introductions	Advanced manufacturing system
	Reduction of product introduction time	Groupware, video conferencing systems, high-bandwidth networks
	Reduction of product development costs	Simulations, virtual reality
	Improved communications	WANs, LANs, VANs, Intranet
	Responsiveness to market change	Source data automation

Table I.
Objectives of process redesign and related IT enablers

aggregate information on revenues and costs resulting from IT investment over an investment horizon.

There are two major components in financial evaluation: revenue and cost. While cost saving is relatively straightforward to estimate, estimation of increased revenue is very difficult. However, if we do not consider the potential revenue increase, the financial evaluation usually tends to discount the value of IT. IT related costs are relatively accurately estimated using market-prevailing IT rates and through requests for proposal to IT vendors. Cost savings derive mainly from operational efficiency such as reduced work force, reduced telecommunication costs, and reduced workspace. To estimate revenue, sales are modeled in terms of the number of customers, purchasing decisions, and responses to service and product quality. Well-known marketing research techniques such as conjoint analysis, surveys, and focus group interviews can be used to estimate the functional relationship between customers' purchasing decisions and operational/strategic performance. For example, the functional relationship between customers' repurchasing decision and their experienced order fulfillment cycle time can be used to measure the impact of order fulfillment performance on future revenue. E-commerce surveys have shown a significant relationship between operational performance such as Web page access time and accuracy of online order processes and customers' purchasing/repurchasing decisions.

Multiple regression analysis using the survey results of *PC WORLD* (1995) showed that lead-time significantly affects customer repurchasing decisions (adjusted R^2: 0.408). Several surveys identified lead-time as one of the most important factors in corporate strategy (Richardson *et al.*, 1985; Ryan, 1987). The functional relationships between customers' purchasing decisions and delivery cycle time can be reasonably determined by customer surveys, company history, managerial judgments, and expert opinions.

Numerous empirical studies indicate that reducing new product introduction time increases long-term market share and revenue (Clark, 1989; Robinson and Fornell, 1985; Urban *et al.*, 1986). A recent Hewlett-Packard study demonstrates that while an engineering cost overrun of 50 percent decreased the overall profitability by just 4 percent, a six-month delay in project completion resulted in a 32 percent loss in after-tax profit (Blackburn, 1991). Reasonable functional forms that capture the sales increase due to early production introductions help managers justify IT investment in new product development processes.

Revenues are determined from the estimated sales volume and price level. Similarly, sales volume determines the total product costs. All IT related costs are aggregated into cash flow formulas. All financial performances are expressed in terms of constant dollars. Financial performances such as net present value (NPV), payback period, and return on investment (ROI) are measured with an appropriate hurdle rate applied. Since technological changes in IT are occurring much faster than in other areas, the investment horizon is usually short, ranging from three to five years. Finally, the best combination of IT and business process is chosen based on the performance criteria.

Although marketing research techniques can be used to develop functional relationships between operational/strategic performance and revenue, other techniques suggested in the literature can also be used. For example, several decision calculus models were successfully used for managerial decision making (Larréché and Srinivasan, 1981; Little, 1970; Lodish, 1971). Taguchi and Clausing (1990) suggested that quality loss can be roughly quantified by a simple quadratic formula, the quality loss function (QLF).

IT performance evaluation methodologies used by researchers and practitioners include mathematical model (Gaymon, 1997), business process simulation (Krieger, 1995; Lee, 1996), queuing network model (Lee *et al.*, 2000), analytical hierarchical process (AHP) (AbouRizk *et al.*, 1994; Goh, 1997; Weber, 1993), and balanced scorecard (Kaplan and Norton, 1992). In this paper, we use business process simulation to estimate the operational performance of IT investment and present simple mathematical formulas that transform the operational performance into financial value.

4. A business process-integrated evaluation of order processing information systems

In this section, we illustrate the use of the evaluation methodology and business process simulation to estimate the value of re-engineered order processing information systems. We also present simple mathematical formulas that transform the benefit of cycle time reduction into increased revenue. To perform an order fulfillment process simulation, we chose to use a commercial software package, Extend, developed by Imagine That, Inc. The benefit of using a commercial simulation package is the speed of modeling and simulation at the expense of development flexibility.

One of the major reasons for order fulfillment process redesign is delivery cycle time reduction. In this illustration, operational performance is measured in terms of delivery cycle time. The following are the basic assumptions for the investment scenario:

- an evaluation horizon is five years;
- sales volume increase is dependent on the cycle time performance;
- initial sales are at 1,800 units;
- product cost is 80 percent of the unit price;
- one million dollars is invested in new IT;
- net present value method is used at a 10 percent hurdle rate;
- new information technology reduces the current processing time at each process by half;
- straight-line depreciation methods for five years are used with a zero salvage value;
- forecast of the base sales growth rate is available from various departments at the time of investment decision; and
- corporate tax rate of 35 percent is expected to apply over the five-year decision horizon.

Processing times for each process are shown in Table II.

While many firms use IT to redesign order fulfillment process, the additional revenue generated from improved delivery cycle time is rarely measured due to the difficulty of estimating revenue increase. We present the following linear sales response function in terms of delivery cycle time performance. The validity of the response function is examined with empirical data in the next section. In our survey of the online CD/book purchase, the delivery cycle time was assumed to be in the range of one to 12 days. However, the valid range of the delivery time performance for the linear sales response function should depend on the specific business/industry they are in. The sales response function indicates that customers' repurchasing decision linearly decreases as the customer experiences a longer cycle time.

$$Y_t = b(x_{t-1} - c) + g \quad (1)$$

where Y_t represents an annual estimated sales growth rate at time t, b the sales growth coefficient which represents a sensitivity of customers' responses to delivery cycle time, x_{t-1} the delivery cycle time performance at time $t-1$, c the base cycle time which represents the cycle time performance where customer's repurchasing decisions stay the same, and g the estimated base sales growth. In our illustration, we assume the following sales growth function.

$$Y_t = -0.01(x_{t-1} - 16) + 1.1 \quad (2)$$

Parameters of equation (2) indicate that the sales growth coefficient is set to -0.01, the base cycle time is 16 days, and the estimated base sales growth is 10 percent. The sales growth coefficient, -0.01 indicates that one-day delivery delay from the base cycle time of 16 days results in 1 percent sales decrease in the next period. Figure 3 shows the sales response function in a graphical form. Suppose that at period 1, the cycle time performance is 20 days. Then, the sales growth rate at time 2 is 1.06 (i.e. $1.06 = -0.01$ (20-16)+1.1).

	Existing process	New process
Review sales order	3	1.5
Create new customer file	12	6.0
Check customer credit	3	1.5
Check product availability	3	1.5
Create backorder	8	4.0
Process backorder	6	3.0
Create invoice	3	1.5

Table II. Estimated processing times at each process

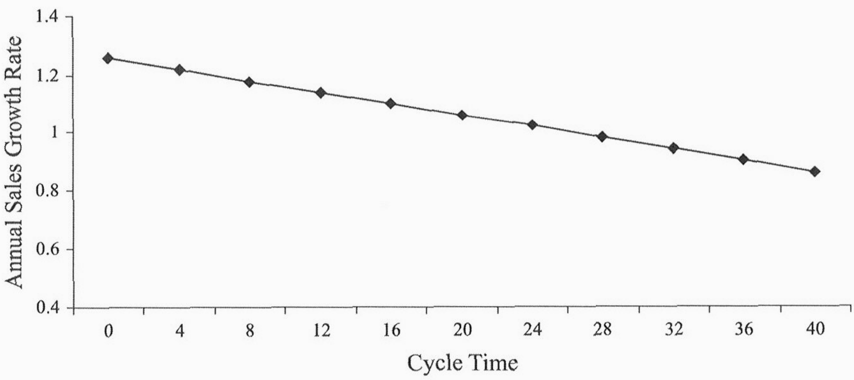

Figure 3. Sales response function

Table III summarizes the estimated sales volume and cycle time, and the sales growth rate over the five-year decision horizon. We made the following observations. First, even though both options start with the same estimated sale volume, the difference of sales volumes widens over time. This means the impact of IT investment gets greater over time due to the cumulative impact of positive customer response. Second, even though the average processing time of new business process are half of the existing process, the average cycle time is much less than half of that of the no investment option. Third, due to the poor delivery cycle time performance in no investment option, the sales growth rate declines more rapidly than the IT investment option. Finally, the difference in cycle time performance widens over time between IT investment and no investment.

Since the investment decision should be made based on financial performance, we investigated the NPVs of both options. Table IV summarizes the financial performance over five years. NPV of IT investment is approximately $0.9 M. Even though the yearly income of the no investment option is greater for the first two years, the income of the investment option exceeds that of the no investment option later. The cumulative NPV of the investment option also exceeds that of the no investment option after year 2 (Figure 4).

Sensitivity analyses can also be performed to understand the relationship between parameter values such as discount rate and coefficient of sales response, and performance. The sensitivity analysis of the discount rate shows that as the discount rate increases, the benefits of the investment option decrease more rapidly than that of the no investment option (Table V and Figure 5). This result suggests that a higher discount rate discourages the investment in IT when IT pays off later over the decision horizon.

Year	No investment	Investment	Difference
Sales volume			
Y1	1,800	1,800	–
Y2	1,910	2,114	203
Y3	2,016	2,478	462
Y4	2,113	2,901	788
Y5	2,199	3,387	1,189
Average	2,007	2,536	529
Average cycle time			
Y1	19.88	8.58	−11.30
Y2	20.47	8.75	−11.72
Y3	21.19	8.93	−12.26
Y4	21.93	9.24	−12.69
Y5	22.71	9.71	−13.00
Average	21.24	9.04	−12.19
Sales growth rate			
Y1	1.0612	1.1742	0.1130
Y2	1.0553	1.1725	0.1172
Y3	1.0481	1.1707	0.1226
Y4	1.0407	1.1676	0.1269
Y5	1.0329	1.1629	0.1300
Average	1.0476	1.1696	0.1219

Table III. Estimated sales volume, cycle time, and sales growth rate over the five-year horizon

	Y1	Y2	Y3	Y4	Y5
IT investment					
Sales volume	1,800	2,114	2,478	2,901	3,387
Revenue ($)	10,800,000	12,681,360	14,868,895	17,407,015	20,324,431
Cost ($)	8,640,000	10,145,088	11,895,116	13,925,612	16,259,544
Depreciation expense ($)	200,000	200,000	200,000	200,000	200,000
Income before tax ($)	1,960,000	2,336,272	2,773,779	3,281,403	3,864,886
Corporate tax ($)	686,000	817,695	970,823	1,148,491	1,352,710
Income after tax ($)	1,274,000	1,518,577	1,802,956	2,132,912	2,512,176
NPV (each year) ($)	1,158,181.82	1,255,022.15	1,354,587.75	1,456,807.55	1,559,863.63
NPV (Total)	6,784,462.90				
No investment					
Sales volume	1,800	1,910	2,016	2,113	2,199
Revenue ($)	10,800,000	11,460,960	12,094,751	12,676,509	13,192,443
Cost ($)	8,640,000	9,168,768	9,675,801	10,141,207	10,553,954
Depreciation expense ($)	0	0	0	0	0
Income before tax ($)	2,160,000	2,292,192	2,418,950	2,535,302	2,638,489
Corporate tax ($)	756,000	802,267	846,633	887,356	923,471
Income after tax ($)	1,404,000	1,489,925	1,572,318	1,647,946	1,715,018
NPV (Each Year) ($)	1,276,363.64	1,231,342.81	1,181,305.52	1,125,569.37	1,064,890.95
NPV (Total) ($)	5,879,472.29				

Table IV. Summary of the financial performance over the five-year horizon

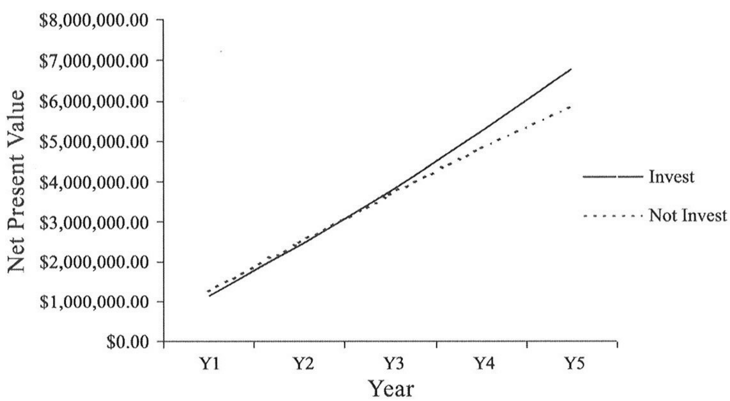

Figure 4. Cumulative net present value over the five-year horizon

In the previous illustration, we used a single performance variable (i.e. cycle time) to transform operational performance into financial performance. In reality, we may identify more than one operational performance variable that affects the values of business process redesign and IT. For example, in addition to cycle time reduction, other factors such as billing errors and service availability may affect customer repurchasing decisions. To accommodate more than one performance variable, we propose the following sales growth function.

$$Y_t = \sum_{i=1}^{n} w_i b_i (x_{i,t-1} - c_i) + g_i \quad (3)$$

where Y_t represents the estimated annual sales growth rate at time t, w_i the weight coefficient for performance variable

$$i\left(\sum_{i=1}^{n} w_i = 1\right),$$

b_i the estimated sales growth coefficient for performance variable i, $x_{i,\ t-1}$ the cycle time performance at time $t-1$, c_i the base performance for variable i, and g the estimated base sales growth. In addition to financial performance, operational and strategic performances observed from the simulation experiments may need to be included into the final IT investment decisions. In this case, a balanced scorecard model (Kaplan and Norton, 1992) and scoring models (Buss, 1983) may appropriately supplement our proposed methodology.

5. Empirical evidence of the cycle time impact on customers' repurchase decision

We have demonstrated that cycle time performance can be financially quantifiable by transforming the customer's response to the cycle time performance into the sales growth rate. An important question is whether the proposed mathematical formula (equation (1)) is empirically valid. To find empirical evidence, we surveyed 99 undergraduate and graduate students on the hypothetical cycle time performances of mail order CD retailers and their repurchasing decisions. We asked respondents how they will change their future repurchase frequency/amount from the same company if they experience a delivery time in the range of 1-12 days. Table VI summarizes the statistical results of the survey responses. We used a regression model to test our formula, a sales growth function.

Table V.
Sensitivity analysis of discount rate

Discount rate	2 percent	6 percent	10 percent	14 percent	18 percent
Invest ($)	8,653,430.33	7,633,921.67	6,784,462.90	6,070,584.12	5,465,841.62
Not invest ($)	7,365,961.52	6,557,592.82	5,879,472.29	5,305,740.08	4,816,474.60
Difference ($)	1,287,468.81	1,076,328.85	904,990.62	764,844.04	649,367.02

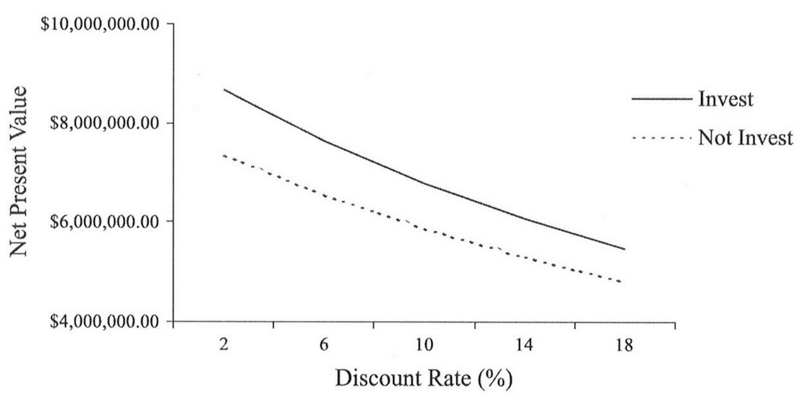

Figure 5.
Sensitivity of discount rate

Summary output

Regression statistics	
Multiple R	0.71273
R^2	0.50798
Adjusted R^2	0.50674
Standard error	0.35084
Observations	396.00000

ANOVA

	df	SS	MS	F	Significance F
Regression	1	50.06972	50.06972	406.78774	0.00000
Residual	394	48.49573	0.12309		
Total	395	98.56545			

	Coefficients	Standard error	t-stat	p-value	Lower 95 percent	Upper 95 percent
Intercept	1.29222	0.02986	43.27071	0.00000	1.23350	1.35093
X variable 1	−0.08455	0.00419	−20.16898	0.00000	−0.09279	−0.07631

Table VI. Summary statistics of response time survey

Our statistical results validate a significant linear relationship between cycle time and a customer's repurchasing decision. There was a significant correlation between cycle time and repurchasing decision (correlation of −0.7123). A regression model shows that an adjusted R^2 is 0.50674 with the repurchasing coefficient of −0.08455 and the intercept of 1.29222. Based on the regression model, we develop a sales growth function as $Y_t = -0.0845(x_{t-1} - 3.45618) + 1$. The sales growth function indicates that to maintain the current sales level, the average cycle time of the order processing should be kept within 3.45618 days. The sales growth coefficient, −0.0845, indicates that one-day delivery delay from the 3.45618 base cycle time results in 8.45 percent sales decrease in the next period. If we assume the natural sales increase of 10 percent, the modified function is derived as $Y_t = -0.0845(x_{t-1} - 3.45618) + 1.1$.

6. Discussion and conclusions

While a larger body of researchers focus on IT's strategic value or industry-level productivity, practitioners demand rigorous IT evaluation methodologies to financially justify IT investment. Conventional wisdom holds that IT has enormous potential. However, despite the potential benefits derived from investment in IT, traditional capital budgeting models have failed to estimate true IT values due to their inability to estimate complex interactions between IT and organizational performance. Many successful IT investment cases indicate that organizational and managerial issues should be addressed when IT investments are made.

Since IT may fundamentally change the ways in which the business organization interacts with internal and external constituents, business strategy and business processes should be considered in the evaluation process. The proposed IT evaluation methodology provides managers with a comprehensive, flexible, and easy-to-use measurement tool that integrates strategies, business process redesign, and IT design. It consists of four phases that guide managers through the process of building an IT evaluation matrix:

(1) Strategic analysis.
(2) Business process redesign.
(3) IT configuration.
(4) Performance evaluation.

To explicitly measure IT's strategic benefits, this evaluation methodology improves on the existing methodologies in two ways. The first is to overcome the limitations of traditional capital budgeting models by integrating strategic and business process decisions into the evaluation methodology. The second is to integrate IT and business processes so that their underlying interactions can be effectively investigated. In addition to the proposed methodology, we showed how a simulation model and sales growth functions can be augmented in evaluating the IT investment options.

Based on the assumption of linear customer response to delivery cycle time performance, we observed that the benefits of IT investment used to reduce cycle time are greater over time. Owing to the typical late realization of the IT payoffs, the discount rate should be chosen carefully since the high discount rate severely penalizes future cash inflow. In order to validate the proposed sales growth function, we surveyed 99 college students about the impact of delivery cycle time on their future repurchase decisions in hypothetical mail order CD/book purchases. Their survey results strongly suggest that there is a negative correlation between order cycle time and customers' repurchases. The regression model validates the presented linear sales growth function. We also proposed a general sales growth function that accommodates multiple performance variables.

While we applied the IT evaluation methodology, simulation, and mathematical formulas to the order process integrated IT investment, the proposed approach can be applied to a variety of business processes and metrics of information systems performance. For example, investment in product development IT can be reasonably evaluated with the use of simulation and mathematical formulas for sales loss due to early/late product introduction into market. Where operational and strategic performances observed from the simulation experiments may need to be included into final IT investment decisions, a balanced scorecard model (Kaplan and Norton, 1992) and scoring models (Buss, 1983) may appropriately supplement our proposed methodology. The proposed IT evaluation methodology will allow practitioners to answer managers' ultimate question: are business process redesign and related IT investment justifiable in terms of organizational performance?

References

AbouRizk, S.M., Mandalapu, S.R. and Skibniewski, M. (1994), "Analysis and evaluation of alternative technologies", *Journal of Management in Engineering*, May/June, pp. 65-71.

Bacon, C.J. (1992), "The use of decision criteria in selecting information systems/technology investments", *MIS Quarterly*, September, pp. 335-53.

Bartholomew, D. (1996), "Ford retools", *Information Week*, 1 April, pp. 14-16.

Barua, A., Kriebel, C.H. and Mukhopadhyay, T. (1995), "Information technologies and business value: an analytic and empirical investigation", *Information Systems Research*, Vol. 6 No. 1, pp. 3-23.

Bender, D.H. (1986), "Financial impact of information processing", *Journal of Management Information Systems*, Vol. 3 No. 2, pp. 232-8.

Blackburn, J.D. (Ed.) (1991), *Time-Based Competition*, Business One/Irwin, Homewood, IL, p. 201.

Brynjolfsson, E. (1993), "The productivity paradox of information technology", *Communications of the ACM*, Vol. 36 No. 12, pp. 67-77.

Brynjolfsson, E. and Hitt, L. (1996), "Paradox lost? Firm-level evidence on the returns to information systems spending", *Management Science*, Vol. 42 No. 4, pp. 541-58.

Brynjolfsson, E. and Hitt, L. (1998), "Beyond the productivity paradox", *Communications of ACM*, Vol. 41 No. 8, pp. 49-55.

Brynjolfsson, E., Malone, T.W., Gurbaxani, V. and Kambil, A. (1994), "Does information technology lead to smaller firms?", *Management Science*, Vol. 40 No. 20, pp. 1628-44.

Buss, M.D.J. (1983), "How to rank computer projects", *Harvard Business Review*, January, pp. 118-25.

Cash, J. Jr, McFarlan, F.W., McKenney, J.L. and Vitale, M.R. (1988), *Corporate Information Systems Management: Text and Cases*, 2nd ed., R. D. Irwin, Homewood, IL.

Clark, K.B. (1989), "Project scope and project performance: the effect of parts strategy and supplier involvement on product development", *Management Science*, Vol. 35, pp. 1247-63.

Clemons, E.K. (1991), "Evaluation of strategic investments in information technology", *Communications of the ACM*, Vol. 34 No. 1, pp. 22-36.

Davenport, T.H. (1993), *Process Innovation: Re-engineering Work through Information Technology*, Ernst & Young, Center for Information Technology and Strategy, Boston, MA.

Davenport, T.H. and Short, J.E. (1990), "The new industrial engineering: information technology and business process redesign", *Sloan Management Review*, Vol. 31 No. 4, pp. 11-27.

Davern, M.J. and Kauffman, R.J. (2000), "Discovering potential and realizing value from information technology investments", *Journal of Management Information Systems*, Spring, pp. 121-43.

Devaraj, S. and Kohli, R. (2000), "Information technology pay-off in the health-care industry: a longitudinal study", *Journal of Management Information Systems*, Spring, pp. 41-67.

Dixit, A.K. and Pindyck, R.S. (1995), "The options approach to capital investment", *Harvard Business Review*, May-June, pp. 105-15.

Dos Santos, B.L. (1991), "Justifying investments in new information technologies", *Journal of Management Information Systems*, Vol. 7 No. 4, pp. 71-90.

Floyd, S.W. and Wooldridge, B. (1990), "Path analysis of the relationship between competitive strategy, information technology, and financial performance", *Journal of Management Information Systems*, Vol. 7 No. 1, pp. 47-64.

Fortune (1993), "How to bolster the bottom line", Special Issue, Summer, pp. 15-28.

Gaymon, C. (1997), "Planning information technology-knowledge worker systems", *Management Science*, Vol. 43 No. 9, pp. 1308-28.

Goh, C.-H. (1997), "Analytic hierarchy process for robot selection", *Journal of Manufacturing Systems*, Vol. 16 No. 5, pp. 381-96.

Grover, V., Jeong, S.R., Kettinger, W.J. and Teng, J. (1995), "The implementation of business process engineering", *Journal of Management Information Systems*, Vol. 12, Summer, pp. 109-44.

Hammer, M. (1990), "Re-engineering work: don't automate, obliterate", *Harvard Business Review*, July-August, pp. 104-22.

Hammer, M. (2000), "Re-engineering redux", *CIO*, Vol. 13 No. 10, 1 May, pp. 143-56.

Harris, S.E. and Katz, J.L. (1991), "Organizational performance and information technology investment intensity in the insurance industry", *Organization Sciences*, Vol. 2 No. 3, pp. 263-95.

Irani, Z., Hlupic, V. and Giaglis, G. (2000), "Business process re-engineering", *International Journal of Flexible Manufacturing Systems*, Vol. 12 No. 4, pp. 247-52.

Johnasen, J., Karmarkar, U.S., Nanda, D. and Seidmann, A. (1995), "Business experience with computer-integrated manufacturing", *Proceedings of the 28th Annual Hawaii International Conference on System Sciences*, pp. 970-9.

Kaplan, R. (1986), "Must CIM be justified on faith alone?", *Harvard Business Review*, March-April, pp. 87-95.

Kaplan, R. and Norton, D. (1992), "The balanced scorecard-measures that drive performance?", *Harvard Business Review*, January-February, pp. 71-9.

Kauffman, R.J. and Weill, P. (1989), "An evaluation framework for research on the performance effects of information technology", *Proceedings of the Tenth International Conference on Information Systems*, December, Boston, MA.

Krieger, J.H. (1995), "Process simulation seen as pivotal in corporate information flow", *Chemical and Engineering News*, Vol. 73, 27 March, pp. 50-61.

Kustermann, K. (1998), "Re-engineering the purchasing function: identifying best practices for the city of Chicago", *Government Finance Review*, Vol. 14 No. 5, pp. 29-32.

Larréché, J.C. and Srinivasan, V. (1981), "STRATPORT: a decision support system for strategic planning", *Journal of Marketing*, Vol. 45, Fall, pp. 39-52.

Lee, Y. (1996), "Simulation modeling for process re-engineering in the telecommunications industry", *Interfaces*, Vol. 26, May-June, pp. 1-9.

Little, J.D.C. (1970), "Models and managers: the concept of a decision calculus", *Management Science*, Vol. 16 No. 8, pp. B466-85.

Lodish, L.M. (1971), "Callplan: an interactive salesman's call planning system", *Management Science*, Vol. 18 No. 4, Part II, pp. 25-40.

Loveman, G.W. (1994), "An assessment of the productivity impact on information technologies", in Allen, T.J. and Scott, M.S. (Eds), *Information Technology and the Corporation of the 1990s: Research Studies*, MIT Press, Cambridge, MA.

Mahmood, M.A. and Mann, G.J. (1991), "Measuring the impact of information technology on organizational performance: a key ratios approach", *Proceedings of the 24th Hawaii International Conference on Systems Sciences*, pp. 251-8.

Markus, M.L. and Benjamin, R.I. (1997), "The magic bullet theory in IT-enabled transformation", *Sloan Management Review*, Winter, pp. 55-68.

Morrison, C.J. and Berndt, E.R. (1990), "Assessing the productivity of information technology equipment in the US manufacturing industries", Working Paper No. 3582, National Bureau of Economic Research, January.

PC WORLD (1995), "Reliability and service: boom and bust", June, pp. 225-37.

Porter, M. (1980), *Competitive Strategy*, Free Press, New York, NY.

Porter, M. (1985), *Competitive Advantage*, Free Press, New York, NY.

Ragowsky, A. and Stern, M. (1997), "The benefits of IS for CIM applications: a survey", *International Journal of CIM*, Vol. 10 No. 1-4, pp. 245-55.

Richardson, P.R., Taylor, A.J. and Gordon, J.R.M. (1985), "A strategic approach to evaluating manufacturing performance", *Interfaces*, Vol. 15 No. 6, pp. 15-27.

Roach, S.S. (1987), "America's technology dilemma: a profile of the information economy", *Special Economic Study*, Morgan Stanley & Co., Los Altos, CA.

Robinson, W.T. and Fornell, C. (1985), "The sources of market pioneer advantages in consumer goods industries", *Journal of Marketing Research*, Vol. 22, pp. 297-304.

Ryan, J. (1987), "Quality and competitive advantage", *Quality Progress*, Vol. 20, pp. 13-17.

Sethi, V., Hwang, K.T. and Pegels, C. (1993), "Information technology and organizational performance", *Information and Management*, Vol. 25, pp. 193-205.

Taguchi, G. and Clausing, D. (1990), "Robust quality", *Harvard Business Review*, January-February, pp. 65-75.

Urban, G.L., Carter, T., Gaskin, S. and Mucha, Z. (1986), "Market share rewards to pioneering brands: an empirical analysis and strategic implications", *Management Science*, Vol. 32, pp. 645-59.

Venkatraman, N. (1994), "IT-enabled business transformation: from automation to business scope redefinition", *Sloan Management Review*, Winter, pp. 73-87.

Weber, S.F. (1993), "A modified analytic hierarchy process for automated manufacturing decisions (using AutoMan, Decision Support Software)", *Interfaces*, Vol. 23, July/August, pp. 75-84.

Wilder, C. and Hildebrand, C. (1992), "Faster! Better! Cheaper! Now!", *Computerworld*, 2 January, pp. 2-6.

Further reading

Bass, F.M. (1969), "A new product growth model for consumer durables", *Management Science*, Vol. 15 No. 5, pp. 215-27.

Conley, P. (1976), "Experience curves as a planning tool", in Rotherberg, R. (Ed.), *Experience Curves as a Planning Tool: A Special Commentary*, Boston Consulting Group (1970), reprinted in *Corporate Strategy and Product Innovation*, The Free Press, New York, NY.

Eldin, N.N. (1997), "A concurrent engineering: a schedule reduction tool", *Journal of Construction Engineering and Management*, Vol. 123, September, ASCE, pp. 354-62.

Green, P.E., Krieger, A.M. and Vavra, T.G. (1997), "Evaluating new products: conjoint analysis offers a level of detail that few concept testing methods can match", *Marketing Research*, Vol. 9, Winter, pp. 12-21.

Herman, S. and Klein, R. (1995), "Improving the predictive power of conjoint analysis", *Marketing Research*, Vol. 7, Fall/Winter, pp. 29-31.

Kahaner, L. (1980), *Competitive Intelligence*, Simon & Schuster, New York, NY.

McFarlan, F.W. (1981), "Portfolio approach to information systems", *Harvard Business Review*, September-October, pp. 142-50.

Ogando, J. (1997), "Concurrent design, prototyping and tooling speed hockey helmet to market", *Plastics Technology*, Vol. 43, p. 35.

Quester, P.G. and Smart, J. (1998), "The influence of consumption situation and product involvement over consumers' use of product attribute", *Journal of Consumer Marketing*, Vol. 15 No. 3, pp. 220-38.

Rockart, J.F. and Short, J.E. (1988), "Information technology and the new organization: towards more effective management of interdependence", Working Paper CISR 180, Center for Information Systems Research, MIT Sloan School of Management, Boston, MA.

Rolstadas, A. (1995), "Planning and control of concurrent engineering projects", *International Journal of Production Economics*, Vol. 38 No. 1, pp. 3-13.

Shank, J.K. and Govindarajan, V. (1992), "Strategic cost analysis of technological investments", *Sloan Management Review*, Fall, pp. 39-51.