Implementing enterprise resource planning (ERP) systems in small and midsize manufacturing firms

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Abstract *Enterprise resource planning systems, if implemented successfully, can bestow impressive strategic, operational and information-related benefits to adopting firms. A failed implementation can often spell financial doom. Currently, most of the information about the failures and successes are based on reports on implementations in large manufacturing and service organizations. But enterprise resource planning vendors are now steadily turning their marketing sights on small and medium-sized manufacturers. The time is ripe for researchers to gather, analyze and disseminate information that will help these firms to implement their projects successfully. This research adopts a multiple case study approach to investigate the implementation process in small and midsize manufacturing firms in the US. The research focuses on implementation activities that foster successful installations and are developed using information gleaned from our field studies of four projects. Avenues for future research are also suggested.*

Introduction

Enterprise resource planning (ERP) systems are designed to address the problem of fragmentation of information or "islands of information" in business organizations. ERP systems promise to computerize an entire business with a suite of software modules covering activities in all areas of the business. Furthermore, ERP is now being promoted as a desirable and critical link for enhancing integration between all functional areas within the manufacturing enterprise, and between the enterprise and its upstream and downstream trading partners.

To date, most of the reported studies on these systems have focused on large ERP installations with individual investment costs of well over $100 million. Hence, most of the information that is available pertaining to the

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implementation of ERP systems and their successes and failures are concerned with larger installations. Over the past few years, however, ERP systems' developers, systems integrators and consultants have consistently been turning their sights on smaller enterprises (Fleishaker, 1999; Parker, 1999). These smaller manufacturers can be adversely affected if they fail to upgrade their information technology (IT) with systems that can readily communicate with their larger supply chain partners or with corporate headquarters (Chalmers, 1999).

While ERP installations often help small and midsize manufacturers to improve their strategic and competitive capabilities (Smith, 1999; Jenson and Johnson, 1999), there are several reasons why some firms are not rushing to install the systems. First, the ERP implementation efforts of many of their larger counterparts have resulted in partial failure, and in some cases total abandonment. Trunick (1999) reports that 40 percent of all ERP installations only achieve partial implementation and that nearly 20 percent are scrapped as total failures. Others suggest that the failure rate may be even higher (Escalle, 1999). Second, small manufacturers often lack financial resources and may be forced to adopt, at best, a piecemeal approach to integrating the typically expensive ERP systems into their facilities (Ferman, 1999). It is also felt that the low IS staff levels in smaller enterprises is inadequate for the rigorous and extensive IT training and development requirements of an ERP project (Hill, 1997).

Smaller firms, with their limited resources, are less likely than their larger counterparts to survive or quickly overcome a failed implementation of an expensive ERP system. Therefore, it is extremely important to gather, analyze and disseminate information that will help them to choose appropriate ERP systems and then implement these projects successfully. This research uses a multiple case study approach to investigate the ERP implementation process in four small and midsize firms in the US. Our objective is to attempt to build rather than test theory. Therefore, the case-study method is used to develop conclusions about activities that lead to successful ERP implementations that others may later test by means such as surveys, experiments or simulation. In addition, avenues for future research are suggested.

This research contributes to the ERP literature in the following ways:

- It outlines the desirable steps in the ERP implementation process.
- It addresses ERP implementation in midsize manufacturing facilities. The very limited empirical research on ERP implementation that has been done has concentrated on larger facilities.
- The findings of this study can help corporate management to better support the deployment of ERP in their divisional facilities.
- Avenues for continuing theoretical and empirical investigations in the field are presented.

An overview of ERP systems

ERP represents the latest stage in the evolution and expansion of production planning and control techniques for manufacturing enterprises from material requirements planning (MRP) (Orlicky, 1975) to capacity requirements planning (CRP) to manufacturing resource planning (MRP II) (Wight, 1982; 1984). MRP II systems began evolving into ERP systems as early as 1988 when Dow Chemical Company purchased its first ERP manufacturing module from SAP AG of Germany (Schaaf, 1999). The term "enterprise resource planning" which describes systems that are designed to plan and schedule all the firm's internal resources was first used by the Gartner Group of Stamford, Connecticut, USA. However, during the period 1988 to 1994 the terms MRPII and ERP were being used interchangeably.

The distinctiveness of ERP systems became more evident in 1994 when SAP AG released its next-generation software known as R/3. The release of R/3 also marked a shift in technology platforms from the mainframe to the increasingly popular UNIX-based client-server architecture. In the ensuing years, manufacturing and some service companies began to make heavy investments in ERP systems offered by SAP and its major competitors such as Oracle, Baan, PeopleSoft and J.D. Edwards. Since activities related to planning and installing ERP are, generally, more costly than the software product itself, consultants and systems integrators have also moved aggressively into the implementation market. The ERP-related revenues for each of the five leaders in the consulting and systems integration markets exceeded $1 billion in 1998 (Escalle *et al.*, 1999). Advanced manufacturing research (AMR), one of the principal ERP industry observers, is forecasting that the ERP market for software sales and ancillary services will exceed annual revenues of $50 billion by 2002.

ERP systems are comprised of a suite of software modules, with each module typically responsible for gathering and processing information for a separate business function, or a group of separate business functions. ERP software modules may include accounting, master scheduling, material planning, inventory, forecasting, finite scheduling, distribution planning and others. A typical ERP system integrates all of the company's functions by allowing the modules to share and transfer information freely (Hicks and Stecke, 1995). In addition, all information is centralized in a single relational database accessible by all modules, eliminating the need for multiple entries of the same data. While large firms usually budget heavily for ERP and may install a substantial number of the available modules (Chalmers, 1999), smaller firms often adopt a piecemeal approach, starting with a few modules or a few components of each module (Ferman, 1999). Customers and suppliers with network security clearance are allowed to access certain types of information by way of an external communication interface.

ERP benefits and limitations

Many industry reports extol the virtues of ERP and its ability to bestow multiple benefits on those firms that can successfully implement these systems. One of the primary objectives for installing ERP as well as one of its principal benefits is the ability to integrate business processes (Brakely, 1999; Davenport, 1998, 2000). The use of ERP has also been found to be critical in improving customer satisfaction. For example, NEC Technologies credits its installation of ERP for increasing its speed of order processing, improving invoicing and in drastically reducing its customer-service response times (Michel, 1997). ERP has also been found to be effective in reducing inventory costs, improving efficiency and increasing profitability (Appleton, 1997; Brakely, 1999). In addition, ERP has also been credited with reducing manufacturing lead times (Goodpasture, 1995). Other potential benefits of ERP include: drastic declines in inventory; breakthrough reductions in working capital; abundant information about customer wants and needs; and the ability to view and manage the extended enterprise of suppliers, alliances, and customers as an integrated whole.

It should be noted, however, that not all enterprises that have implemented ERP are satisfied with the results of their investments. Many businesses consider their implementation attempts to be failures. For example, FoxMeyer Drug, a $5 billion pharmaceutical company, recently filed for bankruptcy. FoxMeyer argued that major problems were generated by a failed ERP system, which created excess shipments resulting from incorrect orders (Bicknell, 1998; Boudette, 1999). In addition, Dell Computer scrapped their ERP system claiming that it was not flexible enough to handle their expanding global operations.

In seeking to explain why some firms succeed in their implementation while others fail, it is critical to understand that, although the technical capabilities of ERP systems are relatively well proven, implementing these systems is not a simple matter of purchasing and installing the technology. Many believe that, as with all advanced technology systems, managerial issues, from planning to implementation, present major barriers to the effective adoption of ERP systems. The need for and importance of empirical studies on technology planning and implementation issues has been emphasized in the literature (Chen and Small, 1996; Voss, 1988).

Case studies in the implementation of ERP systems

The case study research methodology has been highly recommended by many researchers as an ideal tool for improving conceptual and descriptive understanding of complex phenomena (Flynn *et al.*, 1990; McCutcheon and Meredith, 1993; Yin, 1994). ERP implementation is an expensive and extensive undertaking involving activities related to planning, justifying, installing and commissioning of the installed system. An ERP system extends across the entire organization and sometimes even beyond to cover integral partners in the supply

chain. Furthermore, ERP projects can take two or more years to fully implement (Bradley *et al.*, 1999; Parker, 1999). All the above factors contribute to the complexity of ERP installations, and make snap-shot cross-sectional approaches unsuitable for investigating the ERP implementation process.

The case study method also offers many benefits such as the ability to directly observe causality and combine evidence and logic to build, develop or support theory that is not available using other research methods (Maffei and Meredith, 1995). In contrast to survey research formats, it allows for more meaningful follow-up questions to be asked and answered and can result in more extensive findings and insights that are valid, generalizable and rigorous (Meredith, 1998). This study adopts a longitudinal case study methodology to delineate the steps in the process and to investigate the myriad and complex relationships within and between these steps. However, unlike the majority of studies in this area that focus on single case studies, this study reports on ERP implementations at four diverse manufacturing facilities.

Multiple methods were used to collect data for this study. These methods included direct observation by two of the authors who were academic observers for the projects from the project initiation stage. The authors were given free access to historical documents and other records including financial data, and non-personnel related operations statistics. The authors were also allowed to sit in on regularly scheduled project-team meetings. Ongoing, open-ended interviews were also held with corporate officers, divisional managers, project-leaders, super-users, consultants and various project team members both during and after the implementation of the ERP projects. These interviews permitted the project participants to identify and frame the important issues and factors that affect ERP implementation success as suggested in Maffei and Meredith (1995). This approach is consistent with the recommendation that, in an area where theory is relatively undeveloped, researchers should use an inductive approach to the process of identifying issues for inclusion in the study (Spector, 1992; Flynn *et al.*, 1994; Hensley, 1999).

Company business profiles

The four companies covered by this study were divisions of larger companies. They represent a range of firm sizes ($55 million to $200 million in annual revenues), products, types of manufacturing (continuous process, batch and job shop) markets and organizational arrangements. The companies also had different prior experiences with manufacturing and IT. The business profiles of the four companies are detailed in Table I.

The ERP implementation process

This section will outline the results of our investigations. The findings will be presented in three subsections under the general headings of planning activities, justification and selection activities, and installation activities.

Table I. Company profiles

	Company A	Company B	Company C	Company D
Type of business	Chemical manufacturer – division of Fortune 500 company	Inorganic coating manufacturer – division of Fortune 500 company	Electronics assembly manufacturer – division of Fortune 500 company	Centrifugal and static foundry – division of $300 million industrial manufacturing company
Annual sales	$90 million	$75 million	$200 million	$55 million
Primary markets	Industrial buyers only	Industrial buyers only	Original equipment manufacturers (OEM's), retailers and end customers	Industrial buyers only
Type of manufacturing	Continuous process	Batch/repetitive	Batch/repetitive	Job-shop
Performance prior to the decision to implement ERP inventory levels	High finished goods inventory	High finished goods inventory (3.5 months) High WIP inventory High raw material inventory	High finished goods inventory and high WIP inventory compared to their industry	High raw material inventory
Inventory turnover rates	Low compared to industry	Low compared to other divisions in company and industry	Slightly below industry	Low compared to industry
On-time (in full) delivery performance versus [industry on-time performance]	60 percent [85 percent]	78 percent [70 percent]	62 percent [85 percent]	76 percent [60 percent]
Production planning systems used prior to ERP	MRP	MRPII	MRP, SFC	None
Impetus for process change	Declining profits (40 percent over a three year period)	Declining profits over a ten-year period. Profits below corporation targets	Just breaking even in a growing market	Losing money, struggling with shop loads and coordination of orders through multiple work centers
Corporate stance	Improvement or wholesale management changes	Improvement or closure of the division with transfer of work to another country	Improvements or will consider outsourcing	Improvements or closure

Propositions related to each of the activities within each of the subsections will be presented at the end of the discussion of each activity.

Planning activities

Strategic objectives and top management involvement

The corporate management of each of these companies had recent encouraging experiences with enterprise system (ES) installations at their headquarters or in other divisions. Hence, they were favorably disposed to ES solutions and viewed integrated ES as a means of improving efficiencies and communications across all their divisions and between the divisions and corporate headquarters. Given the fact that the main impetus for change came from corporate headquarters it was not surprising that all projects had widespread executive management support. However, achieving divisional management support would prove to be more difficult.

The divisional managers at company A were initially supportive of the IT changes. However, feedback from steering committee meetings suggested that much of this support might have been aimed at appeasing corporate management rather than a strong belief in the strategic value of integrated ES. Except for a few managers who had some training and some positive experiences with integrated operating systems, the divisional managers of company's B, C and D were not, generally, supportive of the proposed ERP projects. Many managers preferred to view them as another unnecessary imposition from corporate headquarters.

Companies A, B and C each had an executive sponsor who was a corporate officer at the vice-presidential level. In company D the executive sponsor was the plant manager. Unlike typical ERP projects in larger facilities, however, these sponsors were not supported by a formal top-level executive steering committee, even though there was no doubt that top corporate management supported the projects. The influence and support of the executive sponsor proved to be especially important for companies A and B, which experienced significant changes in divisional management personnel during the process of the implementation. The constant availability of the executive sponsor kept the project manager and project teams at these companies encouraged and focused.

The results were not as good in companies C and D. The executive sponsor for company C resigned from the corporation during implementation of the project and his replacement did not have the same fervor for the project. In company D, the reassignment of the plant manager (executive sponsor) and the resignation of the project leader and a key super-user effectively killed the project. The new plant manager, who was focused on cost cutting to prevent further company losses, did not view the completion of this project as a priority item.

But achieving success in the divisional setting also requires the support and cooperation of workers, especially those workers that will be involved in the implementation of the ERP. In those projects where divisional management showed enthusiasm for the project, workers tended to be more supportive. In

company A, where the senior division manager who served as project manager for the ERP project moved his desk onto the manufacturing floor as a demonstration of his commitment, worker support was generally high. When divisional management showed a lack of enthusiasm for the projects, workers tended to be less supportive.

In summary, while corporate management encouraged and provided visible support for the development of the ES project as a strategic, operational and information/communications tool, divisional management did not wholeheartedly share their enthusiasm. Although each company started with an executive sponsor, a framework was never put in place to provide top-level corporate support for this sponsor through the aegis of formal executive steering committees. Therefore, it was not surprising that no replacements stepped in when the sponsors for companies C and D left. It is also interesting to note that those firms that maintained the same sponsor throughout the implementation process achieved their initial objectives for installing the systems.

The executives that had the most success had a more proactive rather than reactive approach to their ERP implementations strategy. They were willing to reconcile the trade-offs inherent to the demands of an ERP initiative and focus on the important contributions the system would provide in the next three years. Also, they were able to overcome "short term" corporate expectations by saying no when the expectations on evaluation, risked the ERP projects goals.

The results also show that managing the strategic integration between manufacturing and marketing provided the successful firms congruence of purpose and function for the new ERP systems processes. Understanding corporate objectives, order qualifiers and winners, process choices and support infrastructure provided the ERP implementation team valuable knowledge for developing business cases, performance measurements (current and future), long term strategic and tactical goals and package selection techniques. One telling sign that strategic understanding is valuable was that successful firms had an easier time selecting their software package since they understood what they needed for the future. The unsuccessful companies tended to focus more on current tactical practices such as inventory entry, billing, purchase order entry, etc. and not at strategic alignment issues.

Reengineering efforts

Prior to determining the type of ES changes that were needed, companies A and C conducted reengineering efforts designed to lay the groundwork for streamlining their business operations to more closely match their customers' current and expected future requirements for quality, timeliness, innovation and customization. As suggested by Hammer and Champy (1993) the reengineering activities were focused on identifying and improving the

efficiency of critical operations, on restructuring important non-value-adding operations and on eliminating inefficient processes. Significant emphasis was also placed on mapping information flows related to operation processes and procedures. Detailed mapping and analyses of external transactions with customers and suppliers were also carried out, paying particular attention to their impact on internal functional and inter-functional transactions. Special emphasis was also placed on mapping information requirements and information flows between functional managers and managers on the shop floor. A direct consequence of the reengineering efforts of both of these companies was significant streamlining of work and information flows, departmental redesigns, reductions in paperwork transactions and combination of tasks that had previously been performed by different people.

Company B also evaluated their core business processes prior to choosing an ERP solution, but they focused on improving current processes rather than a comprehensive reengineering effort. Consequently, their "real" reengineering effort was delayed until management recognized that the system that they had initially chosen was inadequate for meeting their future operational and customer support needs. Company D did not reengineer their processes or attempt to redefine any business practices. They naively thought, as Ross (1999) suggests often happens, that the software would solve their problems by imposing discipline and process integration on their organization.

Divisional management at companies A and C considered their reengineering efforts to have been very worthwhile. They felt that the resultant redesign of departments, changes in job descriptions and adjustments in management tasks accurately reflected the required customer-focus. However, these improvements were accompanied by elimination of jobs, creation of new jobs and even a shake-up in the management ranks. But companies A and C avoided the long confrontation that company B had to endure because they reengineered during the project. Even during their reengineering effort, divisional management at company B spent a considerable amount of time discussing the validity of old processes and old mind-sets, rather than focusing on reengineering. The consulting team encouraged corporate management to get the reengineering process back on track by arranging meetings with executives of similar companies that had successfully used reengineering techniques as a precursor to their decision to adopt ERP. Eventually, divisional management at company B completed the reengineering exercise and acknowledged that the reengineering effort had forced them to renew their focus on customer needs and the requirement for operational changes to meet these needs. Of course, the delay in reengineering resulted in an extended implementation process and some costly reconfigurations in the ERP system.

Company D had performed minimal up front analysis and relied heavily on the opinions of the current managers who, admittedly, had little knowledge

about ERP concepts and programs and little formal training or education in ES. The consultant's advice about talking with executives from other companies that had reengineered their business processes prior to implementing ERP systems was not heeded.

On the basis of these results, it appears that reengineering can contribute to streamlining operations and to the design and development of an enterprise solution. Since company C's ERP implementation was eventually abandoned, reengineering prior to project implementation does not appear to guarantee success. Indeed, Welti (1999) suggests that reengineering prior to the ERP project implementation may promote two real dangers: mis-specification of the software requirements (if the firm is unable to accurately project customer requirements) and possible political dangers arising from BPR exercises, which have the tendency to stir up contentious feelings. Therefore, firms should be aware that a contentious BPR project can lead to worker-resistance to ERP projects. Furthermore, they should be especially cautious about converting reengineering requirements into ES configurations.

Reengineering should be undertaken to insure that the strategic objectives mentioned earlier are feasible. The reengineering effort should create a uniform response from all aspects of the business. When goals are common, improvement becomes a shared task (Hill, 2000). By using reengineering techniques to develop a uniform vision depicting the company's processes after the ERP implementation, a firm will likely minimize uncertainty and achieve success.

ES needs analysis

All four of the companies performed "needs" assessments. However, there were some differences in their approaches. Company D used an in-house team and examined software packages from various vendors. Companies A, B and C used independent, third party consultants to assist in their assessments. Companies A and C used the results of their reengineering efforts to develop the configuration for their ERP packages. They performed a checklist assessment provided by the consultants to determine the best fitting software. Company B used a similar checklist and was aided by an outside consultant on their selection of a package. Since they had not yet performed their process reengineering, they selected a package based only on an evaluation of their current processes. After company B's reengineering efforts, changes had to be made to the chosen ERP system to incorporate the requirements of expected future processes. The checklists used by all three companies included questions on:

- current IT systems (including hardware);
- type of business (continuous, repetitive, batch, job shop);
- market analysis (demand management, forecasting, customer relationship management, etc.);

- scheduling (MPS, MRP and BOM requirements, shop floor scheduling, etc.);
- logistics (warehousing, transportation scheduling, etc.);
- purchasing (EDI, Internet, integration of inventory and MRP, etc.);
- inventory (transactions, bar codes, package types, analysis, etc.);
- performance measurements (types of measurements); and
- financial and accounting (GL, AP, AR, credit, on line banking, depreciation, aged inventory, budget control, costing, etc.).

All companies came to the conclusion that they needed to install modern information systems, and that this was at least part of the answer to their problem(s). This conclusion was reached after examining current trends in the market place and after careful consideration of IT needs for their current or reengineered processes, their current IT systems (including hardware), and available IT solutions. The firms all reached several common conclusions about their existing systems that suggested a need for the implementation of new information and manufacturing systems. Following is a list of some of these conclusions:

- The existing systems required multiple points of input and there was significant duplication with the same data being entered at multiple points in the system. While companies A and C had streamlined many of their information flows during their BPR exercise, there were still some pockets of multiple data entry.
- The organization's current and/or future information and manufacturing technology needs were not adequately being met by the existing systems.
- Maintenance and support for the existing systems required significant effort, both in terms of time and human resources.
- The enterprise had islands of information and many of these systems were incompatible.
- In too many instances, employees were unable to respond easily and quickly to questions or information requested by key customers or suppliers.

The IT system of choice was ERP because these systems have been designed to alleviate most of the information-related problems that the firms had identified. The companies expected the ERP systems to provide the required crucial links between factory floor operations and information requirements across all the support functions of the business. The fact that these systems could also be extended to cover partners in the supply chain was also appealing to these companies. The decision was also due, in large part, to the influence exerted by corporate management.

ERP profiles of the companies

As a result of the needs analysis the companies budgeted for ERP investments ranging in cost from $0.7 million for company D to $3.0 million for company C. The configuration of each system is presented in Table II. There were some differences in the components installed by each company, with companies B and C opting for more extensive systems. Company D chose a basic accounting/finance and production package. While companies A, B and C had previous experience with MRP and MRPII systems, company D did not. Table II also depicts the ERP profiles of the four companies.

Although all four companies felt that their "needs assessment" efforts helped them to configure and select ERP systems that would provide a good fit with their operations, it is clear that the process followed by companies A and C was more systematic. It also appears that the approach adopted by company D has a low likelihood of success unless the in-house team is extremely knowledgeable about its processes and about the currently available IT solutions. Only three of this company's management personnel had moderate training on ERP systems. The fact that company D did not attempt to reengineer their business processes prior to selecting their ERP system made an in-house approach even more risky.

Justification and selection activities

Economic and strategic goals

All four companies expected ERP to yield considerable cost reductions (see Table II). Although they did not quantify the expected savings, company C's project team expected the project to yield significant reductions in inventory holding costs. However, the real benefit to the business was expected to be the system's ability to increase customer service level from 78 percent to a sustainable 95 percent. Company D did not perform an analysis, preferring to rely on information from a sister division that indicated that the ERP would yield substantial savings in labor costs owing to headcount reduction, along with improved manufacturing efficiencies. Only companies A and B had set specific quantifiable, although mainly operational, objectives for their projects. These were also the only companies that were eventually successful in installing and integrating the chosen ERP modules. It appears, therefore, that setting realistic strategic and financial goals is an important aspect of the pre-installation decision making.

Economic and strategic justification

Companies A and B completed payback analyses. Company C's justification was strategic and non-financial in nature. Company C's accounting and inventory legacy system could no longer support the advanced, high volume manufacturing techniques required to compete in this industry. Therefore, they believed that changing to ERP was crucial to ensure their long-term survival.

Table II.
Company ERP profiles – modules/ sub-systems installed

	Company A	Company B	Company C	Company D
Estimated ERP cost	$1.0 million	$1.2 million	$3.0 million	$0.7 million
Year of ERP implementation	1993	1994	1997	1998
Estimated (actual) implementation time	One year (two years)	One year (2.5 years)	1.5 years (abandoned prior to full implementation)	One year (abandoned prior to full implementation)
Expected areas of savings and process improvements	Inventory savings of $400,000 AP days outstanding reduction $150,000 Manufacturing efficiency savings $450,000 At least 95 percent customer service level	Inventory savings of $500,000 Overhead savings of $250,000 Direct labor savings of $500,000	Reduction in inventory saving costs Achieving a sustainable customer service level of at least 95 percent	Labor savings owing to head-count reductionImprovement in manufacturing efficiencies
ERP modules/sub-systems selected	General ledger (GL) Accounts payable (AP) Budgeting Sales order processing Master production schedule Material req. planning Inventory Capacity req. planning Shop flow control JIT/Kanban Order entry/billing	General ledger (GL) Accounts payable (AP) Master production schedule Material req. planning Inventory Capacity req. planning Shop flow control Order entry/billing Advanced planning Warehousing Forecasting	General ledger (GL) Accounts payable (AP) Accounts receivable (AR) Master production schedule Material req. planning Shop flow control Statistical process control JIT/Kanban Order entry/billing Demand management Distribution Forecasting	General ledger (GL) Accounts payable (AP) Accounts receivable (AR) Master production schedule Material req. planning Capacity req. planning Shop flow control Order entry/billing
No. of division employees, [number] and (percent) of employees involved in ERP Implementation	87 [14] (16.09 percent)	131 [12] (9.16 percent)	145 [14] (9.66 percent)	106 [9] (8.49 percent)

Although they did not evaluate the proposed benefits or perform any type of financial analysis, this company expected a payback of 18 months. The estimated payback for company D's project was one year, however, this was also based on the experience of the sister division.

Typically, ERP investments in larger firms represent between 2 percent and 5 percent of their annual sales revenue. The initially proposed ERP investments for the four companies in this study only represented between 1.1 percent and 1.6 percent of their annual revenues. While the firms might have been convinced that there was no need for a rigorous justification of these projects, their failure to evaluate all the expected costs and benefits still had a deleterious effect on monitoring the progress of the project. In this regard, the approach adopted by companies A and B, although not as extensive as it could have been, was preferable to the approach adopted by the other firms.

The research shows that the two common denominators used in manufacturing businesses as the basis for control and performance measurement (time and money) are strongly tied to the success of an ERP implementation. Without linking these denominators to the economic, strategic and financial goals of the ERP implementation, a firm may miss-align the essential elements of this investment and not achieve its objectives. Successful firms understand that the traditional investment policies and measurements (ROI, ROA, etc.) are necessary to manage the costs of the investment. However, they also realize that investment appraisal methods are not the only substantive factors that need to be examined. Others include order-winner policies, the supply chain performance as a whole, life cycles of products, new processes and speed to market. By managing both the time and money aspects of an ERP implementation a firm can significantly increase their chances of success.

Installation activities

Education and training requirements

For all companies, the needs assessment exercise had uncovered several training and skills deficiencies. Rectification of the training deficiencies was accomplished in three ways: reassignment or replacement of managers, hiring of new personnel with substantial knowledge in manufacturing and ERP systems, and training of managers and key employees. Two types of training were provided: fundamental ERP systems education and technical training in the usage of the ERP software.

In companies A, C and D, ERP training was provided by outside consultants. In company B, since substantial implementation time was lost in the prolonged reengineering exercise, executive management made a decision to replace several managers with new managers with ERP knowledge and experience, rather than losing more time training the managers. The new managers helped to train the retained managers and other key employees. Vendor personnel

provided software training. All the companies spent considerable time and money training their employees on the use of the software packages. This training emphasized the keystrokes, screens, reports and other tools needed to obtain user information.

Communications provided the biggest barrier to project success, especially in companies C and D. Company C's project, which had been progressing smoothly up to the time of the departure of the executive sponsor, began to unravel because the new executive did not have the same passion for the project. The lack of leadership and understanding that ensued led to divisions in the project team. Deadlines were missed, project meetings were delayed or canceled and project timelines were consistently being lengthened. Eventually, this project was scaled down to the basic accounting, inventory and purchasing modules and currently functions as an accounting system. Management apathy also resulted in failure to assess gains even in the accounting system.

In company D, executive management neither provided enough financial or visible support nor fostered effective communication channels for the project. They effectively assumed that divisional management would be able to handle the project and took a hands-off approach. The project was plagued with problems from its inception. The project did not follow the project management structure. No effective project plan was ever generated. Therefore, project teams were fragmented with lapse reporting requirements. The departure of the general manager, who had been the project sponsor, meant that the project folded after installation of the accounting system. The project was deemed a failure.

The amount of literature, training programs and college courses on the subject of operations management has increased significantly over the past 20 years. However, the research indicates that most mid-market manufacturing managers have not increased their education or training to the level of larger corporations. Thus, the concepts of ERP processes are somewhat foreign and vague to mid-market managers. This may cause a smaller firm to have to invest significantly more time and money (on a per person basis) than a larger firm, and in some cases may require the demotion or replacement of individuals who cannot meet the new responsibilities.

Project monitoring and reporting

Company A used Harvard Project with timelines and critical paths. The team introduced project impact reports, and prepared weekly team reports and quality reports. They also held daily project meetings. Companies B and C used Microsoft Project with timelines. They also introduced project impact reports and weekly team reports. They held weekly meetings. Company D used a spreadsheet-based project outline from the software vendor. While the company also planned for weekly project reports and weekly meetings, the meetings were often delayed or cancelled, resulting in significant time overruns

and eventual abandonment of the ERP project. Although companies A and B were reasonably consistent with their meetings and reports there were still significant time overruns in both projects, suggesting that the original implementation time estimates may have been grossly underestimated.

Company A had estimated completing their implementation in one year, the actual completion time was two years. The actual completion time for company B's project was 2.5 years compared with their expected completion time of one year. Company A and B had cost overruns of 22 percent and 75 percent respectively. The fact that some of these cost overruns were owing to underestimated hardware costs suggests that the needs assessment and financial justification aspects of this project were not as complete as they should have been. The time overruns stemmed from organizational problems related to ensuring managerial competence and employee training and development. Companies C and D spent their budgets of $3 million and $0.7 million, respectively, without completing their projects. Declaring the projects failures, these companies did not provide any ending analyses.

Overall project performance

Information on the outcomes of the four projects in terms of costs, benefits and time is presented in Table III. All information presented was garnered from historical records, company financial data and other operations reports. Companies A and B had implemented all of the ERP modules they had purchased. The modules were fully integrated and there was, for example, no longer a need for multiple entries of the same data. However, the companies were still struggling with issues related to the timeliness of data entry in some departments. These companies were also achieving some of the business and operational objectives that they sought from the systems. Among the benefits being obtained were substantial improvements in on-time delivery performance and improvements in market share. An additional benefit for company B was the elimination of two external warehouses.

Except for concentrating on financial objectives rather than considering both financial and strategic objectives, the successful projects (A and B) paid substantial attention to all the activities outlined in the research. Company C had covered the planning activities quite well, but had failed to adequately address the justification activities. The greatest failure of this project appears to have been the unwillingness of executive management to manage and monitor the implementation process after the planning stage. Company D's project only concentrated on the activities of basic management processes and nothing modern and/or strategic. Admittedly, many of the problems experienced by company D appeared to have been due to gross mismanagement of the entire implementation process.

In summary, those companies that were willing to pay at least moderate attention to all the planning, justification and installation activities for both

Table III.
Company performance

	Company A	Company B	Company C	Company D
Estimated (actual) project cost	$1.0 million ($1.22 million)	$1.2 million ($2.1 million)	$3.0 million ($3.0 million)	$0.7 million ($0.7 million)
Reasons for cost overruns	Hardware requirements	Hardware requirements Reengineering costs Assessment costs	No cost analysis	No cost analysis
Expected (realized) annual savings	$1.0 million ($1.195 million)	$1.25 million ($1.625 million)	N/A	
Expected (realized) payback (years)	1.0 (1.0042)	0.96 (1.29)	N/A	
Cost and efficiency improvements	Reduced inventory requirement by 50 percent, saving $700,000/yr Reduced labor cost by $360,000/yr Reduced overhead cost by $135,000/yr Reject rates reduced by 25 percent to slightly more than 1 percent	Reduced inventory requirement by 40 percent, saving $380,000/yr Reduced labor cost by $1,000,000/yr Reduced overhead cost by $245,000/yr Elimination of two external warehouses		
On-time delivery performance before (after) ERP installation	60 percent (93 percent)	78 percent (96 percent)	62 percent (not available)	76 percent (not applicable) firm closed

(*continued*)

Table III.

	Company A	Company B	Company C	Company D
Market share before (after) ERP	30 percent (35 percent)	65 percent (70 percent)	30 percent (not available)	15 percent (not applicable)
Company assessment of ERP project	All selected modules were installed and have been successfully integrated	All selected modules were installed and have been successfully integrated	Only accounting, inventory and purchasing modules installed	Only accounting module installed
Current status of firm	Company A is still in business and enjoys an excellent reputation in its market. It continues to expand its ERP modules. It also continues to use TQM teams and lean manufacturing principles to improve its business	Company B is still in business and is the largest producer in a declining market. Although this company still enjoys some of the gains from their ERP installation they have not been proactive in embracing new manufacturing principles	Company C is still in business. It lags the industry leader on most financial measures. Only the accounting module of the ERP system functions	Company D closed its operations in 1999

strategic and tactical processes were successful in achieving their initial objectives. The companies that fell down in any of these areas failed.

Discussion

The experiences of companies A and B show that effective executive management commitment can help a project to achieve success. It appears, however, that a considerable amount of this effectiveness is due to the activities of the executive sponsor. Therefore, in the case of deployment of technology to a division, top management should ensure that an effective committed sponsor is chosen from among the corporate officers. The experiences of companies C and D (where the projects faltered after the executive sponsors left) also present a strong case for a back-up executive sponsor.

The research also shows a strong relationship between manufacturing strategy and successful ERP implementations. Companies A and B took a more futuristic, long-term view of their processes and linked the ERP investment with strategic planning and modern evaluation and control systems.

Our study supports the need for reengineering prior to selection of the ERP. However, to be effective the reengineering project should not take place under the assumption that an ERP or any other type of pre-selected information or manufacturing technology, will be implemented. The type of technology to be adopted should flow from an analysis of the requirements of the reengineered process or processes. In this way, management will be assured that the reengineering effort will point to the technology, rather than the other way around. In each of our cases corporate management was predisposed to an ERP solution and this presented a major problem for company D, which did not have prior experience with an integrating technology such as MRP or MRPII.

The "needs assessment" exercise is a very critical aspect of an ERP project. It is from this activity that the basic configuration of the ERP system will evolve. Inadequate attention to "needs assessment" will, most likely, lead to a system that does not fit well with the organization. It appears, however, that our firms used this process mainly to determine the software requirements of the ERP system. The fact that both companies A and B had hardware cost overruns indicates that required changes in the hardware legacy systems were not adequately taken into account. Hence, the needs assessment exercise must be extended to specifically cover hardware requirements. There also appears to be a pressing need to survey management and operator education and skills at this stage to ensure that the company's personnel have the wherewithal to deal with the reengineered processes and any prospective ES. If the gap between required skills and available skills is too wide, as was the case with company B, management should recognize that they have to adopt a less sophisticated system, develop extensive training programs, or hire employees that will be adept at operating the proposed systems. Therefore, management and operator education and skill audits should be included in the "needs assessment."

Careful attention to the planning aspects of the project should help to ensure a smooth justification process. However, the problem of forecasting the time that it will take to break the functional gridlock and encourage the involvement of all concerned operators will still remain. In the four projects covered in this study, most of the time overruns were due to personnel and team problems not directly related to the technology. It is these types of problems that smaller companies must avoid. Hence, executive management and divisional management must focus on developing effective communication and team building skills to create a climate for these multi-layered project teams to thrive.

Conclusion

While this report deals with some of the major activities involved in the adoption of ERP systems, it could not adequately cover all implementation actions. Although these four cases were diverse enough to illustrate some common traits that can contribute to successful implementations, more detailed studies are required to help develop theory in this area. Future studies can focus on specific stages of the implementation process (i.e. planning, justification, installation or commissioning). It is also interesting to note that the ERP implementation problems experienced by the firms in this study are similar to those that have previously been reported for the implementation of integrated information and manufacturing technologies such as MRPII and CIM (Small and Yasin, 1997). The successful firms in our study had also concentrated significant effort on many of the planning, justification and installation practices that have been found to lead to successful adoption of MRPII and CIM. This suggests that there may be some common traits in the implementation of modern technologies, especially among the human-factors related activities.

Future studies can focus on determining if there is a one-to-one matching of successful implementation actions across all types of integrated technology adoptions, or if dissimilar technologies have some unique success characteristics. Whatever the route future researchers into ERP implementation practices may take, it is important to recognize that theory development is only a first step. In this regard, it is important for researchers to be aware of the fact that many firms still view these technologies as proprietary and will be reluctant to share information. It is very likely that the case study methodology will continue to be the empirical research tool of choice in this area until usage of these systems become more widespread and routine. Therefore, the important next step of wide-scale theory testing using more sophisticated techniques such as surveys, may still be a few years away.

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