A MULTI-LEVEL APPROACH TO MEASURING THE BENEFITS OF AN ERP SYSTEM IN MANUFACTURING FIRMS

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This research study examines associations between the business characteristics of manufacturing firms and their perceived benefits from ERP system investments. The perceived ERP benefits are measured at two levels: (1) an enterprise level and (2) a specific IT module level. The perceived value for ERP investments was consistently better explained at the specific IT module level.

With the growing proliferation of enterprise resource planning (ERP) systems, including among midsize companies, it becomes critical to address why and under what circumstances one can realize the benefits of an ERP system. In contrast to previous research, this study examines how managers (president, CFO, production VP, etc.) assess ERP success in specific modules (e.g., suppliers and purchase orders, customers and sales) as contrasted with their assessment of the entire ERP portfolio as one entity. Data collected in 270 manufacturing organizations that implemented initial ERP systems (without additional models such as CRM) show that the benefit from investment in ERP is explained better by organizational business characteristics when examined at a specific ERP module level.

To meet organizational needs, computerized information systems in manufacturing firms have evolved over the past 40 years from accounting and simple inventory control, through MRP (material requirement planning) and MRP II (manufacturing resource planning), to today’s focus on ERP systems (Sarkis and Gunasekaran, 2003). ERP systems are software packages that manage and integrate all the enterprise’s data, and provide information based on this data on a real-time basis. ERP systems can provide the organization with competitive advantage through improved business performance (Hitt et al., 2002; Kalling, 2003) by, among other things, integrating supply-chain management, receiving, inventory management, customer orders management, production planning and managing, shipping, accounting, human resource management, and all other activities that take place in a modern business (Gefen and Ridings, 2002; Hong and Kim, 2002; Kalling, 2003). Yet the cost of implementing an ERP software package is substantial, ranging from $200,000 for small companies with annual sales approximating $10M, through $600,000 to $800,000 for midsize companies with annual sales approximating $50M to $80M, and up to several million dollars for larger companies. This refers to the manufacturing management aspects of the ERP...
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alone, excluding CRM. It was estimated that in the past decade about $500 billion was invest-
ed in ERP systems worldwide and that this would grow to $79 billion annually by 2004 (Carlino et al., 2000). While some companies claim to have reduced their cycle time, improved their financial management, and obtained information faster through ERP systems (Kalling, 2003), ERP systems in general still have a high initial implementing failure rate (Hong and Kim, 2002; Songini, 2004). Many prior studies examining the relationship between investing in IT and the perfor-
mance level of the organization (Weill, 1992) dealt with the ratio of total IT investment (i.e., software, hardware, personnel) to the entire organization’s performance (the total profit of the organization). Many early studies found no positive relationship between the two vari-
ables. Strassmann (1985) examined service-sec-
tor firms but found no significant relationship between investment in IT and high-performing firms. Berndt and Morrison (1992) even found a negative relationship between the growth in productivity and investment in high-tech, al-
though, as they point out, this may have been the result of measurement problems. As Bryn-
joelsson (1993) summarizes, positive returns from investing in IT may not have shown up in previous research because of the inadequate way it was measured. In part, early research may not have found such a productivity in-
crease because of the way IT usage and in-
creased company productivity were measured. When measuring IT investment on a per-user basis, there is a positive correlation between IT investment and overall productivity (Brynjolfs-
son, 2003). Although there is a large variance among companies in the benefit they achieve from their IT investment (Brynjolfsson, 2003), on average there is a $10 gain in company val-
uation for each dollar invested in IT (Brynjolfs-
son et al., 2002). Showing such a positive relationship is important because it affects MIS funding.

Still, whether investment in ERP systems pays off remains a controversial question (Hitt et al. 2002; Sarkis and Sundaraj 2003; Kalling, 2003). ERP systems are very complicated soft-
ware packages that support the entire organi-
zational activities. Hence, it is possible that there are many unknown factors that impact the relationship between investment in ERP and the organizational productivity. This study approaches this problem from another direc-
tion. Instead of looking for the relationship be-
 tween investment in IT and the productivity of

the organization as other studies did, it exam-
ines the senior manager’s perception of the benefit their organization gains from using their ERP system and what impacts this benefit.

The basic assumption in this article is that what an organization expects of its ERP is shaped by the organization’s activities, but that these expectations will be better formulated when examined on a specific level. Because to a large extent ERP activity is determined by or-
ganizational business characteristics and be-
cause these differ among the various ERP modules, it follows that the nature of these ac-
tivities should determine differently the per-
ceived value of each ERP module. In a manufacturing firm, for example, ERP systems coordinate customer orders with materials management, stocks, suppliers, production schedules, product customizations, manufact-
turing requirements, and employee schedules and hiring. An ERP system can have a dramatic effect in such cases, based on the organiza-
ion’s operational characteristics, but different ERP modules will have different impacts.

Accordingly, the objective of this study is to examine whether managers’ perceptions of benefit from their ERP is better explained when measuring it on a module-by-module ba-
sis, rather than on an investment in IT as a whole level. Along the same lines, Barua et al. (1995) explain the need to measure the bene-
fits from IT module by module, rather than ex-
amining investment in IT as one homogeneous technology, and examining these module level effects within the context of the organizational hierarchy. Barua and Lee (1997) also highlight the need to examine IT productivity within the context of how the IT is used. Recent studies support this assessment (e.g., Sarkis and Sundaraj, 2003; Kalling, 2003). For example, a saving in inventory holding costs at the lower operational level will contribute to total cost reduction at a higher level, and ultimately to improved organizational performance. The ap-
proach to valuing IT investments resembles Porter’s (1985) explanation that competitive advantage should be understood at the specific operational activity level, rather than by exam-
in the impact of the entire company’s IT.

However, the benefits derived from the use of IT cannot necessarily be evaluated indepen-
dently of the organization itself. For example, the benefits from an ERP module that handles material requirements planning (MRP), a first-
order effect, may also result in a better return on investment, which is a second-order effect (Barua et al., 1995). Yet to accurately predict
It is proposed that the benefits gained by ERP systems will be better predicted by being measured separately at the level of activity areas within the organization, rather than at the broad level of the entire ERP system. 

The findings are based on a field survey of 270 manufacturing organizations that implemented ERP packages. None of these organizations had a relationship with any of the others. The software packages were from different vendors (e.g., SAP and others). The data was collected during the second half of the 1990s via personal interviews with a senior manager of each organization (most of them presidents or vice presidents). More information on the data collection is provided in Table 1. The companies in the sample varied widely in their characteristics, and Table 2 shows this variability.
Perceived ERP benefits were collected from the respondents at two levels. The perceived overall benefits at the enterprise level from using the ERP system was used to assess the first expectation, while the benefits from individual ERP modules were used to assess the second expectation. In addition, information was collected on several organizational operational characteristics that contribute to an organization’s uncertainty or complexity. Organizations can thus benefit from their ERP systems by reducing the level of this uncertainty or complexity (Ragowsky et al., 1996). Based on Porter (1985), each activity area was represented by relevant organizational characteristics, such as the average number of purchase orders per month for the purchasing activity area, average supply time to customers for sales activity area, etc. If these characteristics are found to have a strong effect on the perceived benefits from specific ERP modules, but little effect on the total perceived benefit from the ERP system as a whole, then there is merit to the claim that organizations should assess the benefits from ERP systems on a specific ERP module basis.

The business operating characteristics measured are described below:

### TABLE 1 Research Methodology Details

The interviews were conducted with the help of trained paid interviewers who conducted structured interviews with a senior manager of each of the participating organizations. One of the authors personally trained each interviewer candidate. Every interviewer candidate first learned the theoretical background of the study and the questionnaire. Then the interviewer candidate joined the author for two or three interviews in which the author conducted the actual interview with the interviewer observing him. After the interviewer candidates felt they were ready for interviewing, they interviewed two or three respondents with the author observing them. Only candidates who successfully conducted the interview when the author observed them were selected to serve as interviewers. The objective of this training was to reduce bias due to differences among interviewees.

The senior managers were well aware of the benefits derived from the ERP. The questionnaire was divided into two sections. The first section included questions about the organization’s characteristics (e.g., number of suppliers, relative share of raw materials cost in the cost of the final product, number of customers, average lead-time to customers, number of products, number of production lines, volume of sales, and number of employees). In the second section, the respondent was asked to assess the benefit the organization derived using its ERP on an overall level: “How would you rank the overall level of benefit derived by your organization from the entire ERP applications portfolio on a scale of 1 2 3 4 5 6 7, 1 indicating very low benefit and 7 indicating very high benefit?” A similar question was asked with regard to other enterprise-level benefits, as well as with respect to the benefits received from implementing key ERP modules.

### TABLE 2 Overall Characteristics of Participating Organizations

<table>
<thead>
<tr>
<th></th>
<th>Min.</th>
<th>Max.</th>
<th>Median</th>
<th>Mean</th>
<th>St. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume of sales (in million U.S.)</td>
<td>1</td>
<td>400</td>
<td>33</td>
<td>41.78</td>
<td>39.52</td>
</tr>
<tr>
<td>Number of employees</td>
<td>10</td>
<td>2400</td>
<td>100</td>
<td>206</td>
<td>321</td>
</tr>
<tr>
<td>Number of suppliers</td>
<td>1</td>
<td>5000</td>
<td>45</td>
<td>177</td>
<td>526</td>
</tr>
<tr>
<td>Number of customers</td>
<td>1</td>
<td>10,000</td>
<td>155</td>
<td>672</td>
<td>1746</td>
</tr>
</tbody>
</table>

Relative Share of Cost of Raw Material in the Overall Cost of the Final Product. Using an ERP system, organizations can negotiate better with suppliers and thus reduce the cost of raw materials by as much as 15 percent (Schlack, 1992). Hence, the higher the relative share of cost of raw material in the cost of the final product, the higher the savings for the organization and, hence, the greater the benefit of the information provided by the ERP system. This variable represents the impact of the decision supported by the additional information on organizational objectives regarding suppliers and the raw material purchase orders activity area.

Differences among the Suppliers. Suppliers can differ in price, quality, supply lead-time, etc. The greater these differences are among suppliers, the more information is needed to choose among them for a specific purchase order. This variable represents the level of uncertainty or complexity with respect to suppliers and the raw materials purchase orders activity area.
Average Lead-Time of the Raw Materials that the Organization Uses. The longer the lead-time, the higher the probability of changes being made in the order, such as levels of raw material demand or the risk of a partial or full cancellation of the order. The longer the lead-time, the more information is needed to manage the purchase orders. This variable represents the level of uncertainty or complexity with respect to suppliers and raw materials purchase orders activity area.

Price Elasticity of Raw Materials. Suppliers sometimes offer quantity discounts. The greater the price elasticity, the more information is needed to obtain the best purchase order. This variable represents the level of uncertainty or complexity with respect to suppliers and raw material purchase orders activity area.

Product Complexity. The greater the complexity of the product, the more information is needed for properly managing customer orders. This variable represents the level of uncertainty or complexity with respect to the customer order activity area. Three kinds of products exhibit different orders of complexity and different degrees of difficulty in tracing the customer's order.

1. Standard products. Customers cannot ask for changes in the products (e.g., food on store shelves). There is no difficulty in tracing customer orders.
2. Standard products with modifications. Modifications are made according to customer requests (e.g., furniture that can be adapted to the customer specifications). Because this type of product is slightly more complex than a standard product, it is necessary to manage information on the special specifications to make sure that the changes have been performed.
3. Custom-designed products. Each order is a special product manufactured to customer specifications. The level of the complexity of the product is the highest. The organization must create product-specific design, raw material purchase, and scheduling.

Average Time Raw Material Inventory Remains in the Organization. Manufacturing organizations can save up to 25 to 30 percent of inventory carrying costs (financing, storing, insurance, etc.) with its IT. The longer the raw material inventory remains in the organization, the greater the potential for cost saving. This variable represents the impact of the decision supported by the added information on organizational objectives with respect to material requirement planning.

Average Number of Levels in the Bill of Materials of the Firm's Products. The greater the number of levels in the bill of materials, the more raw materials there are in each product unit. The more complicated the product, the more information is needed to make sure that every raw material item is available when needed. This variable represents the level of uncertainty or complexity with respect to purchasing and customer order activity.

Average Time of a Work-Order. The longer the work-order, the more complicated the product. Hence, with complicated products, more information is needed to manage the process, such as what operations should be conducted and in what order, and when each raw material is needed in the process. This variable represents the level of uncertainty or complexity with respect to the customer order activity area.

Number of Production Lines. Two factors are primarily responsible for determining multiple production lines: either (1) the organization produces many products or (2) there are several stages that each product must go through, as when different parts are produced on different production lines and are then assembled. In either case, the more production lines, the more complicated the production and the coordination involved. Hence, more information is needed for managing raw material purchasing and for customer orders when there are more production lines. This variable represents the level of uncertainty or complexity with respect to customer order activity.

Percentage of Producing for Customer Orders versus Producing for Inventory. When producing for customer orders (versus producing for inventory), each customer order must be managed separately on issues such as order specifications and special requirements. The more an organization produces for customer orders, the more important and valuable the information about each order is, if the company is to supply the order on time and based on customer specifications. This variable represents the level of uncertainty or complexity with respect to customer order activity.
Average Supply Time for Customer Orders. The longer the lead-time for a customer order, the more complicated production can be. This is because order specification, raw materials, and other resources availability may change. Hence, more information is needed to coordinate all the activities during the lifetime of the order. This variable represents the level of uncertainty or complexity with respect to the customer order activity area.

RESEARCH FINDINGS

How the Analyses Were Done
Table 3 presents the results of the regression analyses. These regression analyses were used to find the degrees of explained variance in the relationships between the different benefits gained by using the ERP as explained by organizational characteristics. In Table 3, the first four columns show the effects of operational characteristics on the total overall benefit at the enterprise level, and on three other enterprise-level benefits (i.e., Organizational Profitability, Market Competition, Cost Reduction). The two right-hand columns in Table 3 show the benefits of specific modules (suppliers and customers). N/A means that the organizational characteristic is not applicable in the case of the specific module. These results show, as described below, that benefits gained by ERP systems are better predicted when measured at a specific benefit and a specific module level.

Enterprise-Level Benefits
Table 3 shows only two organization characteristics have a significant effect on the overall benefit from the ERP: and even then the degree of explained variance, the $R^2$, is low at 6.9 percent. When more specific enterprise-level benefits were examined, the explained variance, while higher, was still low (7 to 11.5 percent). Specifically, we asked about “the overall contribution of the ERP systems to the profitability of your organization,” “to what degree do the ERP systems serve your organization in competing in the market,” and “to what degree do the ERP systems serve your organization in costs reduction.” These results are shown under the heading “Benefit of ERP as a Whole” in Table 3.
The data shows a remarkable difference in the degrees of explained variance regarding the managers’ assessment of the benefit derived from the ERP system as a function of the organizational business characteristics.

Results for the Suppliers and Purchase Order Module

The Suppliers and Purchase Order module manages the suppliers and raw material purchase orders. The information provided by this module helps the organization plan the purchase of raw materials according to its production plan and the anticipated need for raw materials. Using this information, the organization can obtain better prices for raw materials and receive the supply as close as possible to the date it is needed.

As shown in Table 3, four characteristics had a significant effect on the perceived benefits derived from this module: first, the relative share of raw materials in the overall cost of the final product is an important characteristic. With an ERP, an organization can better negotiate with suppliers and reduce the cost of raw materials by as much as 15 percent (Schlack, 1992). Hence, the higher the cost of raw material, the higher the value of raw material cost reduction out of the cost of the product, and the information provided by this application is more valuable. Second, the average lead-time of raw materials also contributed here: Longer lead-times can result in more interactions with the suppliers and more changes that might impact the purchasing (e.g., changes in customer orders that change the production plan and consequently change the need for raw materials). These, in turn, require more information to handle the purchase orders. Hence, the effect this variable has on the benefit organizations gain from the specific ERP module is significant. Also, price elasticity of raw materials and differences among suppliers affect the benefits for this module. The more options for quantity discount and the more differences among the suppliers, the more information needed to compare the different scenarios in order to make the right decision. The much higher degree of explained variance here (39 percent) supports our second research expectation (see “Research Questions and Measures”).

Results for the Customer Order Management Module

The Customer Order Management module manages customer orders (technical specifications, packaging requirements, supply time to customer, details on long-term contracts like “blanket order,” etc.) from the moment the order was accepted until it is delivered. This module helps the organization order according to customer specifications, shorten supply time, and provide timely information to customers about the status of their orders. These could result in increased sales. The degree of explained variance for this module is 40 percent. Again, the higher degree of explained variance can be explained by how each organizational characteristic relates to the actual benefit of the ERP module. The far-right column in Table 3 shows the result of this linear regression. The more the organization produces for customer orders, the more important and valuable the information about each order is, if the company is to supply the order on time based on customer specifications. The longer the lead-time for raw material supply, the higher the probability for changes, and hence the more important this information is. The longer the work order, the more complicated it is to monitor and to make sure it will fit with related customer orders. The longer the supply time for a customer order, the more information is needed to handle it. Usually, when the supply time is long, more work orders are associated with the customer order, and more information is needed to ensure that the order is supplied on time and with correct specifications. The much higher degrees of explained variance here also support the second research expectation.

CONCLUSIONS

Assessing whether investment in IT pays off is an important, if contentious, issue. This study, focusing on ERP systems in manufacturing organizations, examined this question from a new perspective, namely the assessed value that involved managers give the ERP system as a function of organizational business characteristics. The assessment of ERP benefits was made on two levels: (1) an enterprise-wide level where the entire ERP system is assessed regarding different types of benefits derived from the ERP and (2) a specific module (application) level. The data shows a remarkable difference in the degrees of explained variance regarding the managers’ assessment of the benefit derived from the ERP system as a function of the organizational business characteristics. Business characteristics explain between 6.9 and 11.5 percent of the variance in the assessed values of the ERP system at the enterprise level, but explain around 40 percent when it is assessed regarding a specific module.

These results answer skeptics who question the benefits of ERP systems based on enterprise-wide general measures such as ROI. While the explained variance of the benefit
from an ERP as determined by business characteristics is low when examined on an organizational level, it is high when analyzed at a specific module level. Viewed in this perspective, the results may also explain why so many ERP implementation projects seem to fail. An ERP should be installed, like other business solutions, to address specific needs and to fit in with the organization’s business characteristics. ERP may be a one-size-fits-all application, but the benefits still depend on how well they address business needs. The benefit derived from an ERP system may be different for different modules and may depend on the specific type of benefit in question. Accordingly, the data implies the need to integrate the ERP into the organizational work process in a manner that will address specific needs as they relate to the organization’s business characteristics.

References