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A Study on the Manufacturing Performance with ERP Systems†

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요 약 오늘날 기업 전체를 경영자원의 효과적 이용이라는 관점에서 통합적으로 관리하고 최신의 정보기술을 활용하여 공급 사슬상에 있는 기업의 모든 경영자원을 효율적으로 계획하고 관리하는 경영시스템의 하나인 ERP가 많이 이용되고 있다. 본 연구에서는 이러한 ERP 시스템을 고려한 제조 수행를 향상시키는 방법에 대하여 논한다.

Abstract An enterprise resource planning (ERP) system is an enterprisewide management system made possible by information technology. Organizations have been implementing ERP packages for integrating the business processes in various functions. ERP has been helping companies to automate their entire business processes within the organization as a whole instead of just in some functional units. This paper presents five case studies indicating that enterprise resource planning (ERP) systems do enhance the performance of manufacturing organizations. The ERP systems studied are from SAP, Baan, and Oracle. In all five cases, better cross-functional integration was a critical success factor.

1. Introduction

The current dynamic global business environment, which is characterized by customer-driven markets, shorter product life cycles, and narrow niches, requires the manufacturing function to play an active role in an organization in coordination with other functional units in order for the organization as a whole to gain competitive benefits. Recent increases in international competition are awakening U.S. manufacturing companies to realize the need to use manufacturing as a competitive weapon and to enhance manufacturing performance. One of the tools to enhance manufacturing performance is advanced information technologies (IT) implementation.

Manufacturing processes are changing, becoming intellectually stimulating and challenging rather than physically exhausting. The various advanced technologies used in manufacturing, collectively known as, advanced manufacturing technology (AMT) would not have been possible without rapid applications of IT. These computer-based AMTs allow firms to produce a variety of parts and end products of even small volumes by changing the software instead of replacing the hardware.

As much as technology has enabled improvements in manufacturing such as higher productivity, it has also made the process of manufacturing highly complex because of the many different computer software systems used within manufacturing and in other functions. Within local manufacturing facilities, there are discrepancies encountered in fully integrating the automated equipment. Without integration, a plant may have various "islands of automation," and such isolation results in lack of integration and coordination, preventing firms from utilizing the full potential of technology and equipment. Under such circumstances, the investments made in automation may not be fully

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justified[18].

Beatty and Gordon[2] in discussing the barriers to implementing CAD/CAM systems mention that one of the barriers to the implementation of these AMTs is incompatible systems. Computers in the manufacturing division use different software packages that are incompatible; hence, communication among the systems is not possible. They mention that much time and effort are wasted in reentering the same data many times, data that could have been transferred automatically had the systems been compatible. Beatty [3] contends that the final aim of factory automation is to integrate the entire database, including CAD, CAM, and bill of materials (BOM).

At the global level, the effort required to integrate the various production facilities is higher, owing to differences in technology in various countries. Many manufacturers depend on technology to assist them in their efforts to cope with the increasing demands for product innovation, faster delivery, and better quality. As a result, production and manufacturing operations have become more complex, automated, and geographically dispersed in recent years[7]. Such geographical dispersion and related complexities need better planning to coordinate and control. Decision-making involves different time horizons and different geographical dispersions. Sometimes, decisions must be made concurrently, involving different facilities from different geographical locations from both local and foreign sites.

2. Problems with Disparate Systems or Antecedents for an Integrated System

Rockart and Short[15] mention that in the current global economy, in order to capture global levels of manufacturing efficiency, to innovate for global markets, and to under-stand international marketing and world markets, a firm requires increased knowledge and coordination of the firm's operations throughout the geographically dispersed subunits. But the integration and coordination of information technology across the national and cultural borders is not an easy task because of many inherent problems pertaining to the technological differences and other issues in various countries. Kerr[11] reports about the "islands of automation" with reference to various individual units and their respective headquarters, each having a different platform of information systems. A standard of protocol and platforms would alleviate such problems and enable the smooth transfer of data among various units. Gullo[9] based on interviews with executives from RJR Nabisco, stresses that even if a company's businesses are not centralized, the IS department needs to move to a view of data that is as global as possible to attain competitive advantage. Nearly half of the 75,000-person workforce of RJR Nabisco work outside the United States. If various units use different types of computer hardware and software systems, managers will have only a partial view of data and net information gain will be less. With such lack of accurate information, the decision-making process will not gain significantly from the tremendous investments made in building the information technology.

Alavi and Keen[1] mention that the higher the communication and interaction among the various team members, the higher will be the performance of the team. In carrying out a project, the members of the product design team should communicate and coordinate with the product engineers and process engineers and the marketing professionals as well as the suppliers. At a global level, integrated information technology can enable them to interact and make appropriate decisions in bringing out products to various countries; thus, such integrated IT becomes a critical success factor.

If a company uses different kinds of computers in different countries, transmitting information among these disparate systems often requires expensive interfaces, and most of the time, organizational members waste time and effort in duplication of data entry. In addition, as the organization grows and expands, the number of different computer hardware and software systems increases exponentially. Since the 1980s, the business environment has seen many mergers and acquisitions, and such activities have given rise to fragmented information systems within an organization. Rockart and Short[15] define time to market as the firm's ability to develop new products

quickly and to deliver existing products effectively. These authors contend that reducing time to market necessitates increasing coordination among various functional units in an organization, such as design, engineering, manufacturing, purchasing, distribution, and service. As organizations reorganize to work as teams in charge of projects rather than as individual functional units, information must be disseminated across the entire organization, making sure that each individual unit or division is able to capture the information needed and is able to provide that information to the others in the organization who need it. The various database types must be able to communicate with one another so that there is no redundancy in information retrieval and manipulation.

3. Enterprise Resource Planning Systems--An It Innovation to Integrate Disparate Systems

Davenport and Short[6] explained how business processes were developed before modern computers and communications even existed; whenever technology was applied in the organizations, it was to automate or to just speed up the isolated components of the existing process. Such IT application enabled organizations to achieve higher productivity, but it did not give them sustainable competitive advantage of any kind. There were "islands of fragmented automation," which did not allow the organization as a whole to perform better. The emergence of ERP systems has been changing this situation by providing a mechanism for the organizations to achieve "end-to-end connectivity," thus making the various computer systems compatible with one another.

An enterprise resource planning (ERP) system is an enterprise-wide management system made possible by information technology. Organizations have been implementing ERP packages for integrating the business processes in various functions. ERP has been helping companies to automate their entire business processes within the organization as a whole instead of just in some functional units. From the shop-floor activities to performance monitoring in the headquarters, a seamless integration has been achieved through ERP implementation, which makes the various computer hardware and software platforms compatible with one another. Through their case analysis, the authors found that ERP systems help organizations to reduce cycle time, reduce inventories, and share information seamlessly across the organization. Companies that have implemented ERP have made improvements in cross-functional coordination and business performance at various levels. ERP software is the backbone of the manufacturing systems for production scheduling, materials management, and logistics planning[16].

4. Evolution of ERP Systems

ERP evolved from the famous material requirements planning (MRP) systems. The MRP systems evolved into Manufacturing Resource Planning (MRP II) by incorporating a few important aspects of business. MRP II is a sequential technique that is used for converting the master production schedule (MPS) of the end products into a detailed schedule for raw materials and components. It starts with sales and operation planning and demand management and ends with a detailed schedule for components to be made in-house as well as purchased from vendors. MRP II is a tool for planning the engineering, operational, and financial resources of an organization. The vital part of MRP II is the MRP system; around this MRP system other resources are planned and controlled. MRP II deals with sales, production, inventory, schedules, and cash flows, which are the fundamentals of planning and controlling the manufacturing or distribution process.

MRP II systems are the predecessors of today's ERP systems and generally include fewer enterprise-wide functions than ERP packages. MRP II systems often run on proprietary midrange platforms. The ERP system is an advanced IT that overcomes the limitations of the MRP II; in other words, ERP systems are capable of integrating the data from all of the functional units, thus improving manufacturing performance. The marketplace has been changing continuously since the past decade. An integrated system such as ERP is necessary given current market

conditions because customers, having more choices, are becoming more demanding and product life cycles have become shorter. New technologies are changing the way organizations are organized and business processes are designed. A manufacturing planning and control system such as MRP II is becoming less relevant in today's context because of the following important changes :

Manufacturing is moving toward a "make to order" environment rather than a "make to stock" environment. The various products sold are customized rather than standardized thus making the planning process complex.

Quality and cost have become qualifiers or minimum requirements for the firms who wish to compete in the marketplace. Competition is now based on delivery, lead times, flexibility, greater integration with the customers and suppliers, and higher levels of product differentiation.

The ERP applications encompass the philosophy of MES and, at the same time, provide organization-wide information that touches all of the functions. In other words, ERP systems affect everything in an organization from order capturing to accounting and procurement to warehousing. Such systems are especially useful when an organization has discrete manufacturing environments and there is a need to plan, coordinate, and manage these facilities to achieve optimal sourcing and production.

Recently, Davenport[6] stated that an organization collects, generates, and stores vast amounts of data and these data are spread across the entire organizations stored in dozens or even hundreds of different computer systems, and each of these systems is housed in various offices, factories, or divisions. Each of these is based on legacy mainframe systems and may provide automation and enable a particular functional unit to perform more efficiently, but in combination, these individual units only impede an organization's ability to grow and expand.

At Owens Corning, a leading manufacturer of fiberglass-based housing materials and composites where the authors conducted their case study, there were about 200 different systems running on the legacy systems, and all of these were working in isolation from one another. Such a fragmented IT infrastructure impeded the organization in its growth and expansion. The IT structure it had prior to ERP implementation did not fit its business strategy -- that is, it would not enable the company to realize the vision of its CEO.

5. Research Methodology

In order to understand the enhanced manufacturing performance of an ERP system and its potential to overcome the drawbacks of fragmented systems, this research carried out their case analysis in five manufacturing firms. A case study was used because of its inherent advantages in providing information. Because there exists no sound theory base yet in this area, case analysis is a strong means for conducting descriptive research and helps to gain insights into areas that have not been explored previously in the literature. As put forth by Glaser and Strauss[8], grounded theory development should start with observation, and the theory can be built only after initial observations. Theory building is an inductive process that needs a series of observations, modification of received ideas after each observation, and finally concluding with a sound theory.

Benbasat, Goldstein, and Mead[4] mention that case-type research is the most appropriate research tool to use when the research and theory are in their early and formative stages. The research context is rife with challenging and practice-based problems, in which the experiences of the actors are important, and the context of action is critical. Chen and Small[5] mention that the case study approach also helps in situations in which the practitioners have significantly higher levels of knowledge about the subject and the researchers need to gather information from them in their natural setting to build theories. For ERP, research case analysis seemed fitting because it is a recent IT innovation that required elaborate research and understanding before using quantitative techniques based on a large-scale survey.

Open-ended questions were asked, and the responses of the IS executives were audiotaped, thus improving the reliability of the study. To ensure validity, more than one researcher was present during

all of the interviews. The written manuscripts were submitted to the respondents for their review and approval, thus alleviating any misinterpretation of the responses. This further increased validity. The interviews were conducted with the MIS directors or chief information officers or ERP implementation project leaders, because these individuals have a comprehensive over-view of both the technical and business aspects of the system.

6. Results and Discussion

Owens Corning and Viskase use SAP as their ERP system; Valenite and Diebold have Baan and Leeson has Oracle as ERP systems. The reasons for choosing a particular type of ERP are also given in the table. SAP Company most often preferred to offer its products and services to larger firms, and some of the modules of Baan systems (e.g., Product Configurator) made it the system of choice for global companies such as Diebold. The Oracle ERP was chosen by Leeson because of its ability to meet its needs and because of the Webbased network computing architecture (NCA) of Oracle. All of the companies prior to ERP implementation had legacy mainframes, and all of these firms realized that such disparate legacy systems would not enable them to achieve competitive superiority in the coming years. The details of the case studies of each of the companies are reported elsewhere[14].

6.1 Problems with Disparate Systems

There was a common problem found in all of the firms studied --incompatibility among the systems and the corresponding poor manufacturing performance. Various work processes and transfer and access of information among the functional units and divisions were a time-consuming process prior to ERP implementation. For example, at Owens Corning order processing and the subsequent dispatch of materials used to take three days. The paperwork associated with the order-taking process was voluminous, and various documents were circulated from office to office. In every office, copies of the same documents were made and filed. Diebold had problems in manufacturing automated teller machines (ATMs) for its global customers that required incorporating differences in currency, language, and technology in various countries. Diebold also had problems in coordinating its internal supply chain in order to practice JIT. Leeson wanted to get rid of its obsolete legacy systems and enhance manufacturing performance. At Viskase, there was no integration of any sort among the production facilities, resulting in poor manufacturing practices. Valenite realized the need to change from aging mainframe-based systems to new systems to cope with the changing business environment. All of the respondents agreed that they cannot progress and go anywhere with their existing legacy systems, and it was more than inevitable for them to switch to a system such as ERP to obtain an organization-wide integration in order to achieve a smooth flow of information. Especially for internationally active companies, a system such ERP is necessary to compete in the current and coming years.

6.2 Issues in ERP Implementation

A salient aspect noticed during the interviews and analysis is that ERP implementation requires a business process reengineering (BPR) or some kind of discovery process before implementing the system. Such an understanding of the existing process enables the organizations to redesign their organizational processes in order to get the most out of the ERP implementation. Unless the various business processes are redesigned to suit the design of the modules of ERP, the system implementation may not yield the expected success. ERP is not just an office automation software that can be bought off the shelf and installed but a business transformation process that requires some fundamental changes in the way various business processes are designed and conducted. In addition, the organization's members need to have a good understanding of how the system works before actually putting it into use. Valenite, for example, conducted several simulation studies before putting the systems to use in its Canadian facility. Since data entered in one place connects with many areas or databases of an organization, an error made in one place is multiplied

and, if left unnoticed, will result in catastrophe, which may take much time and effort to reconcile.

6.3 Enhanced Manufacturing Performance of ERP systems

All the companies studied realized enhanced manufacturing performance from the implementation of ERP systems. At Owens Corning, an executive from the corporate headquarters in Ohio can monitor and affect the production planning and logistics activities of a plant in the U.K. if so desired, with no delay other than the milliseconds of transmittal time. Thus, there is a centralized coordination of activities across various functions, divisions, and countries. The production managers in various factories do not have to worry about order taking from the customers, tracking logistics, or after-sales service. While the production managers focus on getting the best output from their facilities, the corporate headquarters office takes the responsibility for the remainder of the process from advertising to after-the-sale customer service. The implementation has demonstrated significant contributions to cost savings and performance measures at Owens Corning. Inventory levels have been reduced significantly. Lot sizes and machine allocations have become efficient. Inter-facility coordination has grown significantly. Rather than physical assets being stored as inventory, it is now information access and dissemination that is the vital source of production planning and control that can now be accomplished globally and optimally because of the uniformity of systems. Before the integration of functions and divisions accomplished through ERP, the data collection process was slow and repetitive. Now, the customer can call one location to place an order -- unlike the previous system which made it necessary to call two or more different locations. Information about product availability can be retrieved from any linked terminal in the organization, because the system is standardized and uniform across the entire organization. The manufacturing executives of Owens Corning, during this interview, acknowledged that the SAP systems have significantly improved the performance of the manufacturing function, and the chief information officer mentioned that without ERP, the company would not be able to compete in the global arena.

At Viskase, another firm with SAP, some of the salient benefits realized through implementing SAP include reductions in lead time and inventory, enhanced visibility in inventory planning, reduction in head count, and an integration of information. In any manufacturing organization, the forecast and actual sales orders are converted to plant orders, which are changed into production orders. Prior to SAP implementation, this process was apparent to only a few persons, and only these few were able to comprehend the information and develop plans for production and purchasing. Through SAP implementation, such complex business processes have become available to others in the organization, thus not only connecting the entire organization end to end but also providing related functions with information that they require to work efficiently. Production-based decisions are tied to sales-based decisions in a more timely and efficient manner, and the various complex factory-level processes are becoming transparent to others in the organization. Decision-making times are therefore reduced significantly, and the organization is better enabled to meet customer demands.

At Valenite, the profitability of the Canadian facility definitely increased after the Baan implementation, but actual dollar figures were not provided. The increase was primarily attributed to lower levels of inventory and improved customer satisfaction. Prior to the Baan implementation, order-taking was a time-consuming and tedious process in which the customer service representatives first wrote the information on paper and then keyed it into the system. With the Baan system in place, this task is accomplished without the translation errors involved in moving from paper to digital mode. The data is entered directly onto the screen, and once such data has been entered, the system is automatically updated and current. The users of the system know that the changes and the actions relating to them have been taken. The statistical and daily updates are automatically and immediately made, and the financial and inventory books are always current. When the month-end closings occur, the U.S. facilities, which still have legacy mainframe systems in their facilities, take four days to retrieve the appropriate data and make the required entries. In the

Canadian facilities with Baan ERP in place, the bookkeeping, journal-entry, and other such financial and accounting processes are automatic and the information is available in real time. Month-end closings take hours to accomplish, not days. Exhibit 4 details the enhanced manufacturing performance due to Baan implementation at Valenite and Diebold Incorporated.

Prior to ERP implementation, Diebold was operating in batch mode, in which the databases were updated nightly. The desired data was available, but the "age" of the data made its reliability questionable. Now the data is in real time across the entire organization. Diebold has overcome its Y2K issues in all of the areas in which Baan is implemented. Before Baan implementation, Diebold had some proprietary interfaces between the various modules to transfer data from the disparate database types. These interfaces were minimal, and there existed no organizationwide level of integration. Since Baan implementation, there are integrated interfaces between all of the modules and data entered in one place automatically triggers changes in all the related databases. Diebold has an internal supply chain, in which the end product from one facility becomes the subassembly for the next facility. The coordination of the facilities thus reduces stockpiling and ensures supplies. Any lack of subassemblies in the process will have an effect on the downstream production processes and profitability. The coordination among the facilities in Diebold thus becomes vital for continued success. With Diebold's size and complexity, an ERP system is required to alleviate problems in coordinating and controlling their manufacturing processes. Baan enables Diebold to more readily do product configuration for the global customers. Given Diebold's expected growth in international markets, a system such as Baan is more than essential to meet customer expectations. (The enhanced manufacturing performance at Valenite and Diebold is discussed in detail in Tyler and Rajagopal, 1999).

At Leeson, after implementing Oracle, the number of phone calls and paperwork related to order processing has been reduced greatly. Order processing is streamlined and smooth. With Oracle, there is greater coordination, and the organization as a whole works together -- unlike earlier times, when departments were working in functional silos independent of one another. Order levels and inventory, which were done manually before, are all automated. Before Oracle implementation, the field officers used to fax orders that generated lot of paperwork; with Oracle in place, they do it automatically and directly into the system and various order forms are available in the Oracle system. The order process itself is automatic, all the databases in manufacturing are kept current, and the data is available in real time. Exhibit 5 shows the changes in manufacturing performance due to Oracle implementation at Leeson.

Before Oracle, when MRP II was used, only a few were able to see the various business processes. More often than not, various functional staff were calling others and the MIS department for data and reports. But the Oracle systems have opened up the information in the company and put the information needed to the end users in a readily accessible form. The finance, inventory, and transactions are all clean, and the information is available to the decision-makers without limitation.

Y2K problems have been totally alleviated. In the factory floors, large packets of paper used to go around that contained special instructions and product revisions. By putting more PCs in the shop floor and using Oracle Front Page, such paper-based instructions were eliminated. The Front Page has all the needed information in it; previously that information circulated manually. Of all the IT innovations seen so far, the respondent agreed that the Oracle ERP systems have made the greatest impact in the organization. It is the authors' belief that E-commerce or conducting business over the Internet will be another IT innovation that is capable of impinging upon many functions of an organization.

As can be seen from ERP systems, various criteria to measure performance, especially in manufacturing, such as global optimal procurement, coordination in manufacturing, manufacturing knowledge about the markets, marketing knowledge about manufacturing, customer satisfaction, paperwork associated with order processing, time to process order and deliver, information availability for logistics for optimization, uniformity of the systems in various production units,

forecasting accuracy, positioning for global markets, supply chain management activities, and monitoring of performance in various subsidiaries are all enhanced to some or great extent as a result of the implementation of ERP systems. This shows the wide variety of advantages the manufacturing function is able to achieve from ERP implementation. So far there has been no single IT innovation comparable to ERP systems for affecting the various functional units of an organization simultaneously, resulting in enhanced manufacturing performance.

7. Conclusion

Many organizations have successfully automated their business processes by implementing many different kinds of computer hardware and software systems during the past few decades. What appeared to be making the various business processes easy and simple ended up making them complex and difficult to handle because of the wide variety of systems that were accumulating in individual functional units and divisions in the organizations over the years. With the increasing intense international competition, shorter product life cycles in the market and ever-increasing niches, there is a need for the organizations to be able to digest the vast amount of information from the environment and make fast decisions to respond to dynamic and changing global markets. There is also a need for the organization as a whole to work together and sometimes to work with other organizations as a virtual corporation to make strategic decisions and achieve competitive gains. Toward integrating organizations to reach these goals, information technology has once again proved to be a vital tool by providing "end-to-end" connectivity in an organization through implementation of ERP systems.

This paper has shown the benefits of implementing an ERP system in enhancing the performance of an organization--manufacturing performance in particular. For global organizations, an ERP system may prove to be a vital tool for coordinating the production at a global level, thus achieving optimal production and sales. With many vendors entering the ERP industry, it will be definitely be interesting to see the various types of future information technology integration systems and their capabilities. With such systems providing information at the fingertips of the decision-makers at the right time and right place, the competitive tool in an organization will be the ability of the personnel to focus and develop core capabilities and conceive high degrees of innovation to achieve competitive gains. As much as ERP systems integrate information technology, they are also making organizations understand their core capabilities, reengineer their business processes, solve Y2K problems, and make any changes needed in the business processes to be a market leader. Organizations may take the process of implementation of ERP systems as an opportunity to reengineer their business activities, alleviate Year 2000 problems, and revamp their entire IS/IT structures to compete for the future. The cost associated with ERP implementation is meager compared with the benefits offered by the integration; at the same time, ERP is proving to be a vital tool for future survival in the global marketplace.

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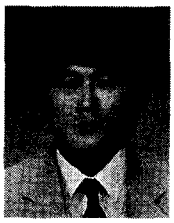

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