The Next Generation of ERP for Engineer-to-Order Manufacturers

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Abstract

Since the 1980s, Enterprise Resource Planning (ERP) systems have been considered a fundamental necessity for controlling manufacturing operations. However, the extent to which ERP is successfully applied often depends on the nature of the products created and the applicability of any given system. For example typical repetitive manufacturing operations have low sales and engineering costs per unit, and high volume output. Conventional ERP adequately supports this business model. Conversely, engineer-to-order (ETO) manufacturing is challenged with relatively high sales and engineering costs per unit. As a result many ETO manufacturers have experienced difficulty leveraging ERP for a justifiable return on investment and employed other means of conducting business. This paper discusses the reasons why conventional ERP can fail ETO manufacturers. It offers an alternative technology philosophy and reviews an emerging software platform known as Enterprise Resource Automation, or ERA.

Introduction

Engineer-to-order (ETO) manufacturers appear to be particularly vulnerable to market and technical shifts. In particular, many managers have become increasingly disturbed about the effects of global issues such as political uncertainty and a rapidly-changing economic environment. A constant concern is the emergence of aggressive foreign competition and the gradual erosion of North America's industrial dominance in many sectors. Consequently, many manufacturing business executives are looking for guidance on how to return their companies to profitability. To do so will require innovative approaches to optimize the use of human capital through the introduction of next-generation technology platforms.

In the latter part of the 1990s, manufacturing attempted to correct falling revenues and profits with emphasis on employee productivity. Corporations spent $billions on Enterprise Resource Planning (ERP) technology and many believed they could not be competitive without ERP. The philosophy was to replace "islands of information" with a single software platform that integrated all management functions, particularly manufacturing and distribution.

Repetitive Manufacturing stressed the optimization of physical production resources. Based on historic trends ERP assisted manufacturers forecast new orders and enabled collection of information to measure efficiencies on the shop floor and worked towards improved standards. It also provided a better means of ensuring that resources (e.g. raw materials) were available when equipment was scheduled to run by automatically creating material requirement planning (MRP) runs for purchasing. ETO Manufacturing on the other hand, was often unable to benefit significantly from concerted efforts to reduce shop floor waste.

As market conditions changed and manufacturing became a more order-driven environment, industry adopted systems such as "Just-in-time" and "Kanban". By this time many existing software applications were unable to adequately support new operational flexibility. As headcounts reduced, the need to input some types of data often became more of a hindrance than a benefit. However, the ETO manufacturing environment was always run on an order-driven basis because of the difficulty in forecasting custom requirements. MRP therefore provided no benefit and ERP systems often demanded more data input without the expected benefits

So how can North America excel in an increasingly competitive environment? There certainly seems to be a need for a fundamental change in approach regarding the use of human capital in ETO manufacturing. Such a change needs to be innovative, easy and quick to implement, non-disruptive, cost effective, and result in significant long-term improvements.

Fundamentals of ERP

Enterprise Resource Planning (ERP) is an established software technology designed to manage the detail of manufacturing a complex product. Figure 1 illustrates the core functions of an ERP system where a user interface enables the input, review, and maintenance of thousands of elemental bits of data. A major proportion of this data is related to a product's definition, i.e. its constituent components and materials, as well as a list of the fabrication processes required to manufacture the product. ERP can readily tally the costs of assets, procurement, and labour for any combination of resources as long as the product definition has been fully detailed.

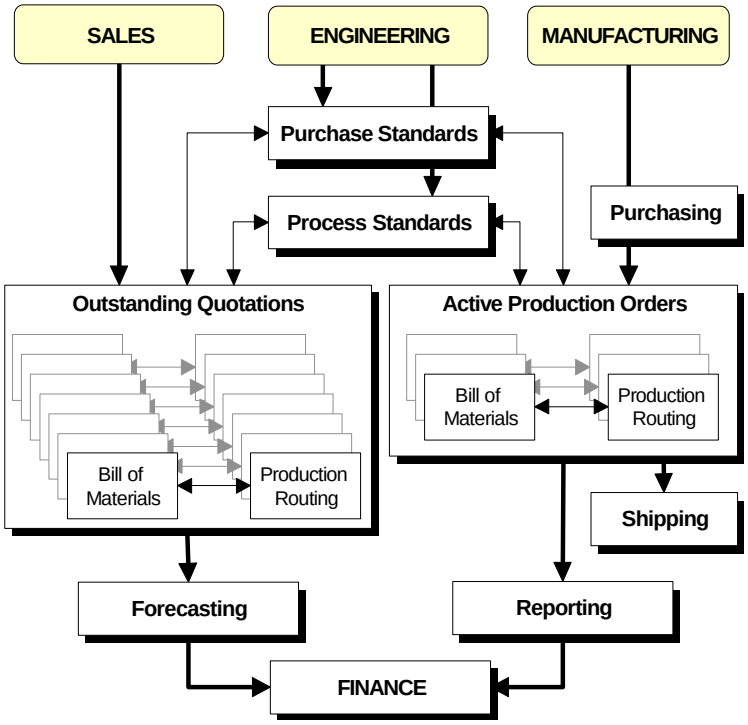

Figure 1 Schematic representation of ERP functionality

Figure 1 illustrates how the Sales, Engineering, and Manufacturing functions provide the inputs intended to deliver real-time feedback to Finance as a measure of the pulse of a business. The number of outstanding quotations managed by Sales can typically outnumber active production orders by a factor of 5 or more.

To be effective in tracking the health of any company, ERP must embody considerable detail in the Bills of Materials and Production Routings. This data is traditionally maintained by staff who understand how a product is designed and built.

Current ERP technology has evolved over several decades into a complex computing environment connecting hundreds or thousands of employees to a central database. Implementation of such systems can consume many man-years to ensure that a company's operational profile is adequately represented.

Changing Market Conditions

When ERP was first introduced in the 1970s, it was known as Manufacturing Resource Planning (MRP). At that time it was an extension of order processing technology which automated the issuing of statements to customers. MRP was so successful in reducing overhead burden that it seemed logical to extend its reach into the realm of manufacturing operations. At this time North America was the dominant global producer and industrial profitability made it feasible to absorb the growing cost of using MRP. However manufacturing has traditionally relied on a high degree of technical expertise provided by experienced staff familiar with formal and informal procedures. This approach can suffer many drawbacks due to poor communication between decision-making engineers and production personnel.

Through the 1960s and 1970s, industry often had to contend with issues such as unresolved product design errors, inferior drawings and non-optimized production processes. To overcome these issues, and as a result of Total Quality Management (TQM) in the 1980s, manufacturers became increasingly reliant on software systems to manage operational data efficiently. A testament to the demand for reliable and reasonably priced product was the insistence on ISO certification by many customers as a prerequisite to doing business. A good business system was often a key differentiator and could make the difference between profitability and failure. However, with increasing system complexity and increased product customization, this traditional approach became more and more problematic.

In the 1990s, functionally-overextended systems began to have a negative impact on manufacturing operations and productivity. This was coincident with the IT downturn, a recession, and increasing foreign competition. It now appears that the recession is actually a correction as global production and supply shifts to other population centers such as China and India. Although human productivity is still higher in North America due to technology, the dramatic difference in labour costs is now becoming a cause for concern because North American ETO products are often overpriced internationally. The marketplace today is quite different from a decade ago. With unprecedented foreign competition and declining profitability which forced numerous layoffs, industry now appears to be critically understaffed in many areas.

The last decade has given rise to the Lean Manufacturing movement which strives to eliminate all unnecessary waste from operations. The indirect manpower once dedicated to maintaining MRP databases is now in short supply. At the same time ERP, the descendent of MRP, is now often so complex that it requires *more* manpower to operate effectively and efficiently. The cost-saving benefits of ERP, once taken for granted, are now in question. Clearly a new approach is required to bolster industrial productivity.

Demand for Product Customization

Today customers demand an unprecedented level of customization in many of the products they purchase. As North American manufacturing moves to jurisdictions offering lower labour costs, the domestic firms are often compelled to meet the demand for "one-off" production. This places a further burden on industry to tailor each order to the customer's specifications while the expectation is for delivery faster than ever before and at lower cost. If an ERP system is to serve its purpose, the Bills of Materials and Production Routings that drive cost accounting must be more extensive and more accurate than was necessary in the past. Often operating at razor-thin margins, manufacturers must have accurate knowledge of their costs in order to win business and be profitable.

This new market environment is where Engineer-to-order manufacturers have traditionally operated. However, the profitability which helped absorb inefficiencies in internal processes is no longer guaranteed. Industry is looking to the Lean movement to remain competitive, and all impacts to the financial bottom line are under scrutiny.

ETO manufacturers are distinctly different from Repetitive manufacturers. Where Repetitive Manufacturing has high volume output at low unit sale value, ETO manufacturing is the converse, low volume output at high unit sale value. This characteristic has a major impact on the ETO manufacturer's product cost structure. ETO product costs more per unit to sell, to price, and to deliver. It is this difference that places a significant burden on the ETO manufacturer to use conventional ERP effectively because the Bills of Materials and Production Routings are large, detailed, and in a constant state of change. This is illustrated in Table 1 which compares ETO Manufacturing to Repetitive Manufacturing with respect to several important variables.

Characteristic	Repetitive Manufacturing	ETO Manufacturing
High Volume Output	Yes	No
Static Designs	Yes	No
Static Routings	Yes	No
Low Unit Labour	Yes	No
Low Cost of Sales	Yes	No
High Skills required	No	Yes
Smooth Supply Chain	Yes	No
Forecasting	Yes	No

Table 1 Repetitive versus ETO manufacturing

Use of ERP in Engineer-to-Order Manufacturing

Productivity must continually increase if industry and the economy are to continue growing. ERP's contribution to productivity must be taken in the context of its application in industry. Figure 2 illustrates how performance of conventional software technologies in manufacturing varies as a function of the degree of product customization. Note that over a 30-year period, the usefulness of technology like ERP has peaked and is now appears to be in decline in many areas as industry switches emphasis from repetitive to engineer-to-order manufacturing. The result under current market conditions has produced a technology gap, i.e. ETO manufacturers are lacking the commercial solutions to provide new productivity gains.

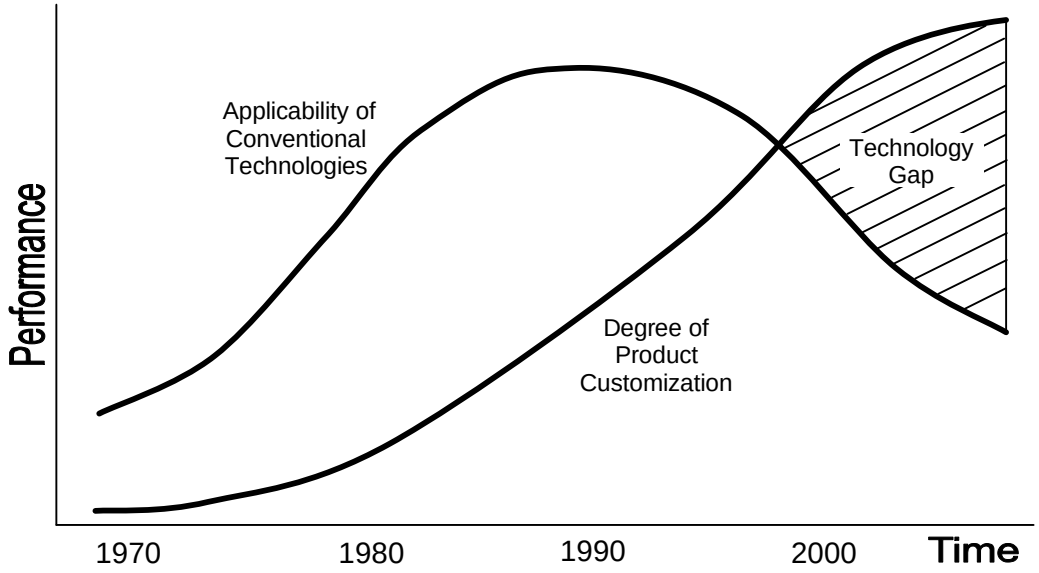

Figure 2 The evolving technology gap in ETO manufacturing driven by changing market conditions over several decades

Approximately 100 Engineer-to-order manufacturers in the United States and Canada were surveyed and most were not using the full range of ERP functions in the systems they have implemented. In fact,

many of the companies surveyed have abandoned or had limited commercial ERP systems in operation at all. Table 2 provides a general breakdown of the major solutions used in the surveyed group. Most of the respondent companies had annual revenues ranging from $25 million to $100 million. Many of the larger companies generally use ERP technology solutions while the smaller companies did not. In addition a number of the users of current ERP technology were considering replacing their systems for the 2nd or 3rd time in the last 10 years.

Nature of Software Technology Tools		% of ETO Companies Surveyed
1	Current commercial ERP system, supports all aspects of the operation	10%
2	Current or outdated commercial ERP system used only for financial functions, spreadsheets used for costing and quoting	30%
3	Home-grown information management system with various single-user commercial software tools	15%
4	No ERP system, using independent commercial applications for quoting, costing, production planning and labour tracking	45%

Table 2 Technology solutions in use by surveyed ETO manufacturers

Many of the surveyed ETO manufacturers expressed frustration with their technology platforms. Hampered by a shortage of personnel, they often did not have the resources to input the details for every quotation and production order. ERP was not always able to assist with revenue forecasting or accurate production tracking. As a result many believed that the only technologies considered to be truly useful were computer-aided design (CAD), computer-aided machining (CAM), and accounting.

The Root of the ERP Problem

Manufacturing any product begins with product design. The more variable the design the higher the cost of delivering a consistently high-quality product within ever-compressed delivery deadlines. Engineer-to-order manufacturers often must design a new product for every quotation requested and for every purchase order. If the design process is performed informally using skilled human resources, a minimum contingent of high-cost indirect workers is required to allow a company to continue operating. Cost reduction options are often limited.

The staying power of manufacturing in North America will rely on delivering engineer-to-order products at pricing comparable to repetitively manufactured products. A viable solution to this dilemma is improved efficiency through better technology and reduction in human labour. This will offset the price advantage of foreign competition due to lower labour costs. Automation must start with Product Design and permeate Sales, Purchasing, Production and Performance analysis. The industrial revolution demonstrated that replicating human behavior with machines produces low cost repeatable and predictable results. Just as computers today have been taught to compete with world champion chess players and win, applications must be taught to decipher input requirements to produce efficient designs that meet customers' expectations. Some work has already been done in this area but much more is required if North America manufacturing is to regain its once dominant position in the world market.

In many cases ERP has not provided ETO manufacturers with cost-saving benefits. This is because ERP does not inherently 'know' how to build a company's product. ERP is not a knowledge automation technology; it is merely a knowledge storage technology. Therefore, use of conventional ERP often adds another layer of overhead to the operations of an ETO manufacturer because after engineers and technicians have informally designed another one-off product, they must then commit the details to a database. In today's highly competitive global economy, there is often simply not enough manpower to do this extra work efficiently and cost effectively.

Changing the Philosophy of Manufacturing

North American manufacturers have long prided themselves on formalizing the production process. It started with leaders such as Henry Ford in the early 20th century. Management has concentrated on reducing the direct labour in manufacturing through investment in high-performance machinery. In parallel, rigorous efforts have been made to press suppliers for lower-cost materials. Unfortunately in many cases one significant contributor to high costs has gone relatively unnoticed. Industry has failed to adopt technologies that formalize the product design process. CAD has dominated the manufacturing landscape since the 1970s but it is still no more than a knowledge storage technology. Attempts at bridging the gap between CAD-based engineering and ERP-based data management have had limited success in the form of Product Lifecycle Management (PLM) technologies because they too only offer knowledge storage. The next great wave of industrial technology will undoubtedly arrive in knowledge automation platforms.

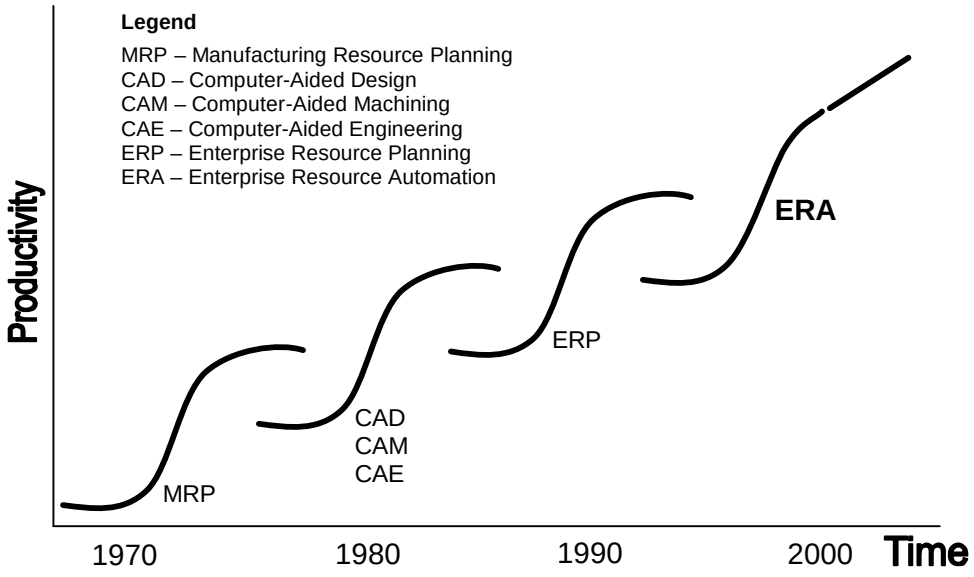

Figure 3 The evolution of software used in manufacturing

Figure 3 illustrates the technology adoption cycle observed for software used in manufacturing. In the 1970s, Manufacturing Resource Planning (MRP) was sufficiently advanced to support repetitive manufacturing. MRP's contribution leveled off in the 1980s. As computers increased in power, engineering software emerged to assist designers describe complex products in great detail and prepare numerical instructions to drive shop floor machinery. Through the 1990s MRP evolved to offer a broader scope of data management in industry and became known as Enterprise Resource Planning. In many cases ERP could not offer the support required for increasing product customization and the technology often failed to generate the expected return on investment.

Engineer-to-order manufacturers were the first to observe some of the problems in their market environment. The ETO industry is now struggling as it investigates alternatives to conventional technologies. A new concept is proposed which introduces the philosophy of Enterprise Resource Automation, or ERA. ERA has the potential to revolutionize manufacturing by minimizing or eliminating dependency on human resources for executing the knowledge processes required.

Fundamentals of Enterprise Resource Automation (ERA)

A brief review of ETO Manufacturing suggests that the following features are required in an ERA system:

1) A straightforward user interface tailored to the processes characteristic of engineer-to-order work flow
2) Sales force automation to prospect and track existing and potential customers
3) Direct link between the customer and the production floor to eliminate delays and errors
4) Automatic design of complex products by non-technical personnel, either sales representatives or customers
5) Automatic generation of all technical documentation required to meet a customer's unique specifications;
   a) *Digital Prototype* – detailed 3-dimensional geometric model of the proposed product
   b) *Bill of Materials and Process Plan* – to calculate delivered cost, i.e. a quotation
   c) *Requests for Proposal* – automatic costing of engineered products purchased from subcontractors
   d) *Purchase Orders* – to ensure the right materials and components are received on time for production
   e) *Production Schedule* – to ensure promised delivery dates are met
   f) *Engineering Drawings* – to ensure shop floor personnel know *what* to build
   g) *CNC Programs* – for automated machining of components and robotic welding of assemblies
   h) *Production Routing* – to direct shop floor personnel exactly *how* to build, using the 3D digital prototype as a visual guide
   i) *Maintenance Documentation* – to guide customers and/or field service personnel in maintaining the product after delivery
6) Integration with Engineering CAD and CAM systems for last-minute pre-production design and fabrication modifications not accommodated in the automatically generated product design
7) Automatic collection of key work-in-process status data, most conveniently through touch screen interfaces on the production floor
8) On-line storage of key operational data for rapid review and analysis including;
   a) Value and probability of closing of outstanding quotations
   b) Demand levels for ETO product by configuration characteristics
   c) Patterns for interest in quotations and purchases by geography, timeline, and industry sector
   d) Materials, components, and labour requirements for outstanding quotations
   e) Outstanding purchase orders for subcontract items required to fulfill a specific customer order
   f) Active production orders and work-in-process status

9) Pictorial representations of key analysis results to permit rapid evaluation and decision-making by all levels of the organization.

10) Classic financial system for managing accounts.

Furthermore, in an ERA environment the operating platform should be web-based for global access by any authorized individuals. This would allow an ETO manufacturer to sell anywhere anytime, even with foreign agents using the company's automated knowledge processes to design and price product accurately 24 hours a day 7 days a week in any language, currency or dimensional unit system.

Note that an ERA platform would revolve around a product knowledge engine that processes any pre-defined set of customer specifications predictably and accurately. This core technology element is the distinguishing factor setting ERA apart from conventional ERP which does not support automated design of a product. Figure 4 illustrates how such an enterprise environment would differ from that of ERP as illustrated in Figure 1.

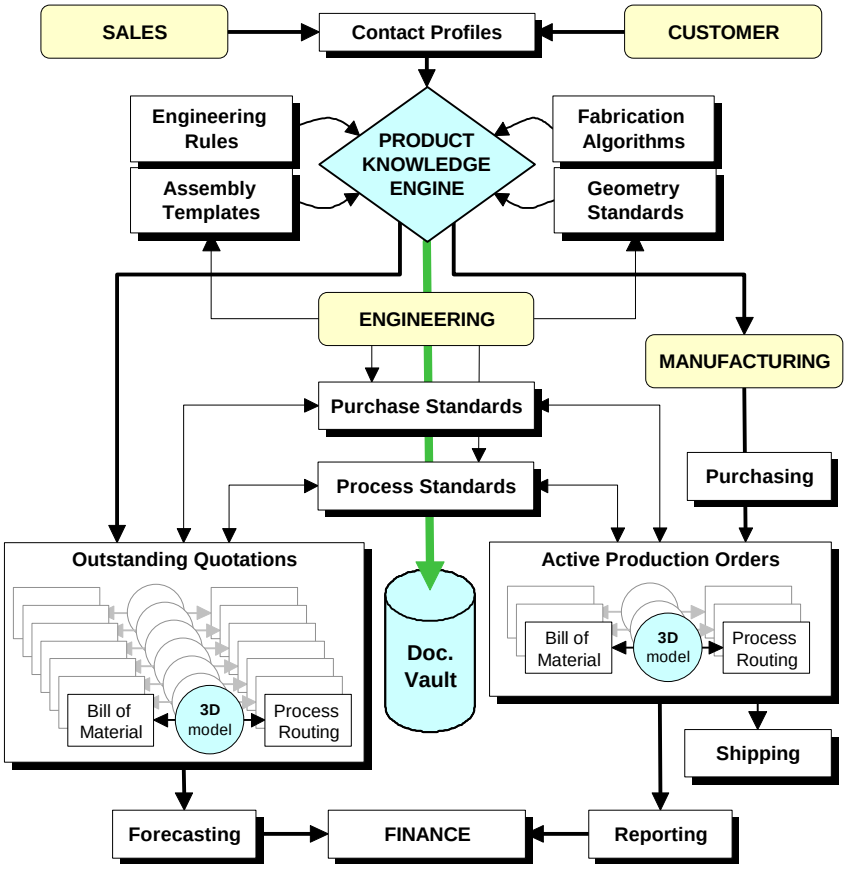

Figure 4 Schematic representation of ERA functionality

In an ERA environment, every event prompting action by the manufacturer would be processed through a Product Knowledge Engine. This 'engine' would be trained by the Engineering Department to compute the design of a uniquely-configured product and generate the documentation required to sell, build, and service the product. The data standards driving the engine's performance would need constant maintenance and update to reflect the company's changing markets and products. All other downstream ERP-like functions would be supported by the following important enhancements:

1. Bills of Materials and Production Routings would be created automatically to provide Finance with an accurate real-time picture of the company's position.

2. Routine processes such as issuing requests for proposal for subcontract materials and manufacture would be conducted primarily without human intervention.

Why ERA Adoption Is Inevitable

The pace at which human labour is replaced with automation is accelerating. In manufacturing, efforts have concentrated on replacing physical labour processes with machinery. In many cases is the knowledge-processing arena, Sales, Engineering, Estimating, Purchasing and Production Planning,

have remained virtually untouched. Manufacturers need to successfully formalize their design and fabrication processes. This can be achieved through automation in a computing environment.

The advantages of using ERA in any Engineer-to-order company are potentially significant. Within minutes of receiving a request for quotation from a prospective customer, the ETO sales representative could automatically design a unique product to meet exacting specifications. A quotation and compelling visuals could be generated within minutes and emailed to the prospect for review and approval. If the prospect were ready to order the quoted product, the sales representative could then launch a Production Order, and ERA would take care of almost everything else. Increased productivity and cost savings could be significant because cycle times for quoting and delivering finished ETO product would be drastically reduced. Human effort and error would be eliminated from most of the process of meeting a customer's unique requirements. Rapid response to customer demand would become the norm and any manufacturer *not* using the ERA approach would be at a considerable competitive disadvantage.

Current Support for The ERA Philosophy

Engineer-to-order design is the most complex of industrial automation tasks. Other subsets of ETO design include configure-to-order, build-to-order, and assemble-to-order approaches. These approaches operate on the basis of pre-engineered components that are combined in a finite number of configurations. True ETO requires that the technology platform actually performs analytical computations to solve engineering equations during the design generation process. Leading ERP vendors offer basic configuration technology integrated with their enterprise environments. These solutions are limited because standard configurators do not perform detailed engineering design or generate digital prototypes or pictorial documentation. Several commercial software systems in the marketplace were reviewed to identify vendors offering viable ERA platforms. This technology is in its infancy and few vendors exist at this time.

The shortage of vendors providing ERA-like solutions can be explained by the complexity of the problem. Many manufacturers have dedicated many person-years to internal projects intended to automate the design of their products. Problems have arisen because a useful outcome must solve two major problems:

1. Standardization of 3D component geometry and associative tabular dimension data for 100s or 1,000s of families of purchased components

2. Encapsulation of engineering rules, equations, and configuration relationships in a robust knowledge platform with enterprise-wide access.

In the next decade North American manufacturers will need to address both standardization and rule encapsulation to be efficient and competitive.

Conclusions

In many industrial applications ERP is no longer able to deliver the productivity gains needed by engineer-to-order ETO manufacturers to remain competitive in a global market. A promising new concept ERA, was discussed. This is an industrial software technology platform that could bolster North American manufacturers' fortunes in the face of increasing foreign competition. Today's ERP vendors need to provide leadership in the ERA realm. Unfortunately many companies appear preoccupied with survival as the industry shrinks and competition increases. Industry's support for ERA may be the answer and will undoubtedly create a new cadre of software leaders.