Adopting Advanced Technology During an IT Downturn – A Case Study

P.E. Doherty, Department of Business & Economics, Wilfrid Laurier University, Waterloo, Ont., Canada, N2L 3C5
Telephone Number: (519) 884-0710 ext. 6295, e-mail: pdoherty@wlu.ca

Paper presented at
The Ninth International Conference on Industry, Engineering, and Management Systems
Cocoa Beach, Florida, March 19, 2003

Abstract

North American industry is constantly being challenged by the need to maintain and/or strengthen its position in manufacturing. In particular, many companies need to continuously adopt advanced technology in order to improve the quality of their products and the speed at which products are designed and produced. This is occurring at a time when there are strong pressures to reduce costs. With each passing year this is becoming more and more difficult because many fixed costs, including labor and material, have been rationalized to a point where there often seems to be little, or no room for improvement. However engineered-to-order assemblies, such as machines, structures, and pressure vessels often bear a high hidden component of engineering expense, a cost that is now threatening to undermine the competitiveness of many companies in the global marketplace. For example in the case study reviewed in this paper, we found that technical human resources could consume up to 10% of a manufacturer's annual revenue in engineering and applications sales. This can occur while delivery lead-time for quotations and production can stretch for weeks.

In order to effectively compete companies need to be innovative, adaptable and use enabling technologies.[1] This is particularly difficult during a technology sector downturn when companies need to find and justify approaches to generate business when resources are difficult to obtain. "Business Intelligence" software has been identified as one of six new emerging technologies that may boost business results as we emerge from the current IT recession.[2] New revolutionary software-based business-enabling technology (BET) is now available to minimize this cost by automating product design processes and costing for custom manufacturing. Manufacturers with the vision to apply design & costing automation (DCA) could benefit from dramatic reductions in costs and delivery lead-time. Unfortunately these products and services are becoming available at a time when companies are having significant difficulty in justifying expenditures during an IT downturn.[3] This paper reviews a novel approach that could have a significant impact on how manufacturers of engineered products do business and the implications for the future.

Details of how a manufacturer of pressure vessels adopted a new design & costing automation (DCA) technology and reduced engineering lead-time by 90% and internal fixed costs by approximately 5% of annual revenue will be discussed. The case study company had marketed its engineered-to-order products worldwide but was losing business opportunities. This was often due to delays in the standard design and quoting processes used. It was recognized that automating some of the repetitive design process could enable the company to respond very quickly to requests for engineering changes and shorten delivery lead-time. In this case the DCA technology was quickly implemented and within months detailed designs for any variation in one product line was in place. Now the company has 10 product lines defined in the DCA platform and can design and cost any variation in less than an hour. The return on investment (ROI) for this particular system was less than six months. However even with this type of success many companies that supply DCA type technology platforms are having difficulty in justifying their approach to other companies some of which have even greater potential. The reasons for this are discussed in detail.

Introduction

In the past decade business-enabling technologies (BETs) have become a more important part of business transactions.[4] For example the use of "Expert Systems" and data handling software has risen sharply in engineering based applications and is projected to reach $13B by 2004.[5] The potential for manufacturing companies to experience time and cost savings is significant. However this has not necessarily resulted in a smooth or steady transition for applicable businesses. This is because management often thinks that their value and logistics chains have been rationalized to the point where there is little or no room for further substantial savings. However based on this and other case studies, we believe that it is possible to make significant savings in production and sales cycle management of many manufacturing companies through a new innovative and novel approach described below. Figure 1 illustrates a general trend in market capitalization of IT companies over the history of the modern computer age. In the 1960s and 70s, IBM was the dominant player with products and expertise in both hardware and software. The computer industry then was so complex, that disparate systems could not be integrated economically. The 1980s and 90s gave rise to new IT companies that developed infrastructure products that *could* be integrated at relatively low cost. Here, companies life Microsoft, Intel, Oracle, etc. built businesses with combined market capitalization significantly larger than that of IBM.

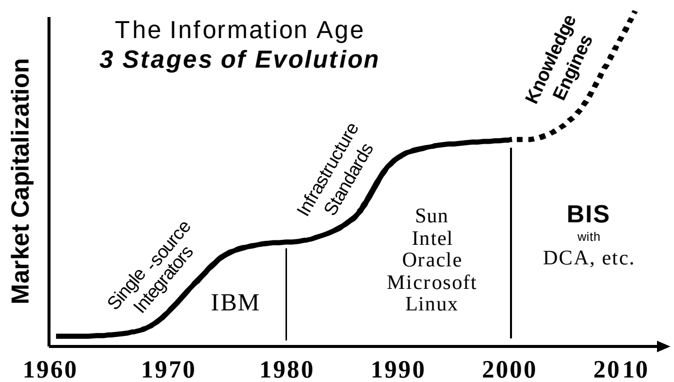

Figure 1 - General trends in the value of IT technology

The dashed part of the curve in Figure 1 represents an extrapolation of the recent history of IT capitalization. The infrastructure components became commodities during the last cycle and will be further integrated by emerging IT companies engaged in embedding human intelligence in easy-to-use technology platforms.[6, 7] The author believes that the next trend will be based on development of true computing intelligence perhaps in parallel with smaller multifunctional computer systems.

Engineered Products

There are a number of arguments that value chain management has been optimized to the point where there are diminishing returns, even after the application of further investment in technology and manpower. This is based on the premise that management may accurately know all the elements in their supply chain. This is often the case with respect to known factors such as transportation and material costs, actual production time, and labor costs. These factors are usually accurately known, measured and controlled. However Figure 2 provides an illustration of the numerous inputs from personnel in any given order process for an engineered product, i.e. the process that occurs between the time an order is taken for an engineered product, until the time it is produced and delivered to the customer. Our study indicates that there is one major hidden factor, i.e. engineering process redundancy. We have found this to be particularly true for manufacturers operating in engineered-to-order industries that produce products that are 80 - 90% "standard" with some degree of customization.

Hidden Engineering Inefficiencies

With right approach and multi-disciplinary expertise it is possible to positively identity areas where there are huge inefficiencies in manufacturing front-end processes even though they can be difficult to spot and quantitatively measure. Problem areas require insight and the appropriate knowledge and approach, including detailed knowledge of many areas including, sales, product configuration, engineering design, production planning, procurement, and shop floor fabrication. For example, it was found that 80% of all engineering drawings are produced using timeconsuming manual processes even with the availability of computer-aided design (CAD) systems. The author has found several cases where “highly efficient,” productive and profitable manufacturing companies had significant hidden inefficiencies/costs.

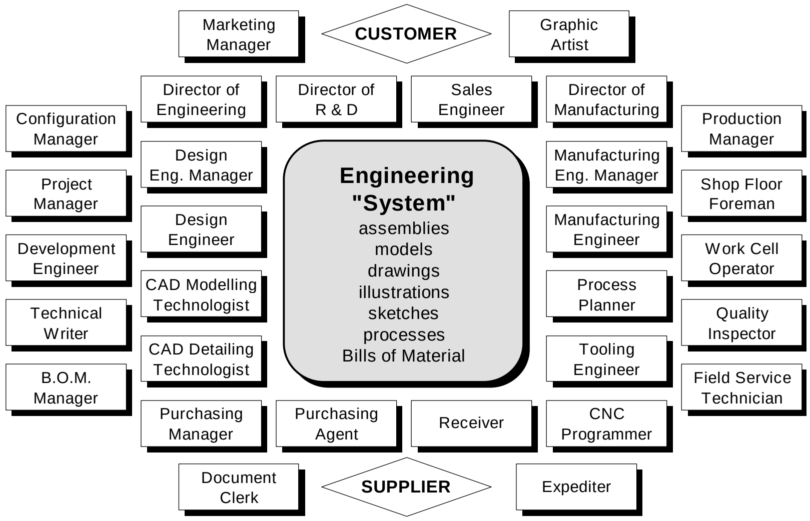

Figure 2 - General Summary of some of the Personnel Involved in Building an Engineered Product

It is clear that there can often be significant redundancy built into many informal processes and many are difficult to measure. This type of redundancy appears to have become more entrenched in recent years as a result of job insecurity and a downturn in the manufacturing sector and engineering work. Given such a scenario, there are huge possibilities for further extraction of waste and efficiency improvements in conventional manufacturing operations. This has the potential to competitively disrupt traditional business approaches. It is envisaged that once the extent of the impact of this problem is fully understood, it will force companies to become more compliant with this type of technology and approach. The increase in competitiveness of visionary companies adopting this approach is expected to have a revolutionary effect on how many manufacturers do business. This article reviews a specific solution to the problem.

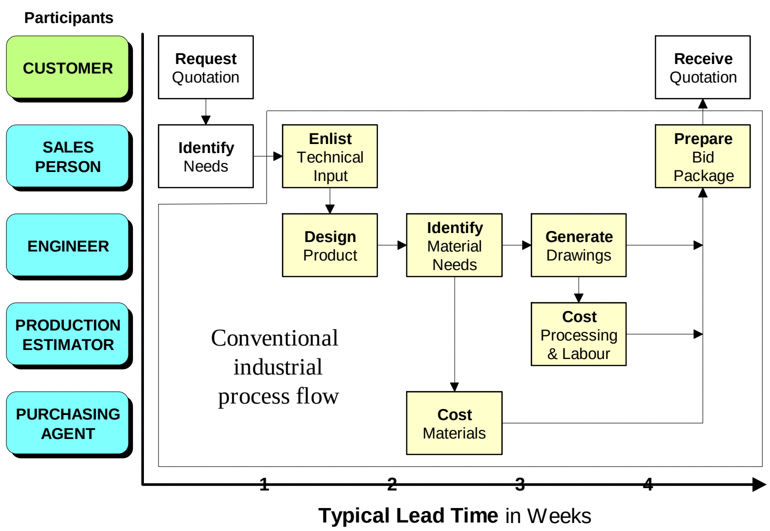

Figure 3 - Traditional Quote Preparation Process for Highly Engineered Products

Figure 3 represents the traditional approach to winning and delivering orders for engineered products. The following steps are often repeated multiple times while a complex designed is iterated to a final, price-optimized configuration:

1. The sales representative interacts with the prospect to collect specifications, which will dictate the detailed design of the desired product.

2. The sales representative persuades the Engineering department to assign personnel to respond to a particular request for quotation.
3. A dedicated engineer develops a preliminary product design. Uncertainties in the process include quality of input as well as qualifications, experience, and dedication of the engineer. The efficiency of the process is highly dependent on the sophistication and ease-of-use of traditional engineering software tools such as CAD and analysis routines. In many cases, one senior engineer supervises the activities of a team of less qualified technologists / engineers. Due to the large number of inputs and variables in many engineered products there are numerous viable designs that can comply with customer requirements and production capability. They are not always optimized for minimum cost and maximum utility. Furthermore, if more than one design project is being processed at any given time, there is more potential for design inefficiency and error. (Its was noted in our study that systematic errors of this kind are very common. These errors are often reflected in Engineering Change Orders that invariably delay purchasing and production.)
4. The engineer then extracts a Bill of Materials from the preliminary design, submitting this critical costing data to a Purchasing agent. The medium of transmission is often paper, a spreadsheet, or an ERP database. Discrepancies in part numbering, typographical errors, or unwitting omissions often interfere. Secondly, the engineer creates one or more drawings to depict the physical product configuration so that the production department can formulate a plan for product fabrication and assembly. This information is generally created interactively using CAD technology or even paper.
5. The purchasing agent refers to the manufacturer's standard cost records to calculate the cost of procured components and raw materials. Without detailed dimensional information and material specifications, there is potential for significant variations in costing. Repeated communication between the engineer and the purchasing agent is often required to isolate a specific requirement. This is the traditional engineering approach and is endemic in the majority of manufacturing companies.
6. Concurrent with procurement costing, an estimator reviews the draft production drawings and summarizes the anticipated total labor and machine processing content of the finished product. After several iterations, and often punctuated with engineering design change, the production planning department commits to an estimate for shop capacity requirement to meet a delivery date.
7. Because several functional departments are involved in this complex process, a project manager is often required to correlate design documentation and dependent costing data. Before a firm quotation can be mustered for delivery to the prospect, the Sales / Engineering / Estimating teams are required to do a final review. It is also likely that an approval drawing must be generated to serve as a contractual document accompanying the itemized quotation.
8. The sales representative finally collects the raw data representing the cost of purchasing materials, fabrication, assembly, and testing, and adds the profit margin to present a firm quotation to the prospect. If price and/or functionality do not meet the customer's expectations, the entire process may be repeated.

Assumptions of the nature of the engineered product being defined and priced in the foregoing process, include:

- Approximately 10% or less of all quotations win a purchase order.
- The end sale price is greater than $10,000 per unit.
- Material cost is approximately 30% of selling price.
- Net margin before taxes averages 10%.
- Quotation delivery lead-time minimum 1 day, average 3 weeks.
- Delivery lead-time proportioned as 50% engineering, 50% production.
- Orders are often lost due to delay in responding to requests for quotation, or unacceptable product delivery lead-time.
- Systematic errors result in unforeseen engineering and production rework. In extreme cases this can result in losses due to unexpected delays, material overruns, rework and errors.

The Business-Enabling Technology (BET) Model

It is approximated that manufacturing companies with annual revenues greater than $10M spend at least 5% of sales in overhead functions dedicated to design and costing.[8] In mature markets, where there is little differentiation, profit margins are often slim and this fixed cost has the potential to make or break a company. Success is often dependent on a differentiation strategy in customer service, product quality, and minor product differences. However in many cases the low-cost producer approach is now in danger of being superceded. This is because it is often not possible, with the global economy, to find significant differences in material costs and production time. Indirect labor content can be the differentiator. As a result, specific types of manufacturing are in steep decline in many parts of the developed world.[9]

The BET model recognizes the fixed cost impact of indirect labor where it is required to deliver high-knowledge technical services. It is clear from the cases evaluated to date that engineering time for many applications is not as efficient as once thought. For example, in the case study discussed in this paper, it was found that there was approximately 80% redundancy in traditional approaches. Management was totally unaware of the inefficiencies inherent in this particular plant. Additional studies briefly discussed later in the paper have proven this situation to be ubiquitous in any plant that requires some customization of traditionally standard engineering practices. For example, in Figure 2 above, management was fully unaware of the redundancy of many of the routine work activities of personnel in Sales, Engineering, Purchasing, and Estimating. It is clear from our studies that many engineers and technologists have an entrenched interest in maintaining the status quo and that management is not fully aware of this fact.

Technology Platform Used In The Case Study

The "Expert System" technology that successfully overcomes the limitations of the traditional model described above, supports the functions of various departments with features including:

1. Internet browser-based providing ease of use by non-technical personnel and for operation on multiple computer platforms
2. Reproducible, automatic generation (for any allowable product configuration) of;
   a) a detailed CAD digital prototype representing an assembled product from pre-programmed configuration options
   b) a Bill of Materials with part numbers and component factors (or quantities)
   c) a compact browser-viewable 3-dimensional model of the generated assembly
   d) any number of 2-dimensional detailed drawings of the CAD assembly
3. Access to the CAD digital prototype for further design refinement following a design automation session
4. A convenient multiuser webserver platform comprised of a Intel-based Microsoft Windows computer connected via TCP/IP to an existing network environment.

Market Position of Design & Costing Automation (DCA) Technology

The position of DCA within the Business Intelligence System" (BIS) marketplace is described in Figure 4. Established industrial technologies and projected 2004 market sizes are included. Technology acronyms used in the figure are:

- ERP – Enterprise Resource Planning
- PDM – Product Data Management
- CAD – Computer-Aided Design
- BIS – Business Intelligence Systems
- DCA – Design & Costing Automation

The dashed curve represents the envelope of emerging technologies that make only *incremental* improvements on ERP, PDM, and CAD. This is because they are still interactive technologies, relying on many skilled workers to operate them on a regular basis.

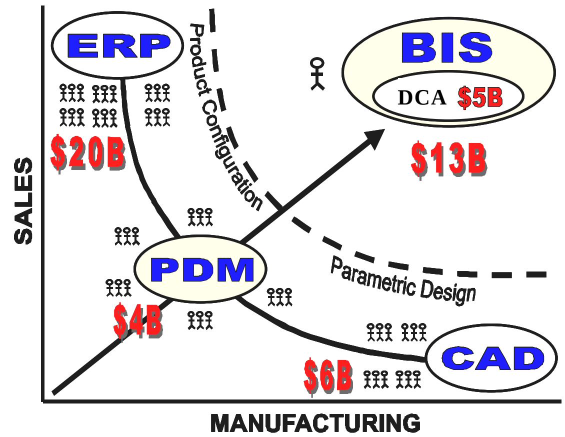

Figure 4 - Position Diagram for Sales And Design Technology Tools
(Market sizes projected to 2005, $US)

DCA crosses into the BIS space with high-value knowledge automation directed at support for manufacturing. DCA's niche is estimated at $5B by 2004 using the following assumptions:

a) An estimated that 100,000 North American manufacturers with annual revenues of $10M or more are prospects for this technology

b) Assume 20%, or 20,000 are ready to buy each year.

c) The revenue model assumes a total sale of $250k (conservative) per installation.

d) Market size is 20,000 x $250k = $5 billion.

DCA technology is expected to take advantage of the current industrial trend to outsource products and services. "Outsourcing, once seen as strictly a cost-cutting move, is fast becoming an accepted business strategy."

Application of The DCA Model

Figure 5 schematically illustrates how DCA technology works. Described by the CEO of the Case Study Company as its "*engineer in a box*," DCA technology uses an "Expert System" approach which virtually eliminates redundancy by reproducibly generating detailed, complex 3D geometric designs, which conform to all pre-programmed rules for product design and manufacturing. As a result, data required for costing and fabrication is inherently accurate as it is intimately tied to the variational dimensions and material specifications mustered by the automation process.

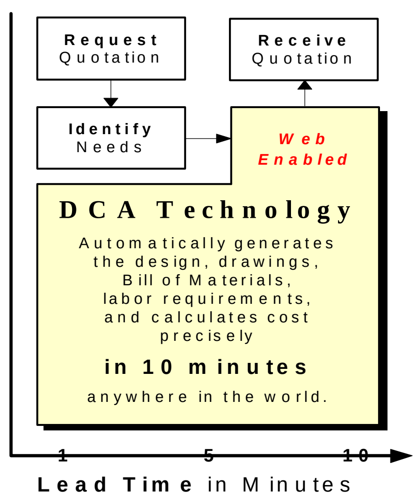

Figure 5 - Novel DCA Quote Preparation Process for Highly Engineered Products

The implementation of a DCA platform demands unique skill sets to formalize product definition as it applies to each manufacturer. The full description of all possible configuration options of a given product must be described in relation to commercially available components and materials. The author noted that for many applications designs were not fully understood or documented (often as a result of experience based decision criteria as opposed to using formal documentation) and this caused several problems in DCA implementation because there were gaps in the information required to do an effective analysis.

System Design of The DCA Model

DCA technology demands the construction of a detailed product knowledge model (PKM) or "Expert System" describing all possible variations of a specific product family. A unique combination of conventional database alphanumeric entries and a pool of associated 3D CAD geometry form the knowledge components of a DCA system, segregated into 4 categories is provided below:

1. **Product specifications**
2. **Product structure template**
3. **Rules base**
4. **Component specifications**

The computer environment that supports a DCA knowledge base is web-based. Commercial software components include an SQL database, a 3D parametric assembly solids CAD engine, multiple document format translators, and an Internet browser with miscellaneous utilities. The DCA platform is concentrated in the rules-based expert system and the data formats, which allow flexible integration of geometric and non-geometric data into a comprehensive product definition. Figure 6 below illustrates a typical DCA technology architecture.

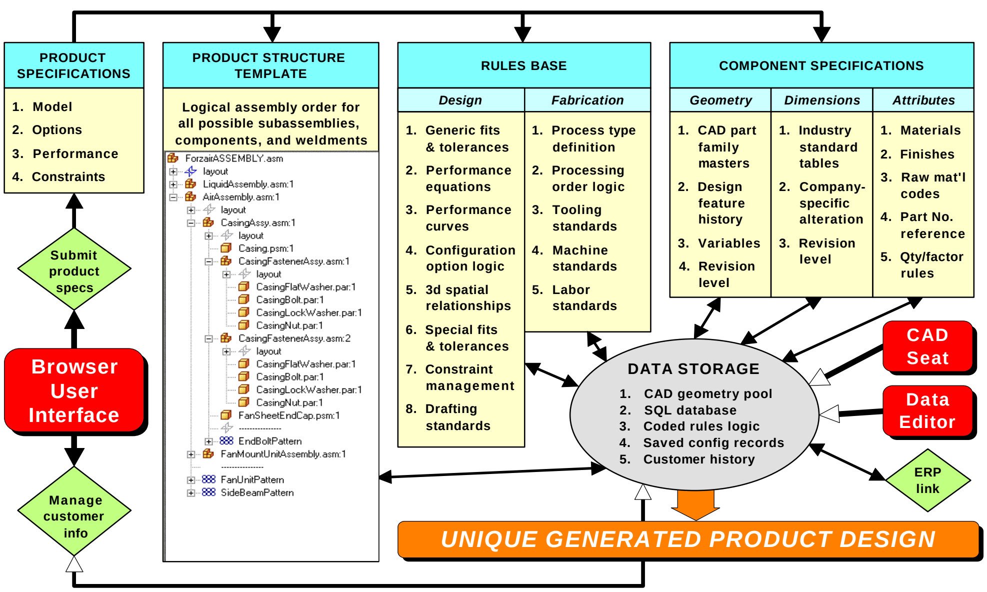

Figure 6 - Typical DCA Technology Architecture

Case Study Company Profile

The Case Study Company has been manufacturing filtration pressure vessels since 1985. The company found that its business opportunities shrank by 20% in recessionary times. In 2000, sales were stagnating even though there were market opportunities in the vessel sector. Cost competitiveness, delivery lead-time, and responsiveness to RFQs were found to be deciding factors in many cases. In addition, many manufacturing activities were not fully optimized or documented due to an informal Engineering process used traditionally in the company. Management realized that the situation needed to be rectified and investigated potential knowledge engine providers in their immediate geographic area. Fortunately a company that was involved with expert systems was able to review their designs and processes and in a short period of time designed and implemented a company specific DCA system.

Product	Filtration Pressure vessels ($10,000+/unit)
Configurability	80% of sales are standard variations
Cost Elements	Engineering, Material, Welding
Annual Revenue	$12,000,000 (240 units/year)
Quote Success	10% (~2,400 quotes/year)
Sales Staff	$350,000
Estimating staff	$100,000
Engineering staff	$350,000
Staff Costs Total	$800,000 (12 people excluding overhead)
Cost of Std. Variations @ 80%	**$640,000** fixed annual cost

Table 1 - Company characteristics

Table 1 provides a general summary of the case study company's characteristics. This company encountered difficulties in implementing DCA because there were many serious deficiencies in their engineering paperwork. The company had no formal product definitions supported by production and process standards. Much of the technology was limited to company know-how, experience, and empirical knowledge. This was their traditional approach, which, by definition, is highly inefficient, prone to error, and subject to abuse. In addition, the company's existing design software systems were used only for 2-dimensional electronic drafting, which, while adequate, did not differentiate them from competitors. In fact, this, coupled with their traditional approach to designing engineered products, resulted in a highly inefficient error-prone process. Other case studies have shown this to be a common practice.

The first step for the company was to work closely with the design automation consultants to formalize product definition, configuration, and Bill of Materials relationships between the design geometry and the purchased materials and components used in manufacture of relatively complex assemblies. The project manager found that relatively simple processes were in fact much more complex and detailed than previously thought. As a result of this process it was possible to encapsulate previously undocumented know-how and process knowledge in formal computerized data architecture. In a period of 3 months, the company processes were transformed into a DCA technology-driven system. The coincident resignation of the company's Engineering Manager had little or no effect on operations, an unlikely result if it had occurred six months earlier.

Significant improvement in 1) sales, 2) design, and 3) production activities was demonstrated by comparing before and after results at the company. With respect to sales, it was found that prior to implementing DCA, it took an average of 3 weeks to deliver a quotation to a customer. This process was dramatically altered to take less than an hour. In engineering, work on quotations was historically cursory, performed only in enough detail to estimate material and labor requirements and was subject to error and numerous corrections. Due to time and resource constraints, it was common for a design to be entrenched with the result that optimized cost / performance was not achieved. With the DCA expert system, it was found that not only was it possible to quickly determine the appropriate design for a customer's requirement, the system had the capability of designing for production at the time of quotation, and could simultaneously produce numerous alternatives that met or exceeded the requirements, in an iterative processes taking only minutes instead of days. Finally, design documents delivered to production prior to DCA implementation were informal and conceptual in nature, relying on experienced shop hands and know-how to actually build the desired products and eliminate built-in error. After implementation, there was a phase shift from draft conceptual paperwork to build-to-spec error-free documentation. While any one given area would be expected to provide some increased efficiencies, it was found that the combination of all three resulted in dramatic cumulative cost-saving benefits to the company.

The cost-saving benefits were so significant that management had difficulty in understanding and believing the effectiveness of the new approach. Instead of minor cost and production efficiencies, there was a significant leap in improvement that had hitherto been assumed to be impossible. A broad-brush comparison of relevant process steps between traditional and DCA approaches, is provided in Table 2 below.

	Traditional Approach	DCA Technology
Features	Less accurate design and cost estimates	Precise cost-base pricing of purchases, processes, labor
	Optimized design rarely the final result, systematic design errors endemic	Supports optimized, error-free design in minutes for each iteration
	Undocumented know-how produced different results by different staff	Bill of Materials and labor content calculated precisely derived from 3-d digital prototype
	No central searchable records to facilitate design iteration	Design retained electronically from first quote to production-ready documentation
	Sales visuals and quote drawings interactively produced at great expense	Browser-viewable sales visuals and drawings generated in minutes for each iteration
	Cumulative quotation lead time average of 3 weeks	Automatic design & quoting system accessible via Internet in minutes
Time	80% x 12 staff x 250 man days/yr = 2,400 man days for quotes & design	10 minutes to produce quote documents, same for iterations
	2,400 man days / 2,400 quotes/yr = 1 mayday per quote or design	
	500 minutes	**10 minutes**
Result	**98% time reduction** 98% x $640,000 = $625,000 savings: $625,000 / $12,000,000 = 5.2% of sales **5% of Annual Revenue reduction in fixed costs**	

Table 2 - Comparison of traditional versus DCA results

Discussion

North America has experienced a significant IT downturn in the past 2 years. For example, Autodesk is a leading engineering design software company, and its sales plunged 23% in its 4th fiscal quarter of 2003.[10] Many other engineering design software companies are experiencing similar difficulties at a time when productivity increases in engineering can be achieved through processes such as, defining and formalizing the engineering rules that are applied to select structural section size and strength and design a component to meet a given set of customer specifications. In addition a product structure template that represents all optional substitutions for assemblies and components that make up an end product can be formalized and designed. Associative assembly drawing templates to detail any design variation in a 'family' could be created as well as computerized sales input form that allows non-technical people to interact with a prospect to define the final detailed configuration of a product. Labor processes can be quantified with respect to variable configurations of 3D CAD geometry both at the component and assembly level. By integrating the collection of rules and data into an Internet browser-driven system it should be possible for numerous new applications to automatically design a component and create a precise 3D digital prototype using a common modern CAD engine, generate a detailed Bill of Materials (with internal part numbers referenced against cost standards on the company's existing MRP system), generates sales visuals, (3D web-viewable models to serve as installation documentation) and maintains a history of every transaction.

Companies can benefit from the DCA approach, especially those that produce structures and components that require some degree of customization (up to 20%) have two alternatives: 1. They can design and systems of their own using their IT Department, consultants, and own engineering and estimating staff. This will involve; (a) in-depth review and documentation of design processes, (b) documentation of engineering rules and component data, both geometric and non-geometric, (c) review, benchmarking, and purchase of seats of 3D CAD solid modeling software, (d) user training and months of defining and constructing standard library components, (e) at least a year of software and database development (without benefit of experience in this field) and (f) testing, refinement, and deployment of a new technology platform or 2. They can invest in a proven *generic* engineering automation platform customized and delivered, ready to operate, within 6 months, purchasing the technology and implementation services from an experienced, reputable vendor.

Based on a review of several small companies, investing in business intelligence technology appears to make *very* good economic sense. Automatic design and estimating to handle routine tasks should be many times faster (and more accurately) than is currently possible with informal internal processes. Many businesses in several industries can grow rapidly with a moderate one-time investment that for most will have a short return on investment. 'Soft' benefits that also translate to an improved bottom line include, (1) dramatic leverage of existing technical staff through automation (no need to add new staff), (2) protection in the event of departure of key technical employees because their knowledge is contained in the automation platform, (3) ability to respond to peak-season demand for quotations and engineering services, (4) higher appeal to the distribution channel because quotes are easy and quick to do, (5) better market image with 'high-tech' automation of the crucial design and quoting function and (6) less waste in production with detailed building designs validated before fabrication.

References

1 Sundar Kadayam, "The New Business Intelligence" Special supplement to KMWorld, Jan 2002
2 "Six New Technologies to Boost Business results" TECHSTRATEGY Brief, Forrester Research, www.forrest.com, May 1, 2002
3 Dan Miller, "Technologies You Need to Know," The Industry Standard, May 21, 2001
4 BET
5 *Program Review of Eigner+Partner's axalant cPDm Program*, CIMdata Inc., Sept. 2000
6 "Computing's New Shape" The Economist, pp 11-12, 23rd November, 2002
7 "The New Blue" Business Week, pp80-86, March 17th, 2003
8 Gordon Hobbs, Process-Driven Design Automation for Engineered Products, *Materials & Manufacturing Ontario Conference on Reconfigurable Manufacturing*, McMaster University, Hamilton, Ontario, Canada, October 23, 2001
9 Manufacturing in developed world
10 CAD/CAM Publishing, News Release, www.cadcamnet.com, February 26, 2003