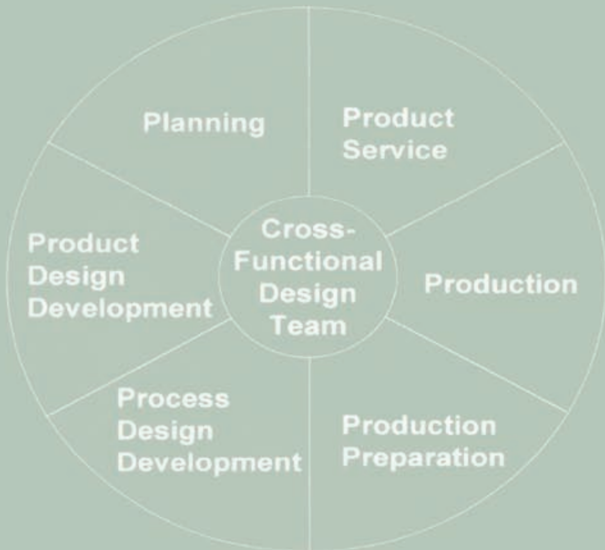
Implementing Concurrent Engineering in Small Companies



Susan Carlson Skalak

Implementing Concurrent Engineering in Small Companies

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Preface

The material for this book was developed over a number of years using the insights gained from my industrial and academic experience, my research with graduate students, and our work with small companies. I spent four years as a manufacturing engineer with IBM working with design teams to bring their designs to the manufacturing line. Both product lines on which I worked used concurrent engineering as an overriding philosophy. As a manufacturing engineer, I designed manufacturing stations and tooling to produce the products. In addition, I had sign-off responsibility for the parts of the design that were assembled in my manufacturing stations. With this responsibility came the opportunity to affect the design in the early stages to ensure that it could be easily assembled, in some cases by robots and in others by human operators. Because this design and manufacturing group at IBM functioned as a wholly independent business unit, I was able to perceive and optimize the value added through concurrent engineering and design for small business units. It was a powerful way to improve designs, eliminate assembly errors, reduce design changes, and generally enhance team morale and productivity.

I next spent three years at Georgia Tech to obtain a Ph.D. focusing on design methodology. After assuming an academic position as an Assistant Professor and later as a tenured Associate Professor of Mechanical Engineering at the University of Virginia, I used both my education and work experience to examine design practices in small- to medium-sized companies over a period of seven years. My graduate students and I found that these companies as a rule did not practice concurrent engineering, and tended to pass their designs from department to department without much interaction between the engineers. We were presented with the opportunity to apply the philosophy of concurrent engineering and develop a methodology that could be used by small companies. Our goal was to develop a methodology that could be easily understood and adopted within a company without the use of expensive consultants, which most small companies cannot afford to hire. This book describes this methodology in detail and is a culmination of fourteen years of research and practice with small companies, small business units within large corporations, and student organizations. My chief aim in making a personal career change back to the private sector is to bring this accumulated experience in what really works to small businesses that would benefit from that knowledge. Small business fires the ability of democratic nations to remain creative, innovative, and stable. In a small way, I hope this book helps to fuel that fire.

The book is divided into nine chapters. The first chapter builds a case for adopting concurrent engineering and design within a small company. The second chapter discusses the infrastructure that needs to be in place to implement a successful change to concurrent engineering. Chapters 3, 4, 5, and 6 explain the core of the methodology, for both product design and for manufacturing line design. Chapters 7 and 8 discuss ways in which the methodology can be adapted to include specific company requirements such as environmental or risk reduction techniques. In each chapter, the main ideas are accompanied by examples of designs developed in various industries.

The ideas presented in this book are straightforward and easy to understand, and are easily adaptable to most industries. However, the implementation of these ideas can be very challenging. Implementation of concurrent engineering will require a philosophical change from top management through the ranks of the company all the way to the manufacturing floor. Because most people resist change, the implementation of this methodology requires a strong, public commitment from upper management. Furthermore, the philosophy and methodology described in this book also require commitment to continuous improvement. A dedication to the continuous improvement of the application of the methodology will produce a competitive company that is agile enough to respond to changing market needs.

ACKNOWLEDGMENTS

I would like to recognize the efforts of my graduate students at the University of Virginia. These students worked as a team with me, with each other, with student design teams, and with small companies and independent business units within large corporations to develop the core of this methodology. Natasha Ter-Minassian laid the groundwork for this methodology through her study of design practices in companies throughout Virginia. The other students are all noted as collaborators in the chapters in which their work has relevance, but I would like to mention them again. Hans-Peter Kemser worked on defining the basis for the design methodology, and has since gone on to apply his knowledge at BMW in Germany. Johanne Phair worked on the sister methodology for the design of manufacturing lines. Kevin Allen developed a methodology for assessing and improving the modularity of products, and is now applying his knowledge as a design engineer for the US Navy. Melanie Born developed the risk assessment methods, and is now working as a consultant. Chris Henson developed the basic structure of the outputs for each of the product design steps, and is now a sales engineer in the automotive industry. Lastly, Mark Sondeen spent many hours understanding the needs of small companies from an environmental perspective. He developed design for environment tools and adapted others for use in small companies. He is now applying his knowledge in the aerospace industry. Without these students, this concurrent engineering methodology would have taken many

more years to develop, and would look very different from the final form presented. It was a pleasure to work with each of these talented people, who all brought many good and new ideas to the methodology.

I would also like to thank all the companies that participated in our studies. Comdial was most helpful in sharing their time and ideas, and allowing us to be part of their design teams for over a year. I would also like to mention IBM, my first employer, which introduced me to the ideas of concurrent engineering and design.

I would like to thank the National Science Foundation, which supported my work over several summers and supported some of the students mentioned above through the Early Career Development Award. Without their support this work would not have been possible. Lucent Technology and AT&T supported the work described in Chapter 8 through their Industrial Ecology Fellowship.

I would also like to thank the editors at Marcel Dekker, Inc., especially John Corrigan, who first approached me with an interest in this work and patiently waited while we developed the methodology, always reminding me that he was interested in this book, and also Helen Paisner who saw this work to completion. I would like to thank my husband, Tom, whose encouragement and support in this work allowed its completion. Finally, I would like to acknowledge my son, Scott, who sits in my lap as I complete this Preface, and who had the good timing to arrive just as I finished the manuscript.

Susan Carlson Skalak

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Contents

1

An Introduction to Concurrent Engineering

In collaboration with Hans-Peter Kemser

Managing a small company has always been a challenge, but today with global markets, the internet, and overnight delivery services, meeting customer needs and delivering quality products on time in a highly competitive market is especially difficult. The temptation for a small- or medium-sized company that has a large market share in its particular niche is to continue doing things the same way it has always done them. Why change when sales are good, the customers are relatively happy with their products, and a product eventually does get out the door even if the schedule slips a little? However, the market is always changing; eventually your company's products will be challenged by domestic or overseas competitors. This book is intended to help change the way small- and medium-sized companies design and manufacture their products to keep ahead of the competition. What manager doesn't want to remain competitive by reducing their time-to-market, improving product quality, and reducing costs? This book introduces a product and process development methodology that can help your company achieve these objectives. Conceptually, the changes needed to achieve more efficient product development are easy, but implementing them is a challenge because it is human nature to resist change unless faced by adversity. Implementation cannot occur overnight, but may take months, even years using continual process improvement as the model for change. This redirection requires a commitment from every employee in the company, from CEO to maintenance worker. The goal of this book is to provide a roadmap that will guide a company to better and more efficient product development and manufacture, and that can be used by every person involved in product development, including design, manufacturing, sales, and service.

This book is intended for small companies, but what is a small company? There are many ways to define a company's size such as by the number of employees or by its sales volume. In this book, we rely on number of employees and number of engineers to define size. Our methodology has been developed for companies having five or more engineers. If a company has fewer than five, then the engineers are usually responsible for seeing a product through the entire design and production cycle. With more than five engineers, the company is usually segmented into functional units, and the design is passed from one function to another. Theoretically, our approach can be used in large corporations; however, most large corporations have their own internally-defined design processes and they would be unlikely to use our approach. Furthermore, our methodology is intended for the products designed by small- to medium-sized companies, which are generally less complex than those of large corporations. For example, the method works well for consumer goods such as toasters and telephones, and for products such as hydraulic cylinders, pumps, and motors. However, the methodology is not intended for complex products such as automobiles and commercial jet aircraft such as the Boeing 777. Finally, the methodology is intended to help companies that are primarily situated at one location, and design and manufacture the majority of the new product in-house.

1.1 IS THIS YOUR COMPANY?

Although few studies have been conducted in small- and medium-sized companies, those studies found that small companies operate similarly [Albin and Crefeld, 1994; Radcliffe and Harrison, 1994; Carlson, *et al.*, 1997]. These small companies are characterized by many of the following attributes:

- Limited resources,
- Engineers' time spread across multiple projects,
- Informal communication among personnel and often little or no input from manufacturing into the development process,
- No sense of ownership,
- Design methods governed by rules of thumb,
- Little documentation of designs and of lessons learned,
- Few formal project management and planning skills,
- Low priority of trial runs and prototyping,
- Concentration on short term goals, and
- Minimal stand-alone influence on industry as a whole.

Furthermore, most of the companies studied practice a sequential engineering design process as shown in Figure 1.1. In a sequential engineering (SE) process, sales and marketing define the parameters of the new product, including the sales

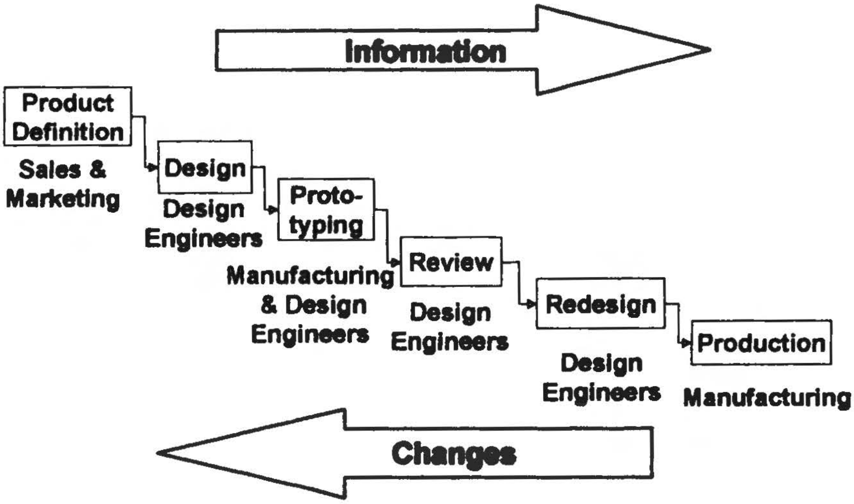

Figure 1.1 Flow diagram of a sequential engineering process.

price, and requirements, which are based on customer needs. Then, they present a product definition document to the design engineers. Using this information, the engineers then define the product specifications, design the new product, and pass detail design drawings to manufacturing. If the requirements ask for a prototype, and the product is not too far behind schedule, then manufacturing will build a prototype. The results are then reviewed by the design engineers. Problems that are identified in the prototype, and any difficulties that manufacturing finds in producing the product as designed are discussed. The design engineers then make changes to the product to accommodate manufacturing and any problems found in the prototype. Finally, production will occur after all problems are solved or minimized to an acceptable level. In this model, the groups rarely interact beyond the hand-off of the design from one stage to the next. Most of the design changes occur in the redesign phase of the sequential engineering process, causing additional costs and time delays. Since the next development phase can only begin after the preceding one is completed, the product launch date is delayed with each change.

Another complicating factor in the development of new products within smaller companies is the lack of focus on the future [Radcliffe and Harrison, 1994; Braiden, Alderman and Thwaites, 1993]. Small companies focus on current products, fixing problems that arise in the field with the products already on the market, and they spend little time on designing new products for customer demands. This leads to a "fire-fighter" mentality in the engineers, in which they focus on answering problems from the field, and new product development takes low priority. When viewed from a distance, this problem is easy to detect and intellectually, it seems clear that this strategy will result in long term decline of customer satisfaction with the current products. The company's products will eventually become outdated as the engineers scramble to keep up only with today's demands. The company feels it is very responsive to customer satisfaction, but what they don't see is that eventually they will not be able to keep up with new demands as the market passes them by and competitors deliver more up-to-date products.

How can a company escape from this destructive spiral? They must fix problems up-front in the design of the product, not when it is already in production. They must change their operations to become more concurrent and team oriented.

1.2 WHAT IS CONCURRENT ENGINEERING?

Concurrent engineering (CE) has been described by many different people and organizations. Companies often practice some form of CE or portions of it without defining it as concurrent engineering. There are many other names that have been applied to the same principles such as simultaneous engineering, integrated product and process design, concurrent design, etc., and these terms are still used. Concurrent engineering is defined by different people as different things. For example, the original definition that is frequently referenced was developed in 1986 by the Institute for Defense Analysis:

> *Concurrent engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule and user requirements.* [by permission from the Institute of Defense Analysis, Report R-338]

Many other definitions have been published since this one. Most focus on integrating and managing the design process to result in a shortened time-to-market. The following list indicates how differently authors view concurrent engineering.

- *A systematic approach to integrated product development that emphasizes the response to customer expectations. It embodies team values of cooperation, trust, and sharing in such a manner that decision making proceeds with large intervals of parallel working by all life-cycle perspectives early in the process, synchronized by comparatively brief exchanges to produce consensus* [by permission from Cleetus, "Definition of Concurrent Engineering," *CERC Technical Report Series, Re-*

search Notes, CERC-TR-92-003, West Virginia University, Morgantown, W.V., 1992].

- *CE is a management and engineering philosophy for improving quality and reducing costs and lead time from product conception to product development for new products and product modifications* [Creese, R. and L. Moore, "Cost Modeling for Concurrent Engineering," Cost Engineering, Vol. 1, 1990, pp. 113-124. By permission of AACE International, 209 Praire Ave, Suite 100, Morgantown WV 25601 USA, Phone 800-858-COST/304-296-8444. Fax 304-291-5728, Internet http://www.acei.org Email: info@aacei.org].

Because these definitions cover such a wide range of concepts from team empowerment to cost reduction, the following attributes have been gathered to characterize a CE design process:

- Customer focus and involvement,
- Early and continual involvement of suppliers in the design process,
- Cross-functional, self-directed, empowered teams,
- Incremental sharing and use of information,
- Life-cycle focus,
- Systematic and integrated approach,
- Concurrent (parallel) design teams,
- Early use of Design for X (DFX) tools,
- Use of modern tools such as CAE, CAD, CAM, finite element analysis, etc., and
- Continuous improvement of all processes.

How does CE differ from SE? The number of design changes in CE are minimized in the downstream stages of design, because every person who has a stake in the product's life cycle is involved in the design process from the beginning. Therefore, issues such as maintenance, manufacturing, and customer use, are addressed from the beginning of the process by the cross-functional design team. Since a cross-functional team is used and customers and suppliers are involved in the process from product definition, the entire development time is reduced. A representation of typical time savings of using CE is shown in comparison with SE (Figure 1.2). When implementing CE, one caution that should be heeded is that the front-end phases become much longer in comparison with SE. Notice that only 3% of the development process was spent on planning in SE, and 27% was spent on design. Compare that with the time used planning in the CE process. The time required was more than 10 times greater, the planning process took about one-third of the entire process time, and design 22%. In SE, only one-third of the development time was spent on planning and design, and the rest of the time was spent fixing problems that arose when the product was transferred to the manufacturing organization. In contrast, over half of the development

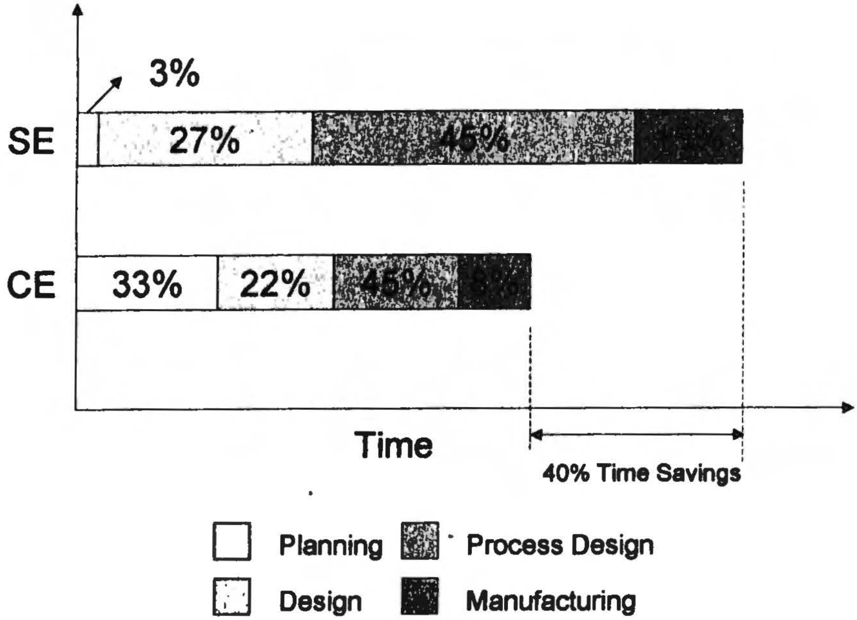

Figure 1.2 Comparison of SE with CE, showing time savings with CE use. [US Air Force R&M 2000 Process Study Report, 1987.]

effort was spent on planning and design in CE, yet there was a 40% savings in time using CE. The problems in the CE process were fixed up-front in the cross-functional design teams, so that when the product got to the manufacturing organization, few problems had to be fixed, and fewer still once the product was in production. Organizations that choose to switch to CE must be aware of the necessary requirement of time in planning and design. Managers should not benchmark a CE process with an SE process, and expect the duration of the stages to coincide. The time savings come at the end of the design process, not in the early stages.

1.3 THE BENEFITS OF CONCURRENT ENGINEERING

Many large corporations have used concurrent engineering since the early 1980's. Therefore, there has been considerable data collected on the benefits of the use of CE in these organizations. The following list of benefits were achieved through the successful implementation of CE in large corporations [Linton, *et al.*, 1991, used with permission of the National Security Industry Association].

Development and production lead time reductions:

- Product development time reduced by up to 60%
- Production spans reduced 10%
- Total microelectronics fabricating process time reduced up to 46%.

Measurable quality improvement:

- Yield improvements of up to 4 times
- Field failure rates reduced up to 83%.

Engineering process improvements:

- Engineering changes per drawing reduced up to 15 times
- Early production engineering changes reduced by 50%
- Scrap and rework reduced up to 87%.

One of the most cited benefits of using CE is the reduction in time-to-market, which is the time required from product definition to production of the first product. Table 1.1 shows the reductions of development times for fast innovators. Table 1.2 shows the reduced time between ordering and shipping. Note that the major contributing factor for time reduction in these examples was the use of a multidisciplinary team.

An example of a medium-sized organization (750 employees, over 60 engineers) that has successfully implemented concurrent engineering is Comdial Corporation, located in Charlottesville, Virginia. Comdial is a world leader in the design and manufacture of business telephone systems, and despite its size, it has competed successfully with giants such as AT&T and Northern Telecom. Comdial began the journey to implementing concurrent engineering in 1984. Because of its policy of continual assessment and improvement, their concurrent engineering process today is much more integrated and effective that it was in 1984. Comdial was faced with a crisis in 1984: they had entered the retail phone market with the divestiture of AT&T. However, they were unable to compete effectively in this market with inexpensive phones that were flooding in from off-shore competitors. In 1984, they decided to focus on business telephone systems only and had to deliver a new product to the fall tradeshow, giving them only 6 months to develop a product that normally took them 2-3 years. With the guidance of their vice-president, who was well-versed in teaming and Japanese development practices, Comdial made the change to concurrent engineering. Tables 1.3 and 1.4 show the improvements Comdial has made since 1984 in its key measurements of time-to-market and quality.

Table 1.1 Time-to-market comparisons for large corporations that have been classified as fast innovators [This figure is reproduced from Biren Prasad's *Concurrent Engineering Fundamentals: Integrated Product and Process Organizations* Figure 4.19a, page 210 in Vol. 1, ISBN 0-13-147463-4, published by Prentice Hall, 1997. Permission received from Dr. Biren Prasad, Author May 2002].

Fast Innovators					Major Contributing Factors
Company	Product	Best Development Time			
		Before CE (mos.)	After CE (mos.)	Reduction	
ABB	Switching systems	48	10	79%	CMS
AT&T	Phones	24	12	50%	ACM
British Aerospace	Airplanes	36	18	50%	MS
Digital Equipment	PCs	30	12	60%	ACMS
Ford	Cars	60	42	30%	—
GM	Engines	84	48	43%	MS
GM/Buick	Cars	60	41	32%	MS
Goldstar	Telephone systems	18	9	50%	CM
Honeywell	Thermo-stats	48	12	75%	MS
Honda	Cars	60	36	40%	—
Hewlett-Packard	Printers	54	22	59%	ACMS
IBM	—	48-50	12-15	70-75%	ACM
Motorola	Mobile phones	36	7	81%	ACM
Navistar	Trucks	60	30	50%	MS
Warner Electric	Clutches/ Brakes	36	9	75%	ACM
Xerox	Copiers	60	24	60%	ACM
Legend: A: Analytical methods and tools, M: Multi-disciplinary team C: Computer integrations, S: Suppliers on the project team					

Table 1.2. Order-to-ship improvements for large, corporate, fast producers [This figure is reproduced from Biren Prasad's *Concurrent Engineering Fundamentals: Integrated Product and Process Organizations* Figure 4.19b, page 210 in Vol. 1, ISBN 0-13-147463-4, published by Prentice Hall, 1997. Permission received from Dr. Biren Prasad, Author May 2002].

Fast Producers			
Company	**Product**	**Order-to-Ship**	
		Before CE	**After CE**
Brunswick	Fishing reels	3 wks	5 days
GE	Circuit breakers	3 wks	3 days
HP	Test equipment	4 wks	5 days
Motorola	Pagers	3 wks	¼ days

Table 1.3 Comdial's time-to-market improvements [Used with permission from Comdial Corporation, 106 Cattlemen Road, Sarasota, FL 34232].

Product	**Time-to-Market**		
	1984	**1998**	**Improvement**
Printed circuit board design	2 mo	1.5 mo	25%
Telephone systems	18 mo	9 mo	50%
Key service unit	24 mo	12 mo	50%

Table 1.4 Comdial's quality improvements [Used with permission from Comdial Corporation, 106 Cattlemen Road, Sarasota, FL 34232].

Measure	**1984**	**1998**	**Improvement**
Rate of field returns	5%	1%	4%
First pass success rate	90%	98%	8%

In general, the following benefits can be achieved by implementing CE within an organization:

- Improvement in product quality,
- Reduction of product cost and lead time,
- Lower test and inspection costs,
- Reduction in number of engineering changes,
- Increase in profitability,
- Improvement in competitiveness,
- Increase of ownership among employees, and
- Higher customer satisfaction.

These improvements can only occur when all aspects of CE are implemented. Mixing CE with SE processes leads to chaos and employee frustration. CE can only be successfully implemented with the commitment and dedication of senior management.

1.4 HOW CONCURRENT IS YOUR COMPANY NOW?

The following questionnaire is included to help you look at the current product development practices of your company and to identify areas that need improvement. The questionnaire [*Concurrent Engineering* by Carter, Baker, © Adapted by permission of Pearson Education, Inc., Upper Saddle River, NJ].is divided into four parts: Organization, Communication Infrastructure, Requirements, and Product Development. After completing a CE implementation, an organization should be able to answer all these questions positively.

Organization

- Are the specifications and priorities for the assigned tasks understood by each team member?
- Is the product development process understood by each team member of every team?
- Are design decisions made by a cross-functional team?
- Do customers and vendors participate in your design decisions?
- Is a cross-functional team (including customers and vendors) responsible for the development of engineering specifications, scheduling, and system design specifications?
- Are teams rewarded for their contributions?
- Is adequate training provided for each member of the team regarding procedures, tools, and standards they should know?
- Are cross-functional teams provided adequate team training?

Communication Infrastructure

- Are the tools for each team member integrated within the company?

- Are electronic mail capabilities available to each team member?
- Are query and online reporting capabilities available to each individual?
- Are interactive product data browsers available to each individual?
- Are technical reviews conducted at appropriate milestones?
- Are the management team and the customer concurrently informed of problems and their status?
- Do individuals and teams have electronic access to company-wide product development data that includes data from customers and vendors?
- Is the product development data stored, controlled, changed, and versioned in a common computer database?
- Is the data in the product development database interoperable among the various design automation tools?
- Are evolving product requirements, specifications, and development data under automatic changes and versioning controls?
- Are action items, problem reports, enhancement requests, and all other decisions analyzed to continuously improve the product development process?

Requirements

- Does your company measure best-value product designs for cost, functionality, fitness for use, reliability, performance, and supportability?
- Does your company use design standards to ensure product testability, manufacturability, supportability, etc., and are these standards regularly reviewed and improved?
- Can the cross-functional team access the product life-cycle specifications as part of decision support?
- Are adequate planning methods used for deciding upon product requirements?
- Are engineering and process specifications validated to the customer needs?

Product Development

- Is the component library system linked to a decision support tool to assist each designer in making component or unit selections?
- Are analysis tools used during conceptual and detail design?
- Are goals for product and process improvements in place?
- Are major project decisions and the factors leading to them documented, distributed, and analyzed for guidance on other projects?
- Are product designs, development processes, specifications, and tools concurrently analyzed and continuously improved as a part of a company-wide optimization strategy?

1.5 REQUIREMENTS FOR SUCCESS?

Taking the tremendous step to move from an *ad hoc* design process to the more systematic concurrent engineering process requires rethinking how processes are performed. Organizations must change their structure, product and process development approach, interaction between employees, and their interaction between the customer and supplier. New methods must be embraced and adopted such as employee empowerment, total quality management, and continuous improvement and innovation. These methods lead to a change of culture of the entire organization and can only be achieved with the full commitment of senior management.

Since the benefits of CE are so obvious and dramatic, and so many organizations have already implemented CE successfully, the question is why don't all companies change? One reason is given below.

> *One of the difficulties in bringing about changes in an organization is that you must do so through the persons who have been most successful in that organization, no matter how faulty the system or organization is. To such persons, you see, it is the best of all possible organizations, because look who was selected by it and look who succeeded most within it. Yet these are the very people through whom we must bring about improvements.*
>
> *-George Washington, Second Inaugural Address*

The successful implementation of CE can only be achieved if senior management embraces and supports the change by establishing clear guidelines of how the change will take place, and how teams and individuals will be awarded in the adoption of the new system. Management must lead employees through the operational changes by explaining why the changes are necessary and what may happen if changes do not occur.

1.6 PHILOSOPHY OF THIS BOOK

This book was designed to help small- to medium-sized firms adopt concurrent engineering as a design management methodology within their company. Concurrent engineering has been around for more than a decade, and many large corporations have found that its use has resulted in significant gains in productivity accompanied by a reduction in time-to-market, costs, and quality problems. Smaller corporations will be able to see similar results with the use of concurrent engineering. This book is intended as a "how-to" guide for managers and engineers to help them learn a systematic approach to concurrent engineering, and one especially developed for use in small companies. The engineering design process is not always well understood, and this book will guide the practicing engineer and manager through the process step by step, using industrial examples throughout.

The book begins with an overview of concurrent engineering, its challenges, and its benefits. Next, teams and how they are used in the context of concurrent