DESIGNING FOR PRODUCT SUCCESS

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Abstract

This paper is about the techniques used by world-class companies to guide the design, development of high quality products in a step-by-step manner using analytical tools and case studies. Many engineering programs in the country are re-examining the design content in their curriculum. Engineering curricula is being modified to incorporate vertical integration of design through large projects between the first year and the last year of their programs. By interacting with industry, the product design students become familiar with the steps in creative product design starting from the concepts to production and marketing. New approaches are provided to enable students to learn how to work smarter. In view of the recent development in lean manufacturing and information technology, emphasis on value stream mapping and its influence on product development is important. A good product design course should familiarize the product designers and students with the concepts, techniques and tools of new product design and development. The course should relate the topics of creating a self-directed product team, following the steps of creative design methodology, learning the tools of production process, identifying the integrated issues of design and production and finally managing product innovation.

I. Introduction

When one uses a toaster, microwave, or any other product, little does he or she realize the complexities of what goes into its creation. Designing a product involves a constant decision-making process which includes problem-solving in a sequential fashion, and analysis of the constraints at each step. The philosophy underlying our method of design is unique. Human beings are a special kind of designer and our design philosophy influences our own life and environment. In general, design represents an answer to a problem, an answer that has visible form, shape, and function. Various professions define design differently, as business professionals, physicians, architects, and engineers all have their own unique views on the nature

of design and their own personal experience with its usage. However, let us limit our discussion to the professional design as practiced by engineers. Designing is providing a set of rules for reorganizing the elements of creation toward some greater purpose, known as "design intent." It is the design intent that has ethical and moral dimensions.

The product creation process is very much influenced by the process of designing, as well as the overall product cost. The cost of a product grows from conception, through the stages of technical research, design, development, market testing, use, maturity, until finally, its disposal. An organization has greatest control over a product at the early stages of its creation, when the market, its factory cost, operational cost and life cycle are determined. At this stage, a product's status can be unstable as the organization tries to optimize the distinctiveness of the product for

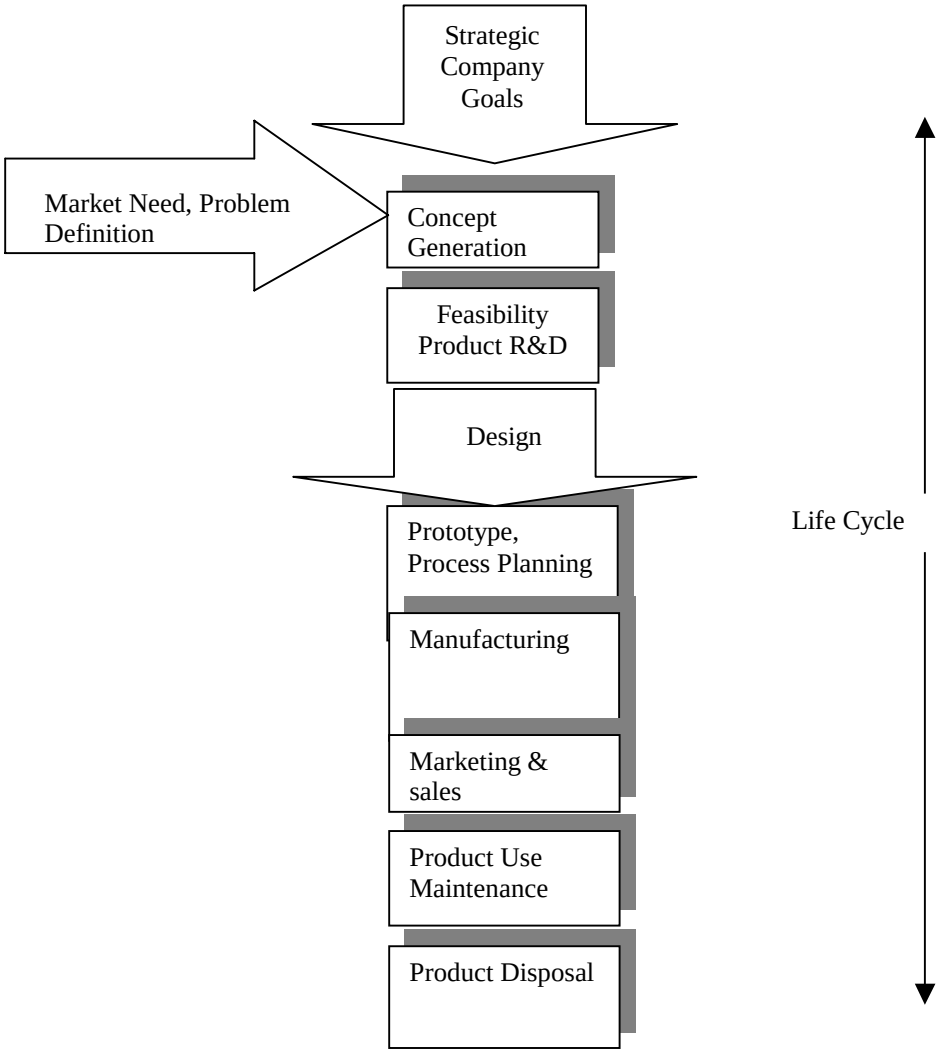

Figure 1 ***Product Life Cycle***

greater market acceptance. Naturally, a product's features determine its performance and cost. The speed of a product's development process, market testing, and manufacturing, are important in a product's life cycle.

Figure 1 shows different stages of a typical product's life cycle. The cycle is composed of many individual processes. First, it is initiated by the market need. It starts with the task of planning a product based on the strategic goals of an organization, going through the stages of feasibility analysis, research and development, design and prototyping, market testing, commercial manufacturing, marketing, product use, maintenance and disposal. The products that become well defined in the early design stages have higher chances of success than the products that lack this preparation. Many studies have shown that conducting early design work, preparing sketches and prototypes, simulation studies, cost estimation and talking to potential customers reduce the chances of uncertainties in a new product launch.

2. Building Blocks of Product Design

Producing a marketable product from its initial requirements takes many steps. The probability of a product's success significantly increases if the design process is planned and executed carefully. It is imperative that the processes integrate many different aspects of design into distinct logical steps. Important contributions to the development of design methodology have come from various countries. Roth (1) has developed a design theory characterized by a set of integrative steps, including problem formulation, functional phase and embodiment phase. He also developed a catalog of design entities in graphical form. Cross (2) developed a design methodology aimed at making the design process more algorithmic by dividing the design process into descriptive, prescriptive and systematic models. Finger and Dixon (3) developed a review of design methods and computer-based models for design process. Pahl and Beitz (4) and Hubka (5) developed guidelines for design decision-making. Dixon (5) proposed a structure representing the relationship between engineering design and the cultural world. Pugh (6), Ulrich and Eppinger (7) introduced integrative methods for product design and development. Hubka and Schregenberger (8) introduced the idea of grammar being used to assist design. They found that the linguistic habits of the designers affect their ways of conceiving design and approaching it. Jean Le'Mee (9) proposed how the processes of design can be expressed through a grammatical approach. He viewed design as a process involving a language right at the start.

Systematic Process

Companies need a systematic design process, which must be communicated to all of their designers. The actual process by which product designers implement their tasks and responsibilities is typically a function of the individuals involved. Their approaches, degree of documentation, habits, etc. are unique and randomly acquired. Hence, it is sometimes difficult for one person to follow up another's work, not being familiar with the design philosophy and approach of the former. A well-developed product development process enables companies to select, propose, design, develop and market new products effectively. A systematic product design and development process is a key element to the infrastructure of an organization. Such a

process can provide a stable structure for strategic planning, decision-making, operation, effective communication, implementation and control. **Figure 2** shows the components of product development.

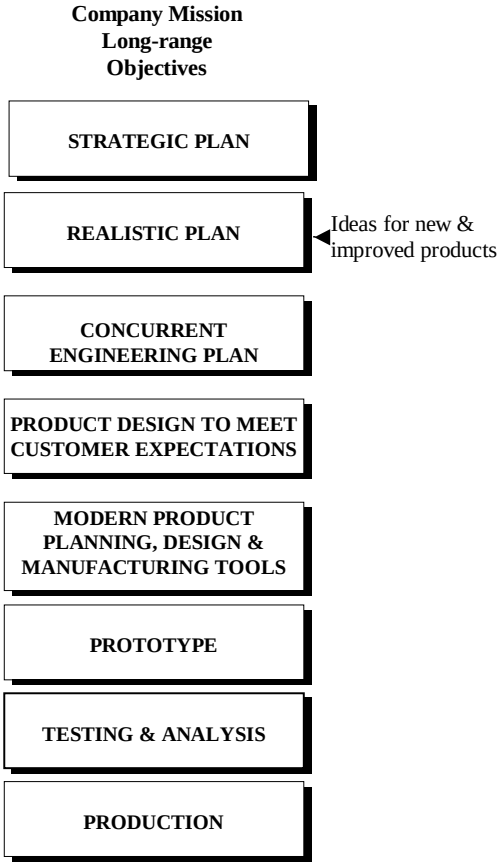

Figure 2 ***Components of Product Development***

Companies around the world have been influenced by various studies that show improved production process structure that take care of fluctuations in workloads, reduce variation in products and eliminate bottlenecks. Paul Adler (10) has studied a dozen companies that have started applying the process management techniques to product development, including Raychem, Motorola, Harley-Davidson, Hewlett Packard, General Electric, AT & T, Ford, General Motors and NEC. The results of this study have shown three significant observations:

- The product development projects are accomplished quickly if the organization takes on fewer projects at a time.
- Investment made by the company to relieve project bottlenecks results in early market launch of the product.
- Eliminating unnecessary variation in workloads and work processes removes distractions and delays, thereby freeing up the organization to focus on key areas of the project.

3**. How do promising products fail?**

Why should products with high expectations fail, in spite of clear signals of market need? One reason may be that any innovative product, especially if it has advanced technological content, meets customer resistance and sells slowly until consumers perceive it as safe.

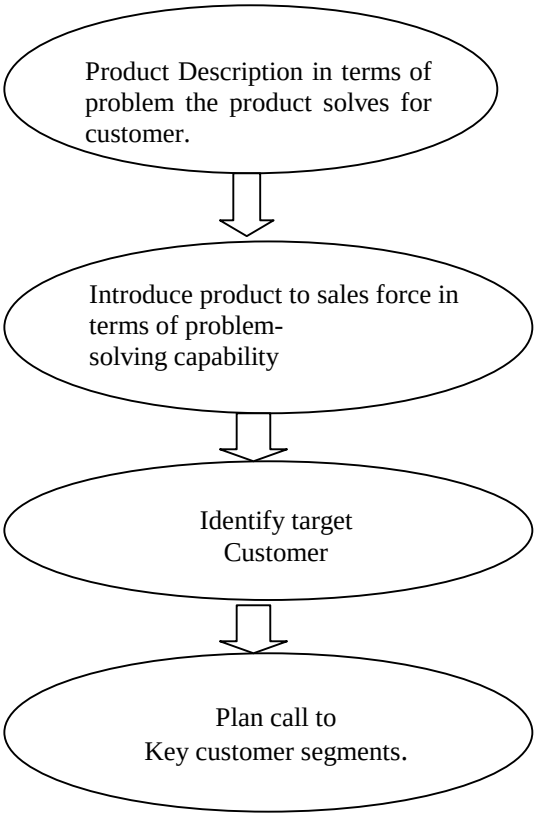

Figure 3 ***Steps for Introducing a Product to the Sales***

Neil Rackham (11) suggests that the main problem is dependent on the way highly innovative products are launched to the sales force, which, in turn, influences the manner in which the product is sold. **Figure 3** identifies the steps for introducing a new product to the sales group. Focusing on all of the new features that make the product highly innovative draws the sales force's attention away from the most important issue in the process: the needs of the customers. The sales force learns product-centered information about product capabilities, and communicates this information to customers, in the very same way it was communicated to them. The launching of the product becomes product-centered instead of being customer-centered, which, thus, decreases customer interest. A more customer-oriented approach, by dwelling on the product in terms of problems it solves for the customer, is more successful.

The design and development of a product invariably involves considerable investment of time, effort, and money. It is essential that a new product is thoroughly examined and reviewed before it is presented to the public. A company's credibility, reputation, and finance rest on the

launching of each of its products. The fundamental questions a product designer has to look into are the **Why? What? How? Who?** and **When?** pertaining to the product.

Table 1 provides a summary of five key characteristics involved in new product design and the product launching process.

	Strategic objective	**Financial consideration**	**Market consideration**
Why	• Survival of the company. • Business opportunity.	• Financial reward.	• Synergistic impact.
What	• Product definition. • Adopt or modify existing design.	• Joint venture. • Collaboration. • Licensing	• Projected product demand
How	• Strengths. • Weaknesses. • Physical infrastructure.	• Financial benchmark	• Market response
Who	• Structure decision-making. • Human consideration	• Accountability & responsibility.	• Information retrieval. • Information dissemination
When	• Timing is critical	• Money and investment.	• Market window.

Table 1 ***Summary of five key characteristic of new product launch.***

4. Tools and Techniques

The goal is to develop the product that is best for function, manufacturing, reliability and servicing. This is the ideal design, but one that is difficult to achieve. Thus, the process has to be managed in steps, which ultimately have to be integrated successfully.

Table II shows the tools and methodologies linking them to the product development phase.
Table III shows a typical curriculum that can be used for product design courses. A typical product design curriculum should make the students familiar with the steps in creative product design starting from concepts to production and marketing. The students should be introduced to various product redesign techniques using case studies. They should learn about issues of design for disassembly, reliability, and maintainability and different tools that can easily have an impact on the new product development process.

Concept Development Phase	Market Studies Voice of the Customer House of Quality
Design and Development	Function Analysis Design for Manufacturing Design for Disassembly Product Modeling using CAD/CAM Simulation Optimization Design for Six-sigma Analysis Rapid Prototyping Design for Environment & Service
Analysis and Testing	Failure Mode Effects Evaluation Robust Design Statistical Reliability Analysis Tools Design for Life-cycle
Process of Product Creation	Workplace Design Flexible Automation Tools Value Stream mapping

Table II **Tools and Techniques**

4. **Focused Approach To Product Design**

- *Focus on the Environment*

Looking at the evolution of technology over the years and noting its impact on society, we see that the economic growth of the countries has been marked by a series of important technological landmarks in materials, methods, consumer products, transportation, agriculture and pharmaceuticals. Computerization and new materials have made production of just about anything cheaper and more efficient, and quality easier to maintain. We have roared into the 21st century wired to the Web, facing and consuming a new technology as soon as it is introduced. The innovation of new products has been exerting a more serious impact on our life and environment than ever before. These technological innovations have caused higher rates of productivity, and therefore, higher return rates on investment. Unfortunately, these technological changes have not always taken the impact on the environment into account, in the enthusiasm of maximum profit and efficiencies, and thus, become one of the major causes of environmental crises.

PRODUCT DESIGN – Product Realization Process	Design Approaches Why Should Promising Products Fail? Building Blocks of New Product Design Comprehensive Strategic Plan Impact of Design on Environment Concurrent Engineering in Design Impact of Modern Manufacturing Tools and Techniques
PRODUCT DESIGN – Conceptual Phase	Design Concept Development Methodology Concept Selection Using Function Diagram Function Analysis for Product Design Understanding the Customer Customer driven Product Development Axiomatic Design Method Inventive Problem Solving
PRODUCT DESIGN - Design and Assembly	Design for Manufacturing Methodology Impact on Manufacturing Processes Systematic Process Selection Manufacturing Processes and their attributes Design for Disassembly Design for Life Cycle
PRODUCT DESIGN – Tools and Techniques	Tools of Optimum Design Learning Curve Analysis Robust Design and Process Capability and Control in Product Design Failure Mode Effects Analysis Product Modeling using CAD/CAM
PRODUCT CREATION – *Streamlining the Process*	Workplace Design Product Line Design Based on Variation, Volume and Optimization Ergonomics in the Industrial Workplace Managing Product Development Building Successful Product Groups Group Interaction Self Directed Working Group

Table III ***Product Design Curriculum***

Let us look at the impact of design on the environment. There is no doubt that the globalization, new economies, and information technology will have an effect, not only on business, but also on the types and forms of products that the new markets will require. The impact, these events will have on the cycles of materials, energy, and information worldwide is tremendous. The global nature of product design and usage has enhanced the relationship between the producer

and the user. It is logical to conclude that the design stage has to be enlarged, first in terms of the ecological impact of the products, and second, in terms of the dualistic mental framework in which the design activity and indeed the activity of the organization itself are viewed. (9, 10)

There is a powerful trend in product design toward material substitution, in using new, synthetically designed materials, which have the highly desirable characteristics of toughness, lightness, durability, and flexibility. These technological advances are spurred by higher rates of productivity and, therefore, higher return rates on investment. In all these cases, the new technology exerts a more serious impact on the environment than the older one if we are not careful. Thus, the major cause of environmental crises has been these technological "improvements," which have originated from a faulty design, failing to take the environment into account, in the quest for narrowly defined efficiencies. There should be concern at the corporate level for the larger consequences of design. By neglecting such safety factors in design, we end up borrowing on the future, running an environmental repair and clean up.

Ecological effects in product design are an important area of concern. Just as we cannot put up a plant without preparing an ecological impact statement, a product needs to be studied for its environmental impact before it is put on the market. This aspect is becoming critical, as the life cycle of the product is getting shorter and shorter.

- *Focus on Modularity*

.Modularity is an important consideration in maintenance of the product. Modularity allows the product to be repaired easily since parts are removed and replaced in modular form. As a result, the re-cyclability of these modules must be considered during the design phase. This also brings the life cycle of the modules into question. In general, the life cycle of any product can be broken down into four areas of interest:

- Design and development
- Production
- Operational Use and maintenance support
- Retirement and material disposal

It is becoming increasingly obvious that during the design phase, engineers must think about modularity. With *modularity*, some of the devices from existing designs can be utilized for the newer designs. Electromechanical products such as computers, telecommunication devices, and peripherals are the most affected by this fast technology. The best example is the Personal Computer. It is estimated that the processor speed increases 1.5 times every 18 months. This essentially means that while the processor becomes obsolete very quickly, other devices within the CPU may not become obsolete. The hard-drive, video card, modem, monitor and RAM may be appropriate to utilize again with the newer CPU. Since all of these devices are modular, many customers upgrade their PC simply by replacing the processor only. Product modularity is an important design for maintenance issue for electromechanical products such as computers, telecommunication devices, and peripherals. The short technology life cycle of many of the functions in these products combined with customer demand for a wide variety of features

necessitates that product designers optimize the modularity of components for manufacturability and serviceability.

- *Focus on Materials and Management in Product Design*

The rapid developments currently taking place in certain research and development fields will have tremendous effects on product design. The changes we have witnessed in the electronic industry in the last thirty years, from the vacuum tube to the present day computer chip, are just a glimpse of what is in store for the future. Wide spectrums of information technologies, biotechnologies, along with other new materials are influencing the market significantly.

In the field of materials, interest in such subjects, as superconductivity is high. The engineering community is currently in the process of developing new materials with special characteristics, such as high technology composites that are light, never wear out and can withstand high temperature, high performance plastics, super glues, and new alloys. These products are on their way to replace more familiar materials, and extend enormously. For instance, these materials are known for their power to weight ratio in engines and-their efficiency. They work at much higher temperatures and at the same time do not require any lubrication or cooling. Therefore, design changes and substitution of one material for another, are what we may expect on a larger and larger scale.

Micro miniaturization has been going on in the electronics industry side-by-side with miniaturization of mechanical products. Micro-electromechanical systems are now being made in laboratories and finding applications in markets in manufacturing, bioengineering and medicine. From microns for typical parts of machinery, we are now down to parts measured in fractions of microns. And already, in the distance, "nano technology" provides measure in billionths of a meter, literally the molecular level. These are products and processes that emulate the mechanisms of biological life.

The importance of managing the design process, i.e., of not letting things just happen, is that of systematically creating favorable conditions that promote innovation and new ideas. The importance of people, of cooperation within multidisciplinary teams, of communication and of the fact that these skills and this knowledge are decisive factors in ensuring the success of the design process and of the product. Balance within the team and in its interaction with the customer is crucial, as well as an emphasis on production, use and consumption. It also clearly demonstrates that designers are decision-makers; that design is nothing but decision-making. Now these decisions have implications and consequences that often go far beyond the simple designer-customer relationship.

- *Focus on Modern Manufacturing on Product Design*

As we transition into the twenty-first century, the marketplace has become truly global. Most companies have much wider product ranges. These companies are introducing new products more quickly with a sharp focus on the market.

In early eighties, most of the industries were involved in organizing manufacturing operations under control through the use of formal production and materials planning, shop floor scheduling and enterprise resource planning. This has happened with varying degree of success. In the 1990's the many industries have attempted to achieve world class status by implementing total quality management methods. Some of them introduced just-in-time manufacturing techniques like cellular manufacturing, quick change-over procedure, one piece part flow, kanban, and other techniques resulting in inventory reduction. Spurred by success stories, the industries moved to team-based continuous improvement and experimented with self-directed work teams. Studying best practice used by others and benchmarking them has become a standard procedure.

As we move into the new century, we need to incorporate these improvements to develop truly agile product development process. Agility is the ability to succeed in an environment of constant and unpredictable change. There is trend towards a multiplicity of finished products with short development and production lead times. The impact of this is seen in many companies in the areas of responsiveness inventory, organizational structure. Mass production does not apply to products where the customers require small quantities of highly custom, design-to-order products, and where additional services and value-added benefits like product upgrades and future reconfigurations are as important as the product itself. An agile approach to manufacturing faces the reality that we must serve customers with small quantities of custom designed parts with perfect quality, 100% on-time delivery, and at very low cost. Companies are forced to organize themselves in such a way that high quality products can be developed very quickly in response to customer requirements.

- *Focus on the Customer*

Customers' requirements and competitive pressures have resulted in the need for companies to decrease product development costs and overall product costs, reduce product development cycle time, and improve quality. World-class manufacturers have placed great emphasis on being close to the customer. The design process can be significantly enhanced by having the customers fully participate in the design of he product. The customers bring their design skills to bear of the project and your company adding its production skills into the equation. In some cases the suppliers and outside process vendors can also be integrated into the design process so that the product is designed to meet the customers needs very effectively. This close cooperation allows for the development of service-rich products that can evolve over time, as the customer and the company work closely together. The products may be designed to not only meet current needs but to be reconfigurable to meet the customers' future needs. Attention is paid to configurability, modularity, and design for the longer term satisfaction of customer requirements. The advantage of close relationships with the customer is that they help ensure that the product being developed really meets customer requirements

- *Focus on Product Teams*

The use of cross-functional product development teams has a major effect on both cycle time and quality. With people from different functions working together, development gets done faster because activities can be done in parallel rather than in series. Quality improves because people from different functions work together to understand and solve development problems. The process is quicker and quality is better - so the net result is that it is also cheaper. In a cross-functional product development team, product developers from different functions work together and in parallel. Team members come from functions such as marketing, design, service, quality, manufacturing engineering, test and purchasing. Often, key suppliers are included in the team. Sometimes, representatives of the customer are also included in the team, allowing the Voice of the Customer to be heard throughout the development process. Team members work together, sharing information and knowledge, and producing better results faster than they would have done if operating in a traditional product development mode. The end result is that products get to market faster, costs are reduced and quality is improved.

- *Focus on Information*

The skills and knowledge of the people within the company become a paramount consideration as a company develops results-based marketing. This knowledge includes product knowledge and experience, but it also includes a rich depth of knowledge of the customers needs, anxieties, and service requirements. Increasingly, the best way to create close customer awareness is to provide the people within the company, and the customers themselves, a great deal of information. This may be product information, company information, education and training, product upgrades, manuals, instructions and specification. Orders can be placed automatically from the customer and scheduled within the plant, yielding the customer accurate delivery promises. The design requirements can be automatically picked up in the customers information systems without drawings or specification being printed and passed. This enables the company to address customer needs with great speed. Design, delivery information, history, accounts receivable, customer service contact can all be integrated.

Some of the technologies required to achieve this level of information sharing and availability have only become available. The wide access to the Internet and the World Wide Web opens up a standard and direct method of access information and providing the customers with a standard link into a companies system. The Internet, and other networks, allow the customer to have a simple and standard link to place orders, make inquiries, send message, and specify their needs.

- *Focus on Cycle Time*

Cycle time has become a key parameter. Reduced lead times open up new market opportunities and improve profits. They reduce market risk by reducing the time between product specification and product delivery. The sooner customers use a product, the sooner their feedback can be incorporated in a new, improved version. In fast-evolving technological environments, products become obsolete sooner. The reduced time between product launch and product retirement

erodes sales revenues. Since this phenomenon depends on factors beyond a company's control, the only way it can lengthen a product's life is to get it to the market earlier.

Bringing products to market quickly means that product offerings will be fresher and the latest technology can be included because less time passes between definition of the product and its arrival on the market. Less time in development means less labor and less cost. The company responds quicker to customers, gets more sales, and sets the pace of innovation. A company which is good at developing new products can use this advantage to gain market share. While competitors are busy developing the same abilities, the leading company introduces new products and features faster, and also develops new abilities.

- *Focus on Development Process*

The cycle time of any development operation depends closely on the development process. Any attempt to improve cycle times will involve investigation and improvement of the development process. A clearly defined and well-organized product development process lies at the heart of an effective engineering environment, yet only a few companies have taken advantage of the potential advantages it offers. To make improvements, the process has to be analyzed and understood in detail. A new, fast, waste-free, low-cost process has to be defined and then implemented. Probably many existing tasks will have to be removed, some new ones added, and the overall organization of the process will change significantly. Without a well-defined development methodology, it's unlikely that the members of the product development work to maximum efficiency. The rules for working together during the development of a product have to be delineated. A clearly-defined approach to development, that is appropriate for the product family, and is understood by all team members, will provide the best results.

Product development is a complex process involving many poorly understood variables, relationships and abstractions. It addresses a wide range of types of problem, and is carried out by a wide variety of people, using a wide range of practices, methods and systems, working in a wide variety of environments. Converting a concept into a complex multi-technology product under these conditions is not easy. It requires a lot of effort, definition, analysis, investigation of physical processes, verification, trade-offs and other decisions. Companies without a well-defined product development process won't get the benefits they expect from initiatives to improve engineering performance. Without a clearly defined methodology, it's not known which systems and practices are most appropriate - so the necessary integration of an initiative will be difficult to carry out. Any gains that come from use of an initiative in one place are likely to be lost in another place because a coherent solution hasn't been prepared. Companies that understand this and put in place a clear product development process supported by a well-defined development methodology have every chance of becoming market leaders. They can use the methodology as the basis for involving people at all levels and in all functions in defining, designing, and producing the best product and getting it to the market faster.

- *Focus on Supplier*

To respond to the need to get products to market faster, to reduce the cost of developing products and to make sure the product provides customer satisfaction, the product development process needs to be re-organized. There are many possible approaches to re-organization. Many of them will increase the reliance on suppliers. Companies that focus on upstream product specification and design activities where they can best use their resources will want to outsource downstream activities where they are not cost-effective or are less competent than specialized organizations so suppliers will have a greater role to play in these areas. For many companies, the cost of purchased materials accounts for more than half of their expenses, so it's a good place to try to reduce costs. As well as increased use of suppliers, the future will also see them being involved earlier in the product development process.

- *Focus on Prototyping*

Computer-based simulation and rapid prototyping provide fast and low-cost proof of design concepts. In the coming years, there will be a lot of pressure on companies to improve their product development performance. They will have to develop products faster, at a lower cost, and with better quality.

Simulation and rapid prototyping will help them meet these objectives. Simulation is carried out to study the performance of a system, product or process before it has been physically built or implemented. It involves the development and testing of a computer-based model of a part or product. Rapid prototyping is the production of a physical prototype directly from a computer-based model of a part or product.

There are savings in reduced material costs. There are savings because all the activities of defining the process for making the prototype and then building it and testing it are no longer needed. Quality is improved because it is possible to define and test many more potential designs using a computer-based model of the part than when using physical prototypes. The benefits of simulation come from use of computer-based models. The benefits of rapid prototyping come from use of physical models produced directly from computer-based models.

Companies that don't use simulation and rapid prototyping will find their product development cycles are longer, and their development costs higher, than those of companies that do use them. Both practices offer the advantages of reducing development costs and cycles and improving quality. Benchmarking is the continuous process of measuring products, services, and practices against a product development organization's toughest competitors or those renowned as industry leaders. If the other organizations are found to have more effective operations, then the product development organization can work out why they are better, then start to improve its own operations.

- *Focus on Concurrent Engineering*

Key concepts of new product development include customer orientation, major decisions, up-front, concurrent development of product design and production processes, using cross functional teams, and use of efficient design and manufacturing techniques. It is important to convert customer inputs into specific product functions, features, and specifications. The "voice of the customer" must be translated into product requirements that meet the needs and expectations of the customers. This is an important step and must be done in the beginning. Customer satisfaction is a primary factor in the success of a product. These expectations can be summarized in four terms: better quality, reliability, free maintenance, and lower price. The product development process uses the customer expectations as an input and concurrent engineering as a design approach.

In addition to the voice of the customer, there is increased pressure to get products of ever-higher quality to the market in ever-shorter times. Customers are scrutinizing product price/performance ratios more carefully. The traditional “serial” approach to product design and development reduces the ability to compete effectively on the global market with following weaknesses:

- Insufficient definition of the product
- No clear guidelines on how they will develop in detail before production
- Inadequate cost analysis
- Changes occurring in the design process

The appropriate response to these weaknesses is in the concurrent and multidisciplinary approach, in the early stage of the product development process. The new approach initiates design of product and associate processes, which is not the case in the traditional approach. Studies show that more time spent early in the design process is more than compensated by saved time when prototyping takes place. It offers the possibility to reduce costs and time to market, while at the same time increases the product quality and customer satisfaction.

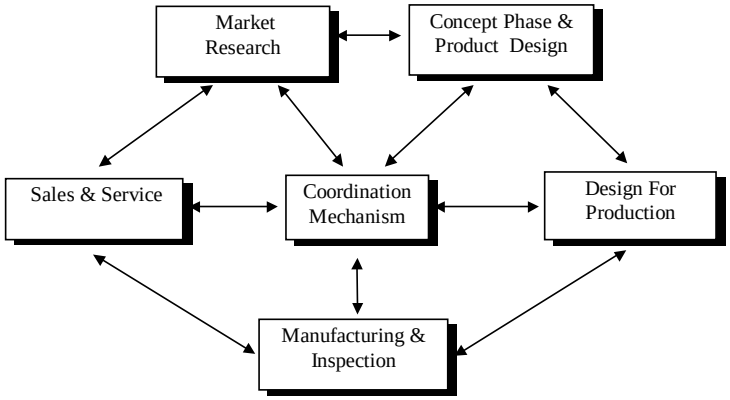

Figure 4 ***Basic concurrent engineering model***

Figure 4 shows the basic concurrent engineering model. Concurrent design improves the quality of early design-related decisions and has a large impact on the life cycle of the product. Successful implementation of concurrent engineering is possible by coordinating adequate exchange of information and dealing with organizational barriers to cross-functional cooperation.

- Concurrent engineering bridges design and manufacturing.
- A traditional barrier between design and manufacturing is removed. Concurrent design improves the quality of early design decisions and has a large impact on the life cycle of the product.
- Creating a quality culture in an organization, introducing a team focus and product focus approach to project management generates the total philosophy of concurrent engineering in the organization. It is well suited for team-oriented project management, with emphasis on collective decision-making.

- *Foucus on Costing*

Activity based Costing (ABC) is a costing technique used to overcome deficiencies of traditional product costing systems which may calculate inaccurate product costs. The reason for these errors is often that the attributes chosen to characterize costs related to a particular product are attributes of unit products (such as direct labor hours per product) whereas many costs (such as set-up time) are related to batches of products. ABC is based on the principle that it is not the products that generate costs, but the activities that are performed in planning, procuring and producing the products. It is the resources that are necessary to support these activities that result in costs being incurred. ABC calculates product costs by determining the extent to which a product makes use of the activities.

6. **Conclusions**

The techniques listed in this paper are used by world class companies to guide the design, and development of high-quality products in a step-by-step manner using analytical tools and case studies. A typical product design course should include specific topics such as- how to build a product team, characteristics of a self-directed product team, new product creation strategy and process, creative design techniques, principles of design for manufacturing, design for disassembly, optimization, and ergonomics. In view of the recent development in lean manufacturing and information technology, emphasis on value stream mapping and its influence on product development is important. The paper concludes by summarizing the special topics that need a focussed approach to product design.

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