# Re-engineering life-cycle management of products to achieve global success in the changing marketplace

**B. Prasad**
Electronic Data System (EDS), General Motors Account, CERA Institute, West Bloomfield, Michigan, USA

**Today, most companies are under extreme pressure to develop products within time periods that are rapidly shrinking. As markets change so do the requirements. The immediate effect of changing requirements and players keeping the process intact is the lengthening of product development efforts. Life-cycle management means "managing process" for systematically incorporating a new product family or a new technology, handling continuity, and a revision-type product change. Describes the differences in management styles for both Japanese and UK companies. Enumerates the better ways of redistributing the life-cycle efforts in product development without exceeding the original cycle time.**

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## Introduction

The combination of new and old practices, such as old-fashioned habits, a new life-cycle environment, organizational changes and mounting regulations, has increased the complexity of the product development efforts. The complexity results from five main sources:

1 inherent product complexity;
2 process complexity;
3 team co-operation and communication complexity;
4 computer and network complexity; and
5 a maze of specifications including international regulations and safety.

Over the past few years the diversity, variety and complexity of new product introduction (NPI) have grown from "very simple" to "very complex". At the same time, the time-to-market dimension has shrunk (Prasad, 1994). This is shown in Figure 1. The changing market conditions (such as global manufacturing, economy and new innovation) and international competitiveness are making the time-to-market a fast shrinking target. Today an automobile with a complexity several times higher than before can be manufactured in less time (often less than three years). The same product, about half a decade ago, used to take over five years to bring to the marketplace. Its complexity ten years ago, by today's standard, could be characterized only as "very simple". The workstation market is another good example. With new innovation in chip technology, workstation companies have continually shortened the time between new product introductions. In 1985, when a new central processing unit (CPU) was introduced, it was quite innovative – but was nowhere close to today's standard in complexity. Every 18 months thereafter, a new CPU, twice as complex, was introduced at twice its performance at roughly half the price. In 1988, a four-times-as-complex and four-times-as-fast CPU was introduced at a quarter of the price in a 12-month period. In 1990, the development cycle for a new CPU (16 times faster) was introduced in only six months at nearly one-sixteenth of its 1985 price. The CPU case is an example of the changing environment that a company is facing today. There are many such examples. The average development time for a compact disc (CD) player today is nine months, a PC is 14 months, and a knowledge-based engineering (software development) system ranges from two to four years.

Among such complexity, it is easy to overlook the fact that requirements of the customer are also constantly changing. The customer is also becoming more sophisticated. Each time a company fulfils the customer's wants in a product, the level of the customer's expectation also moves up a notch. They demand customized products more closely targeted to their personal, social and cultural tastes. The same is true for the expectations of the performance indicators discussed in Section 1.6 of *Concurrent Engineering Fundamentals* (Prasad, 1996). Product gets old quickly – customers' excitement fades away, and demand declines. There is a great danger that, a few years after its introduction, a product may not remain attractive to the market that existed at the launch time. Introducing new products at frequent intervals is not a good business solution. New products require significant investments in redesign, retooling and manufacturing costs. Development costs consist mostly of expenditures for staff and testing. These costs tend to increase proportionally with the overall time taken to complete the design. For this reason, most manufacturers have focused on shortening the time taken for new models to be designed and tested. Toyota, for example, had set its sights on reducing the average development time of its automobiles from 30 months to 18 months by 1996 year-end. The US Department of Defense (DOD) computer-aided acquisition and logistics support (CALS) initiative identifies CE as an enabling technology that can help potentially lower development and operational costs while appropriately managing the moving targets.

## Shrinking life cycle

There are many ways one can describe a product's life-cycle efforts. Terms related to time include useful life; lead time; art-to-part time; design and development time; launch-to-finish time, life-cycle time, etc. The literature uses these terms quite loosely. Figure 2 describes these terms so that their meanings are uniform and consistent. The two terms that are widely used are lead time and life-cycle time. Lead time is the time required to finish one unit of a product, which could be an operation or a service. Since a product is made out of several units (subsystems, components, parts, etc.), there are many possible units of lead times. Figure 3 gives an example of a lead time for a machining operation. The machining operation is shown broken up further into smaller activities (for example load/unload time, set-up time, process/operation time, move/transfer time, rework time, storage time, etc.) to facilitate accurate computation. Life-cycle time is the total elapsed time. It is the total time a product takes from cradle (the time when the initial idea was born) to grave – that is until parts of the product are recycled. The immediate effects of changing requirements and players keeping the process intact are to lengthen product development efforts. As the product design cycles stretch out, costs mushroom and quality suffers. The real pressure to reduce development costs and life-cycle time comes from overseas competition. Not too long ago, mechanical typewriters had a 30-year useful life span, and electromechanical typewriters had over a ten-year life span. They were both quickly replaced by word processors and personal computers. Development time and cost are becoming crucial in all engineering industries. It is becoming particularly serious in electronics industries where profits have been squeezed the most over the last decade. For example, the development life cycle (when pay-off or returns-on-investment start coming in) of audio/video products, such as compact disc players and VCRs, is now less than a year (close to nine months). The average useful life span of a VCR when someone replaces one – already in use or broken – has gone down to about five years. Figure 4 shows such trends (average) in useful life span and development life-cycle time of products across a number of key competitive manufacturing industries.

$$\text{Elapsed time} = \sum (\text{load/unload time} + \text{setup time} + \text{process/operation time} + \text{move/transfer time} + \text{rework time} + \text{storage time} + \text{delay/wait/idle time} + \text{certification/inspection time}). \quad (1)$$

The pay-off period begins when the product development life-cycle time ends. It continues until product remains in use. The hatched area in Figure 4 represents a time period during which the company reaps maximum profits. This is referred to as "lead time". The period of profitability changes from industry to industry and from product to product. It is the lowest for consumer electronic industries and for computer products.

The global marketplace of the 1990s has shown no sympathy to tradition. The marketplace recognizes only results and is insensitive to efforts. Among the features present, customers appreciate only what they find useful in the products; they do not care how they got there. The reality is that if the products manufactured do not meet the market needs, demand declines and profits shrink. As profit margins dwindle, so does the window of opportunity for the company to change profitably. Furthermore, suppliers, subcontractors and partners feel the squeeze as their clients begin to cut costs and reduce time-to-market. The 1990s are not the first time the importance of time has been recognized. In the early 1980s, manufacturers (predominantly in Japan) had developed successfully a set of production techniques for "assembly-oriented plants" to supply the component parts on a 'just-in-time' basis. This technique was clearly one of the first to emphasize "time" in its orientation.

Today, most companies are under extreme pressure to develop products within time periods that are rapidly shrinking. As the market changes, so do the requirements. This is more pronounced if the products are

**Figure 1**
A case of a constantly moving target

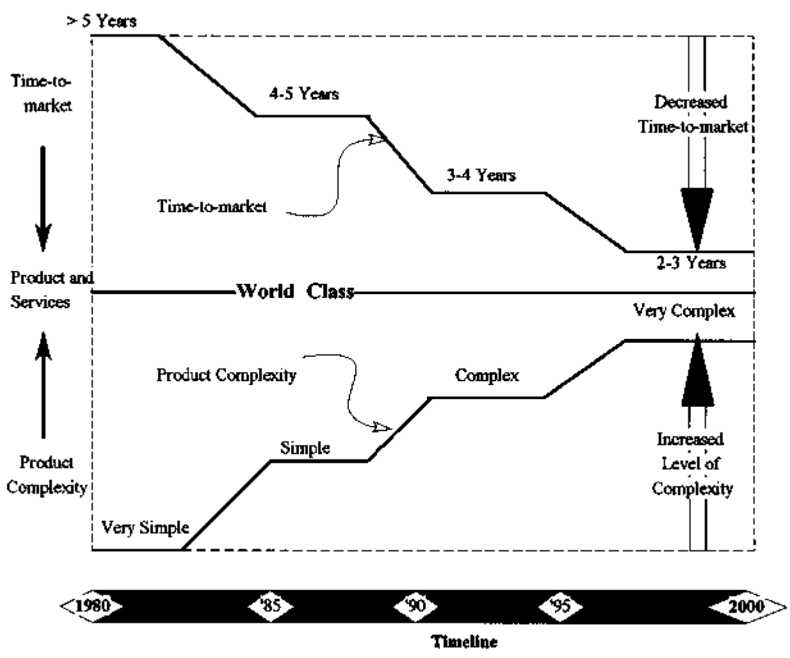
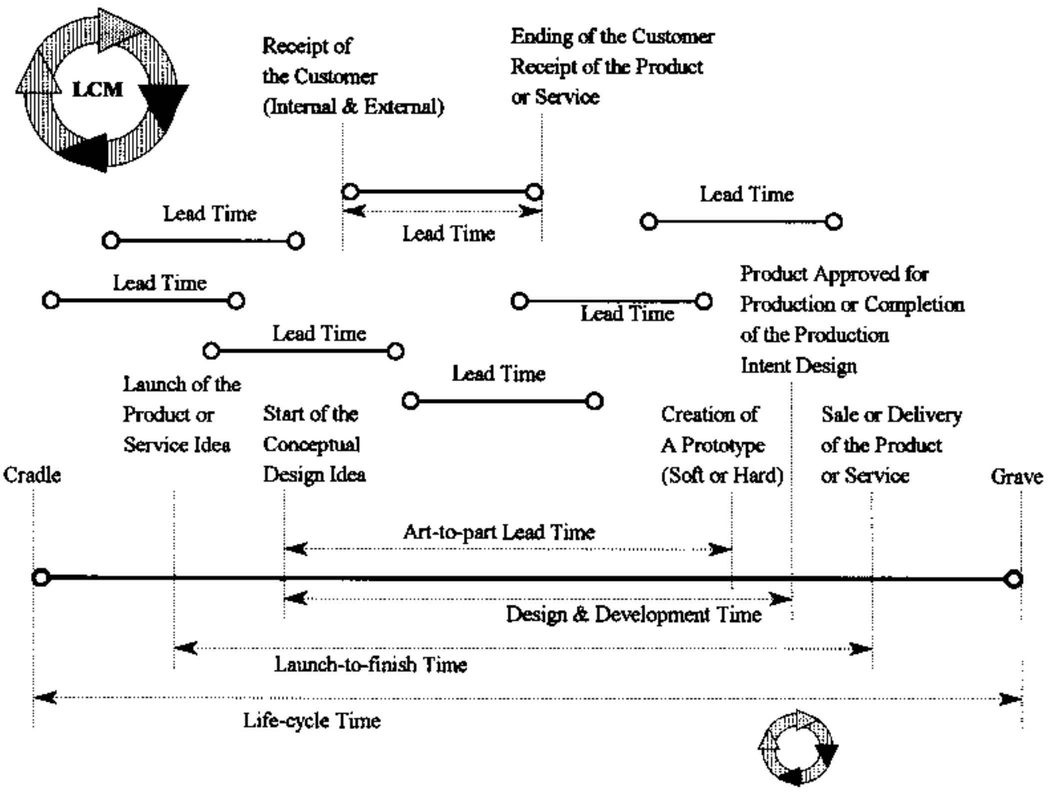


**Figure 2**
Terms describing life-cycle efforts




**LEGEND**

| | |
|---|---|
| ***Useful-life*:** | Duration of time in which product is in use in the field by the customer |
| ***Lead Time:*** | Total time required to complete one unit of a product or service |
| ***Art-to-part Lead Time*:** | Design and development of a prototype part |
| ***Design and Development Time*:** | Time it takes from the start of the conceptual idea to the creation of the production intent design |
| ***Launch-to-finish Time*:** | Duration it takes from the time product is first launched until the sale or delivery of the product or service |
| ***Life-cycle Time*:** | Time it takes from cradle to grave -- until the part is recycled. |

consumer based. For instance, the product that a consumer wants today may not be appreciated when delivered three years from now. Associated with this are the urgencies and pressures on the manufacturers' part to modify their product characteristics based on the up-to-date requirements, while the product is still being developed. This has chilling effects in managing the complexity of such continuously varying product specifications and handling the ongoing changes. This is because it takes a considerable amount of time and effort to propagate the specifications throughout a product design development and delivery (PD3) process and then turn them into opportunities for growth and profits. The ongoing success of an organization lies in its ability to:

- continue to evolve;
- react quickly to changing requirements;
- reinvent itself on a regular basis; and
- keep up with ever-changing technology and innovation.

Many companies are stepping up the pace of new product introduction, and are constantly learning and embracing new ways of engineering products more correctly the first time, and more often thereafter.

## Re-engineering product development efforts

A question often asked is: "If the product design process is to be changed, what would be an appropriate approach to product development?" The answer is not very difficult. Figure 5 illustrates the pattern of resources

**Figure 3**
Unit lead time for a machining operation (an example)

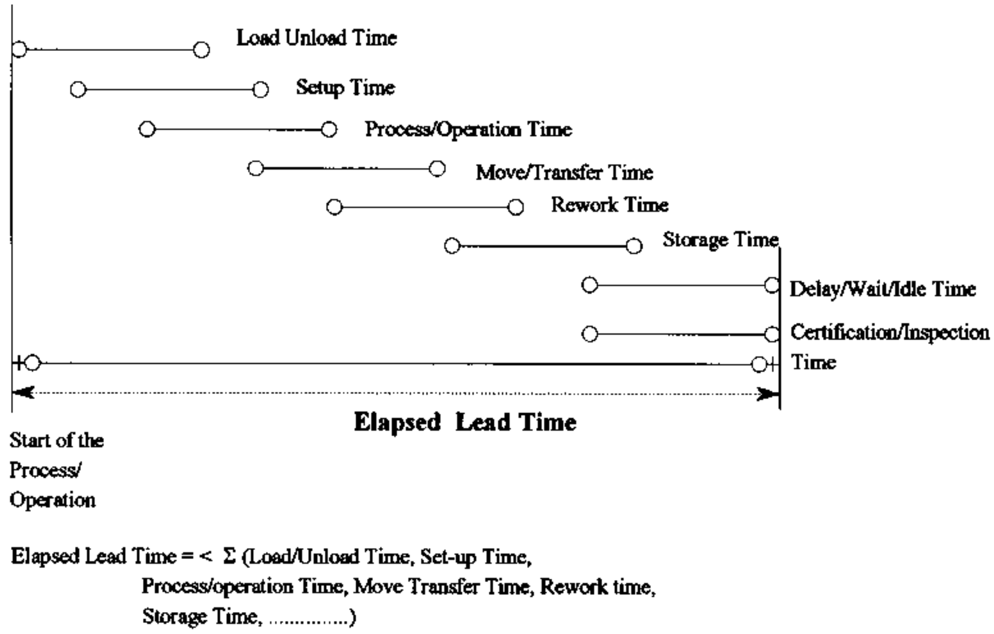
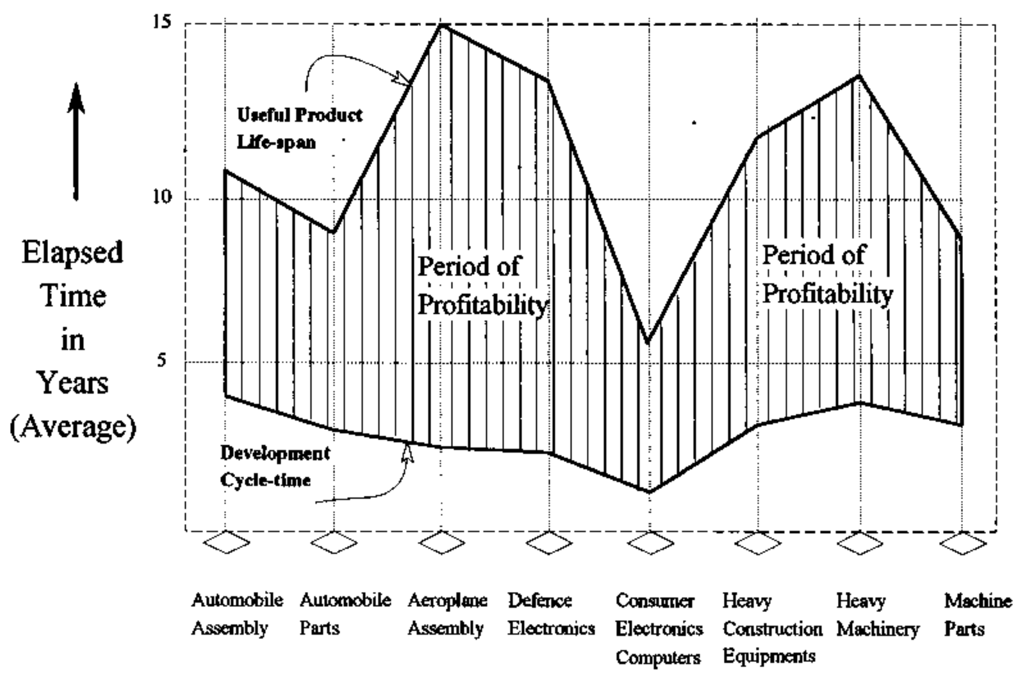
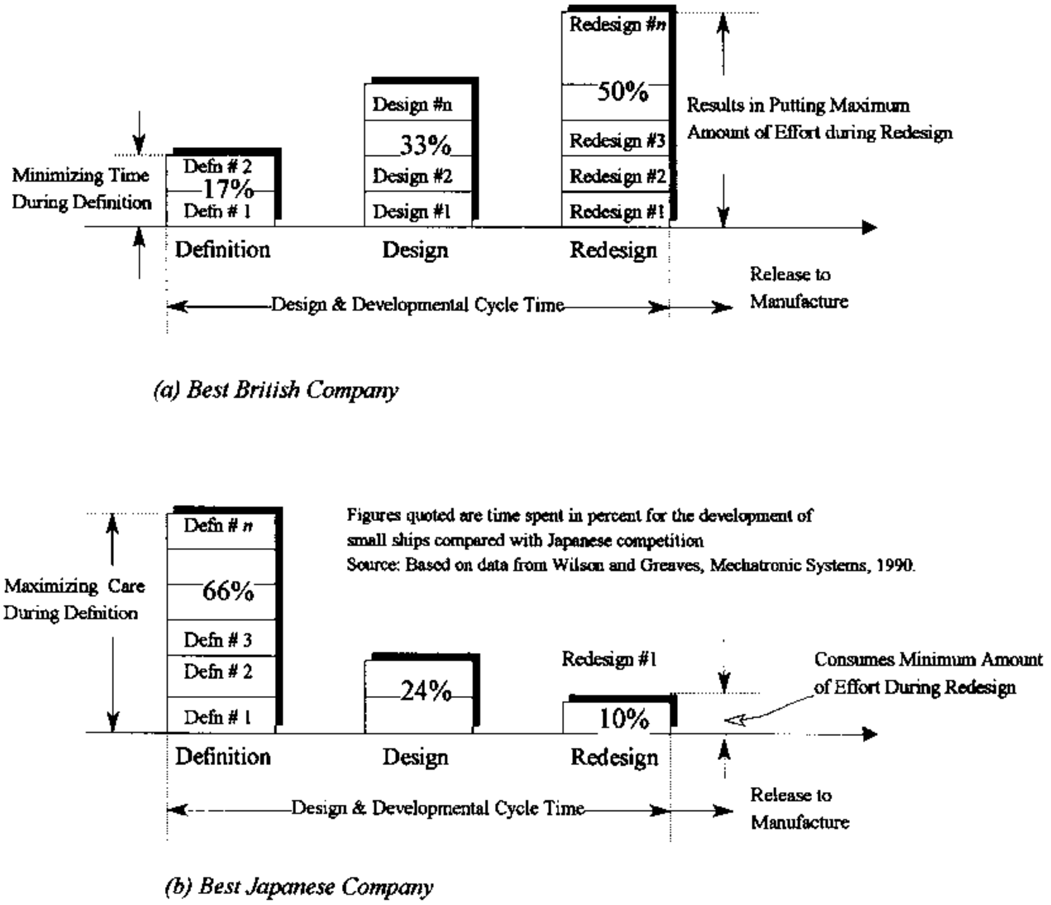



**Figure 4**
An industry-wide trend showing useful product life span and start of pay-off period (average)




that are spent in a product's definition, design and redesign phases for both British and Japanese companies (Wilson and Greaves, 1990). The British pattern (mirrored in the USA) is one where meagre resources are committed to the definition/design phases (17 per cent), compared to what is ultimately spent in the redesign phase (50 per cent). For example, some firms take people off projects/tasks that are just starting up and move them to projects/activities that are already late. They feel that since the projects/tasks are just starting, taking resources away perhaps will not cause problems. They do not understand that the

**Figure 5**
Distribution of product development efforts (a) Best British company (b) Best Japanese company




mesh they are in could be the result of their own creations. The tasks are late because they made careless decisions in the starting stages. The result is that they are always in a fire-fighting mode; there is never time to do less important things because there is always something urgent. To achieve a comparable level of quality, the Japanese do things in quite the reverse order. They strongly focus on product definition supported by optimizing techniques during design (a hefty 66 per cent of the effort is spent here). This results in getting the product design correct the first time, thus reducing the need for any extensive redesign. The average time spent by the Japanese in the redesign phase is relatively very small – somewhere in the 10 per cent range.

The percentage quoted in staff hours is for a British company designing small ships and that of a Japanese counterpart. In the British company case, the penalty was further compounded by the cost when another similar vessel was ordered. The incremental design cost for a second Japanese vessel was almost negligible (10 per cent) but that for the British vessel was five times more (close to 50 per cent of the total effort) (Wilson and Greaves, 1990). Today, the relative gap, however, is closing. Some US manufactures have achieved impressive results. Chrysler brought the viper automobile to market in a three-year development cycle time, significantly breaking previous five-year standards.

The difference between the Japanese and British approach thus boils down to two main points:
- difference in life-cycle management methodology; and
- effectiveness with which life-cycle management is practised. Those who are able to make sound decisions during the early life cycle will win the biggest competitiveness and profitability prize.

In a separate investigation, Andreason, Myna and Han (1987) report a very similar distribution of the operating costs incurred by various departments. This is represented in Figure 6 by a pie chart. Clearly the design is a tiny piece of the development pie, but it locks in a bulk of later (in downstream processes) spending.

It has been reported (Patton, 1980) that 70 per cent of the total cost of manufacturing a product is committed by the time of conceptual formulation. It rises rapidly to 85 per cent at the start of development time before any hardware is built. Since the actual time and expense in product development during this initial stage are low (10-30 per cent range), any changes introduced at this point cost very little but can greatly influence the subsequent costs of the production (Nevins and Whitney, 1989). On the contrary, if the changes are made during the later stages, such as manufacturing planning of the part, only 10-20 per cent of the product costs are affected. Most people in many companies do not realize this fact. They start too late looking for the source of the problems and end up spending too much time and money in "fixing" the problems at a "wrong" place. In reality they end up fixing only the "symptom" of the problems. The "real" fix for a bad manufacturing process is not more of SPC (process control), SQC (quality control) or any similar controls on the factory floor. It is the discovery and elimination of the source of the problems at the upstream stages, so that the redesigned process is insensitive to such variations.

It is further said that unknowingly making wrong decisions at early stages, on an average over a number of tasks, turns out to be a more cost-effective way than being precise. For example:

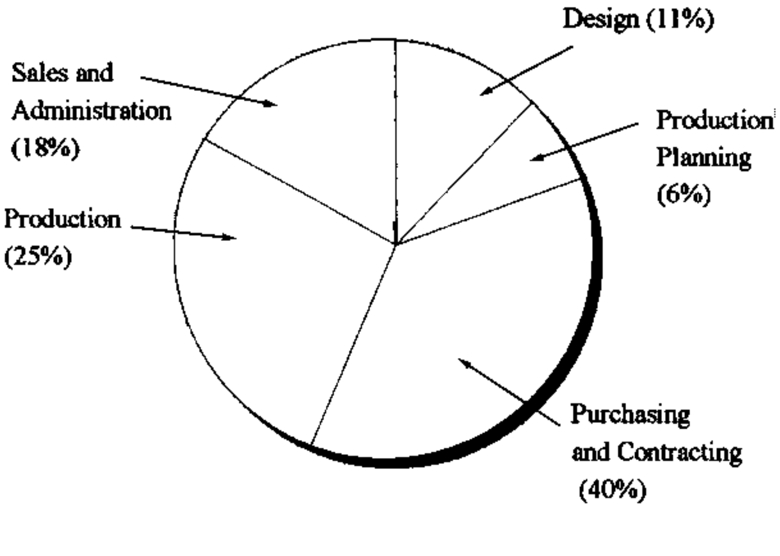
> The sum of costs of cancelling *N* tasks at 25 per cent completion stage (if in doubt) + associated penalty of making an unknowingly wrong decision (to cancel them), is far, far less than the sum of costs of cancelling those *N* tasks at the 75 per cent point, if found that the original decision to continue at the 25 per cent point was clearly wrong

where *N* could be any number of tasks, usually more than one. The differences between the two cost scenarios are more pronounced when *N* is large. In general, the penalty for cancelling even a few tasks at the 75 per cent point is normally so large that it does not make sense to wait for availability of precise information. In other words, it does not pay to make decisions late in the PD3 process, even though most decisions at that point are likely to be the right decisions.

A similar trend occurs for the cost incurred in fixing a mistake and for the amount of control one has at any stage (see Figure 7). A mistake committed and discovered during the planning and design phase is comparatively inexpensive to fix. However, if it is overlooked and discovered later during process engineering, such a mistake can cost manufacturers several thousand times more. By the time a mistake comes to actual manufacturing, for example, it could cost millions more to fix compared to what it would have cost if detected earlier. After a few initial stages, changes are expensive because the CAD model, the prototypes, the intent definition, the DFX checks, analyses, documentation, and the processing have all been completed or begun. These steps must be redone or modified.

Detecting and early fixing of design can save a considerable amount of time, which can otherwise result in material waste, additional planning time, design time, reprocessing, and lost time-to-market implied by the correction process. The actual cost of designing a typical product is however a small percentage (10-20 per cent) of the total cost of the product. For heavy engineering products in the aerospace and defence industry, such costs could reach up to 40-50 per cent. There are thus dual disadvantages in delaying the decision-making process – the cost becomes high and at the same time the degree of control is sharply reduced.

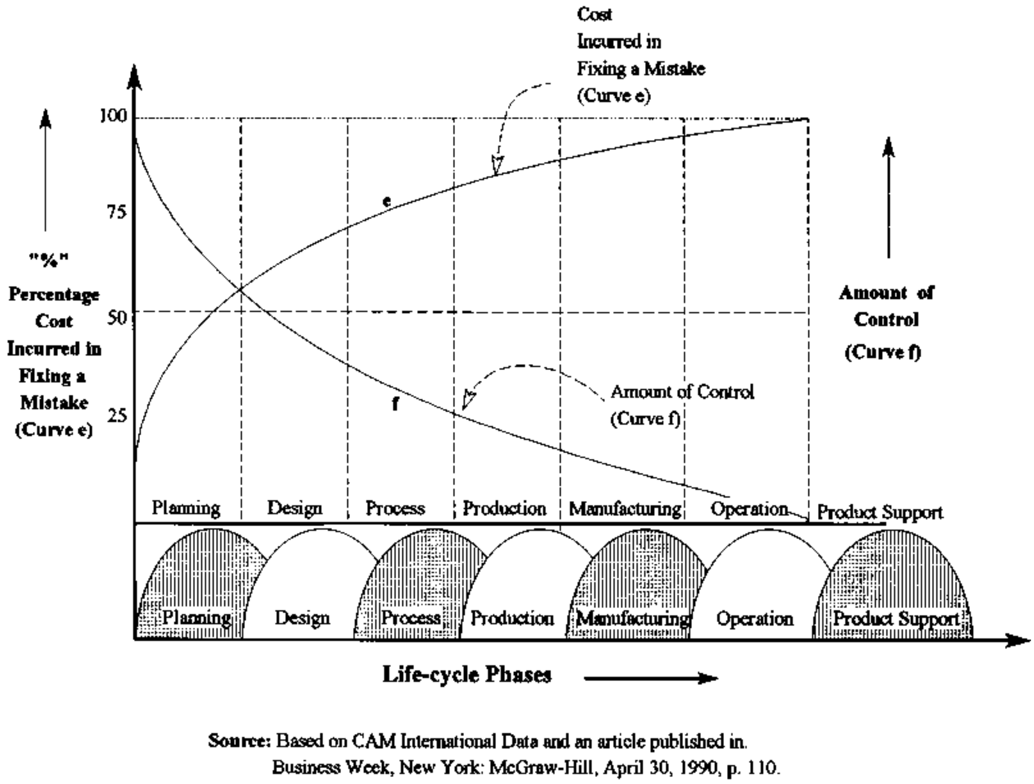
**Figure 6**
Percentage of actual operating costs incurred by various departments




## Life-cycle management

Many progressive companies are interested in maintaining a competitive edge in the world market and in producing high quality products. They would like to maximize the life-cycle value of a product while containing costs and environmental burdens. These values, for example, include characteristics such as manufacturability, serviceability, recyclability and other environmental issues. They would like to manufacture the product

**Figure 7**
(e) Cost incurred in fixing a mistake; (f) the amount of control




at a cost much lower than their competitors. Life-cycle management (LCM) is a process often used to accomplish these goals. LCM is actually a transformation process. It transforms a set of raw resources to a useful product, energy or services that consumers want or intend to buy (see Figure 8). The resources may be present as follows:

- material resources (such as water, wood, oil, miners, etc.);
- energy resources (such as chemical, nuclear, electrical, hydraulic, etc.); or
- in other forms (such as capital, manpower, real estate, etc.).

There are three types of transformation that are usually present in such a system:

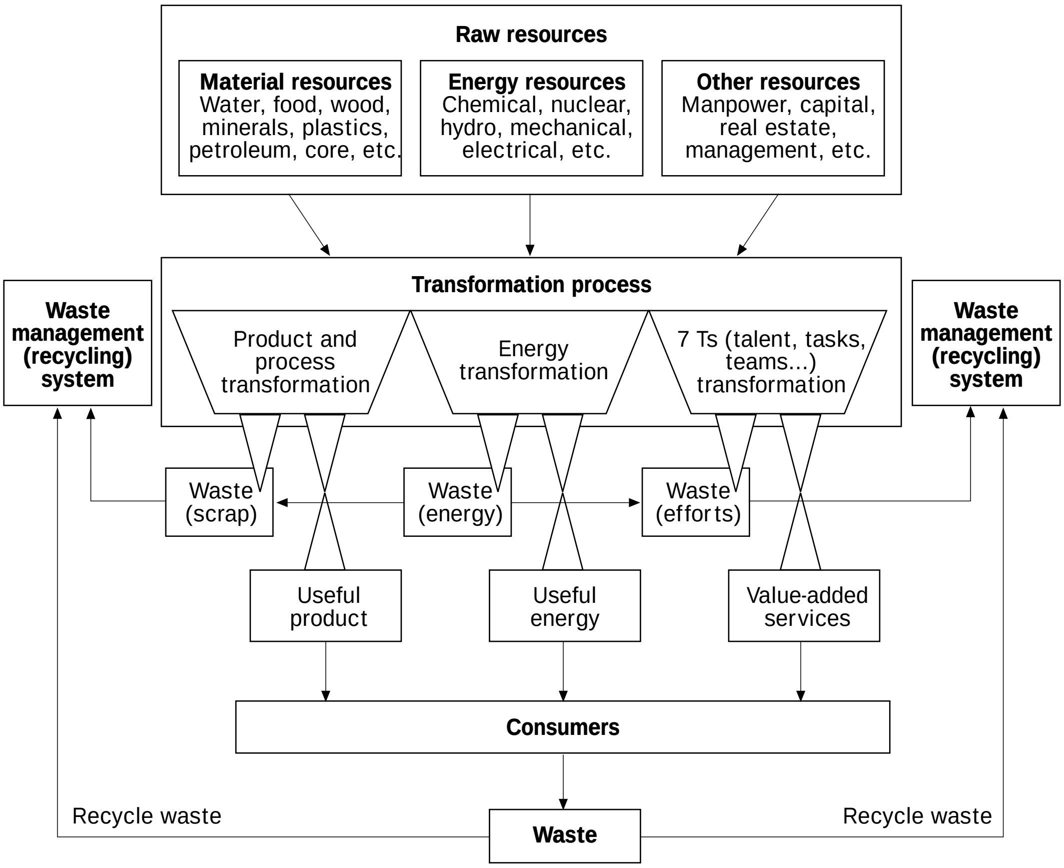
1. Product and process transformation that produces a useful product or unexpected scrap.
2. Energy transformation that produces a useful energy and some unexpected energy waste.
3. Seven Ts transformation (Prasad, 1996) that produces a value-added service and some wasted efforts.

LCM includes not only the effective conversion of the raw resources into useful outputs but also the management of the waste resulting from it. There are two types of waste:

1. waste from the process of transformation;
2. the consumers' waste that needs to be safely disposed or recycled.

To date, many companies view product realization as characterized by long lead times, a multitude of engineering changes, manufacturing complications, and ultimately heavy costs to satisfy the customer requirements. The number of engineering changes that occur in the best US company is 40 to 60 per cent more than the best Japanese company (see Figure 9). This is because in most US companies, efficient decision-making processes are lacking. They either limit the process to conventional "design review" or "red-team" meetings that inhibit free flow of information. These serve no purpose but to postpone the decision from being made until after the meeting, or centralize the decision-making authority in some committees or hierarchical (tall silo) structure. For example, an engineer's choice of "design for X-ability" decision is often perceived as a functional service to be called on periodically for incremental improvements in product quality, new product lead times, and costs. However, the perception is clearly different in successful engineering companies, where DFX is seen as

**Figure 8**
Scope of life-cycle management



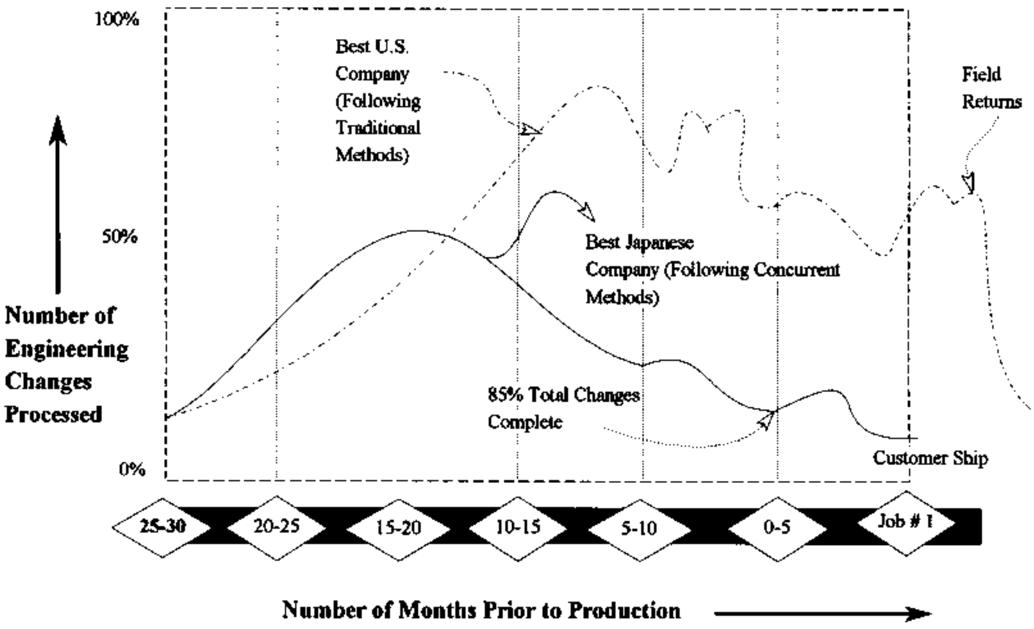

a pervasive set of engineering activities that form the life blood of the CE co-operating teams. There, decision making steers the PD3 process. There are companies which determine what subsystems, components, parts, etc., to develop. Companies define a set of consistent product objectives with respect to company and customer goals, set priorities, and allocate resources.

Table I compares the actual 1990 automobile production data between the USA and Japan. In all the five categories shown, US production levels fall short. It takes 43 per cent more design effort and about 21 per cent more time to finish the design than that taken by the Japanese automobile company. At any time the number of models in production for Japan is twice that which the Americans seem to put through their own production system. The average replacement period per model for the Japanese is about 50 per cent smaller, meaning that they were able to replace two car lines in the same period in which the Americans could do only one. The Japanese could manage to replace the car lines, even though their annual production was half that of the American annual production volumes. This goes with what someone once said: “Japanese say adopt, then become adept, and only when there is nothing else to adopt, they adapt”.

## Concluding remarks

Change happens all the time in all organizations. Most of the time, however, change is unplanned, unmanaged and uncomfortable. Life-cycle management means learning to deal with new product introduction, changing technologies and systems, initiating quality leadership, process management, shaping direction for the change, taking control and establishing the improvement process. Life-cycle management means management process for systematic incorporation of a new product family or a technology, handling continuity, and a revision-type product

**Figure 9**
Number of engineering changes in best US and Japanese companies




**Source:** Based on American Supplier Institute (L.P. Sullivan) Data

**Table I**
US and Japanese automobile production data

| Concept-to-delivery life cycle | US (Japan) data during 1990 | Competitive advantage (percentage) |
|---|---|---|
| Design time per model (months) | 60 (47) | 21.7 |
| Design effort per model (million man hours) | 3.0 (1.7) | 43.3 |
| Average replacement period per model (years) | 9.2 (4.2) | 54.3 |
| Average annual production per model (thousands) | 230 (120) | 47.8 |
| Model in production (number) | 36 (72) | 50.0 |

**Source:** Based on data published in *The Economist*, 14 April 1990

change. There are four aspects of life-cycle management:
- new product introduction;
- strategic technology insertion;
- managing continuity; and
- managing revision change.

With the advent of new process and design techniques, current processes may need to be restructured, reprocessed, or re-engineered to exploit their maximum potential on product life cycle. One of the major challenges in CE is to find an appropriate balance between "continuity", "revision" and "restructuring". Continuity is used here to indicate carrying the day-to-day operation, with the exceptions of "engineering change-order" procedures or minor alterations. "Major change" means changing the life-cycle methodology, process re-engineering or anything new that is introduced.

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