# UNIT 16 PHYSICAL DEVELOPMENT OF THE PRODUCT

**Objectives**

After reading this unit you should be able to:

- explain the significance of physical development of the product
- discuss the importance of planning for product architecture
- identify the need for designing the product and industrial design
- discuss products for manufacturing designers
- understand the basic principles of concurrent engineering
- describe developing product prototype
- explain the product development process.

**Structure**



## 16.1 INTRODUCTION

In the earlier unit we have seen how to generate different ideas and how to convert and test them as product concepts. Our interest really lies in how to develop the selected concepts into physical products what really consumers are going to buy, utilize and consume. The physical development of a product concept would include number of steps like, defining an product architecture, developing industrial design for meeting the expectations of consumers as well as incorporating product manufacturability, prototyping for evaluating the product physically and testing the product for consumer and trade acceptability. During this process number of functions and departments are involved, they may pull the project to their advantage, it is the responsibility of project manager to bring in the capabilities together and focus the efforts and resources in achieving a successful product by meeting the requirements of different stakeholders. In the following sections we would discuss some of the important issues related to physical product development and testing.

## 16.2 PRODUCT ARCHITECTURE

Product Architecture is the arrangement of the functional elements of a product into physical blocks. A product's architecture emerges during concept development in the sketches, function diagrams and proof-of-concept prototypes. The architectural decisions are finalized after the product concept is selected. This is followed by detailed design of the product during the system-level design phase. During this phase modeling, analyzing, and testing the system-level performance of the product, choosing values for key design variables, and selecting key components and supplies is undertaken.

The purpose of the product architecture is to define the basic physical building blocks of the product in terms of what they do and what their interfaces are to the rest of the device. Architectural decisions allow the detailed design and testing of these building blocks to be assigned to team individuals, and/or suppliers, such that development of different portions of the product can be carried out simultaneously.

A product can be thought of in both functional and physical terms. The functional elements of a product are the individual operations and transformations that contribute to the overall performance of the product. Functional elements are usually described in schematic form before they are reduced to specific technologies, components, or physical working principles. For example some of the functional elements of a clock are `showing time' and `giving alarm signal at a pre-specified time'.

The physical elements of a product are the parts, components and subassemblies that ultimately implement the product's function. For example, some of the physical elements of a clock are "dial" and "hands". The physical elements of a product are typically organized into several major building blocks called chunks or some times as modules. Each chunk is then made up of a collection of components that implement the functions of the product. The architecture of a product is the scheme by which the functional elements of the product are arranged into physical chunks and by which the chunks interact. To explain let take for example a television set. Here some of the chunks, which make up the product, are "picture tube", `volume control', `speaks', and "channel tuners'. Consider the chunk speaker; it is made of the following components, diaphragm, voice coil, magnetic core etc. This design exhibits a modular architecture.

A modular architecture has the following properties:

- Chunks implement one or a few functional elements in their entirety.
- The interactions between chunks are well defined and are generally fundamental to the primary functions of the product.

The opposite of modular architecture is an integral architecture. It exhibits following properties.

- Functional elements of the product are implemented using more than one chunk.
- A single chunk implements many functional elements.
- The interactions between chunks are ill defined and may be incidental to the primary functions of the products.

Modularity is a relative property of product architecture. Products are rarely strictly modular or integral.

**Implications of the Architecture**

Decisions about how to divide the product into chunks and about how much modularity to impose on the architecture depend on following issues: product performance, product change, product variety, component standardardization, manufacturability and project management.

**Product Change**

The architecture defines how the chunks relate to the function of the product, hence it also defines how the product can be changed. Modular chunks allow changes to be made to few isolated functional elements and require changes to several related chunks.

Some of the motives for product change are:

- **Upgradation:** As technology advances or user needs evolve, some products have to be upgraded. (For example MICROPROCESSORS have evolved through PC-X'1 PC-AT, AT-286, AT 386, AT-486, PENTIUM, PENTIUM-CELERON, PENTIUM-II and PENTIUM-III as of now).
- **Ad-ons:** Many products are sold by a manufacturer as a basic unit, to which the uses adds components, often produced by third• parties, as needed (e.g. Mass storage devices like compact disc drives can be added to a basic computer).

- **Adaptation:** Some long-lived products may be used in different use environments, requiring adaptation. (e.g. Wet grinders working in 220V power in India have been adapted to work in I 10V power for the use of Indians in America.
- **Wear and Tear:** Physical elements of a product may deteriorate with use, necessitating replacement of the worn components to extend the useful life d the product (e.g., tires on vehicles can be replaced).
- **Consumption:.** Some products consume materials which can be easily replenished (e.g., watches run on replaceable batteries).
- **Flexibility in Use:** Some products can be configured by the user to exhibit different capabilities (e.g., food processor comes with more than one utility attachments like, wet grinding jar, dry grinding jar, coconut scrapper etc ).
- **Reuse:** In creating subsequent products, the firm may change.only a few functional elements while retaining the rest of the product intact (e.g. TV manufacturers make variation in knobs, speakers, colour of cabinet etc.)

In all the above cases, a modular architecture allows the firm to minimise the physical changes required to achieve a functional change.

**Product Variety**

Variety refers to the range of product models the firm can produce within a particular time period in response to market demand. Products built around modular product architectures can be more easily varied without adding complexity to the manufacturing system, e.g. Watch manufacturers usually retain the same inner mechanism (movements) for their watches but create variety in the dial colour, size, shape and, in the case and wrist bands.

**Component Standardisation**

This refers to the use of the same component or chunk in multiple products. If a chunk implements only one or a few widely useful functional elements, then the chunk can be standardised and used in several different products. e.g., Transformers of a particular winding can be used in different power conditioning equipments.

**Product Performance**

This refers to how well a product implements its intended functions. Typical characteristics are -speed, efficiency, life, accuracy and noise. If performance characteristic depends on size, shape or man of a product, it can be enhanced through an integral architecture. e.g., cars are compared in terms of mileage, which is the number of kilometers it can run per litre of fuel.

**Manufacturability**

in addition to the cut implication of product variety and component standardisation, the product architecture also affects the ability of the team to design each chunk to be produced at low cost. An important design for manufacturing (DFM) strategy involves the minimization of the number of parts in a product through component integration. Management of Product Architecture Development

Responsibility for the detail design of each chunk is usually assigned to a relatively small group within the firm or to an outside supplier. Chunks are assigned to a single individual or group because their design requires careful resolution of interactions, geometric and ,otherwise among components within the chunk.

Modular and integral architectures also demand different project management styles. Modular approaches require very careful planning during the system-level design phase, but detail design is largely concerned with ensuring that the teams assigned to chunks are meeting the performance cost and schedule requirements for their chunks. An integral architecture may require less planning and specification but such an architecture requires substantially more integration, conflict resolution and coordination during the detail design phase.

**Activity 1**

Having aquainted with the concept of Product Architecture. How can firms be benefited by this concept. List out at least '5 benefits will examples.

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## 16.3 INDUSTRIAL DESIGNING IN PRODUCT DEVELOPMENT

The Industrial Designers Society of America (IDSA) defines industrial design as the "professional service of creating and developing concepts and specifications that optimize the function, value and appearance of products and systems for the mutual benefit of both user and manufacturer".

The five critical goals that industrial designers have to achieve when developing new products are:

- **Utility:** The product's human interfaces should be safe, easy to use and intuitive.. Every feature should be shaped so that it communicates its function to the users.
- **Appearance:** Form, line, proportion and colour are used to integrate the product. into a pleasing whole.
- **Ease of maintenance:** Products must also be designed to communicate how they are to be maintained and repaired.
- **Low costs:** Form and features have a large impact on tooling and production costs, so those must be considered jointly by the team.
- **Communication:** Product designs should communicate the corporate design philosophy and mission through the visual qualities of the products.

Industrial designers are typically educated through program where they study sculpture and form; develop drawing, presentation and model making skills; and gain a basic understanding of materials, manufacturing techniques, and finishes. Industrial designers are primarily responsible for the aspects of a product that relate to the user ii the product's aesthetic appeal (how it looks, sounds, feels, smells) and its functional interfaces (how it is used

**Importance of Industrial Design**

A convenient means for assessing the importance of ID to a particular product is to characterise importance along two dimensions namely, ergonomics and aesthetics.

**Ergonomic needs**

This encompasses all aspects of a product that relate to its human interfaces.

- **Ease of use:** This is important for both frequently used products like a pen to infrequently used products such as a fire extinguisher. When ease of use is very important it is to ensure that the features of the product effectively communicate their function.

- **Ease of maintenance:** If a product needs to be serviced frequently, then this factor is crucial. It is critical that features of product communicate repair procedures to users.

- **User interactions:** The more interactions users have with a product, the more the product will depend on ID. For example a doorknob has only one interaction but a portable computer may require a dozen or more.
- **Novelty of user interaction needs:** A novel user interface may require substantial research and feasibility studies such as the built-in trackball in the first Macintosh Power Book note book computer.
- **Safety in usage:** Such issues present significant challenges to the designers as in the design of a child's toy.

**Aesthetic needs**

**Product differentiation:** Products with stable markets and technology are highly dependent on ID to create aesthetic appeal and hence differentiation. But a product such as the hard disk drive of computers, which are differentiated by its technology, is less dependent on ID.

**Pride of ownership, image and fashion:** An attractive product may be associated with high fashion and image and creates a sense of pride among its owners, e.g., a stylishly designed car like Matiz.

**Motivation to Industrial designers:** A product that is aesthetically appealing can generate a sense of pride among the design and manufacturing staff. It motivates and unifies everyone associated with it.

**Process of Industrial Design Development**

Many large companies have internal industrial design departments. Small companies use the services of consulting firms. Engineers will generally follow an established procedure to generate and evaluate concepts for the technical features of a product. Similarly Industrial designers follow an established procedure for designing the aesthetics and ergonomics of a product. Industrial designers also generate multiple concepts and then work with engineers to narrow these options down through a series of evaluation steps. The ID process is made up of the following phases:

1. Generating information about customer needs
2. Conceptualization of product to meet the customer needs
3. Product concept refinement
4. Concept screening and selection
5. Developing control drawings
6. Integrating different functions like, engineering, manufacturing and vendors in the design development.

**Generating information about customer needs**

Industrial designers are skilled at recognising issues involving user interaction; ID involvement is crucial in the needs process. For example in researching customer needs for a new model of a pen, the designers would study the usage conditions, interview different users, and conduct focus groups. The involvement of marketing, engineering and ID leads to a common, comprehensive understanding of customer needs for the whole team. It allows the industrial designers to give an intimate understanding of the interaction between the user and the product.

**Conceptualization of product to meet the customer needs**

Once the customer needs and constraints are understood, the industrial designers have to conceptualise the product. The engineers find solutions to the technical subfunctions of the product. The industrial designers concentrate upon creating the product's form and user interfaces. They make simple sketches, called thumb nail sketches of each concept. These sketches are fast and inexpensive medium for expressing ideas and evaluating possibilities. Concepts are grouped and evaluated by the team according to the customer-needs, technical feasibility, cost and manufacturing considerations. It is beneficial to coordinate the efforts of industrial designers and engineers to avoid concepts, which are technically infeasible but have form and style.

**Product concept refinement**

At this phase industrial designers develop models in full scale using foam or foam-core. boards. These models allow the designers, engineers, and others and some times even the potential customers to touch, feel, and modify the models to suit the requirements of several stakeholders.

**Concept screening and selection**

In this phase industrial designers advance from soft models and sketches to hard models and information intensive drawings known as renderings. These show the details of the design and often depict the product in use. Renderings are drawn in two or three dimensions convey a great deal of information about the product. These are used for colour studies and for testing customers' reception to the proposed product's features and functionality.

Hard models are -technically non-functional but close replicas of the final desi^g^n. They are made of wood, dense foam, plastic or metal; are painted and textured; and have some "working" features such as buttons that push or sliders that move.

Hard models are used to gain. customer feedback, to sell the concept to senior management within an organisation, in promotion and to further refine the final concept.

**Developing control drawings**

These document functionality, features, sizes, colours, surface finishes and key dimensions. They are used to fabricate final design models and other prototypes. These drawings are given to the detailed part designers for completion.

**Integrating different functions**

The industrial designers most continue to work closely with engineering and manufacturing personnel throughout the subsequent product development process.

The selection and management of outside vendors of materials, tooling, or components, as well, as vendors to perform the final assembly of the product is very important.

**Management of the Industrial Design Process**

Industrial design may be incorporated into the overall product development. process at any time during a development program. To explain the timing of the ID effort it is convenient to classify products based on whether they are technology-driven or user-driven products.

**Technology Driven Products**

The primary characteristic of such products is that its core benefit is based on its technology. Customers may most likely purchase the product primarily for its technical performance. The product's external appearance is designed to as to communicate its technological capabilities. For example an Uninterrupted Power - Supply System (UPS, generally has a box like chassis with several indicators and meters.

**User Driven Products**

The core benefit of any product is the functionality of its interface and aesthetic' appeal. There is a high degree of user interaction for these products. Hence, the user interfaces have to be safe, easy to use, and easy to maintain. External appearance is also many time important to differentiate the product and to create pride of ownership.

**Technology and User Driven Products**

These products have a high degree of user interaction and have stringent technical performance requirements. When a company develops a product based on a new core technology the company is often interested in bringing the product to market as quickly as possible. Mere looks or usage is less important. But as competition increases, the product may have to compete along user or aesthetic dimensions. For example Nokia cellular phone has introduced with technology in mind but now the advertisements talk more about Human Technology, with differentiation in colours, shapes, sizes, in-built antenna etc.'

**Activity B**

If you were asked to design a consumer electronic (Transition) far the Indian rural market. What major considerations you would .onsider keeping in mind the profile of the rural buyer.

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## 16.4 PRODUCT PRTOTYPING

Prototype is defined as "an approximation of the product along one or more dimensions of interest". Any entity that exhibits some aspect of the product that is of interest to the product development team can be viewed as a prototype, and it includes concept sketches to fully functional artifacts. Prototyping is the process of developing such an approximation of the product.

**Types of Prototypes**

Prototypes are usefully classified along two dimensions. The first dimension is the degree to which a prototype is physical as opposed to analytical. Physical protatypes are tangible artifacts created to approximate the product. Aspects of the product of interest are actually built for testing and experimentation. Examples of physical prototypes include: models which look and feel like the product, proof of concept prototypes used to test an idea quickly, and experimental hardware used to validate the functionality of a product. Analytical prototypes represent the product in a intangible, usually mathematical manner. Interesting aspects of the product are analysed, rather than built. Examples include computers simulations, systems of equations encodes within a spreadsheet, and computer models of three dimensional geometry.

The second dimension is the degree to which a prototype is comprehensive as opposed to focussed. Comprehensive prototypes implement most, if not all, of the attributes of a product. It is a full scale, fully operational version of the product. An example is a beta prototype given to customers in order to identify any remaining design flaws before committing to production. But focussed prototypes implement one, or a few, of the attributes of a product. Examples include foam models to explore the form of a product and wire-wragged circuits boards to investigate the electronic performance of a product design. Two types of focussed prototypes are - "looks like" prototype and "works like" prototype.

**Uses of Prototypes**

Within a product development project, prototypes are used for four purposes: learning, communication, integration, and milestones.

- **Learning:** Prototypes are used to answers two types of questions: `Will it work?' and ..'How well does it meet the customers needs? When used to answer such questions, prototypes serve as learning tools focussed analytical prototypes are generally used.

- **Communication:** Prototypes enrich communication with top management, vendors, partners, extended team members, customers, and sources of financing. A visual, of the Product tactile three dimensional representation of a product in a physical prototype is a much easier to understand than a verbal description or even a sketch of a product.
- **Integration:** Prototypes are used to ensure that components and subsystems of the product prototypes work together as expected. Comprehensive physical prototypes are most effective as integration tools in product development projects because they require the assembly and physical interconnection of all parts of subassemblies that make up a product common names of these comprehensive physical prototypes are experimental, alpha, beta or preproduction prototypes.
- **Milestones:** In the later stages of product development, prototypes are used to demonstrate that the product has achieved a desired level of functionality. These prototypes provide tangible goals, demonstrate progress, and serve to enforce the schedule. Senior management (and sometimes the customers) often require a prototype that demonstrates certain functions before they will allow the project to proceed

**Principles of Prototyping**

Several principles are useful in guiding decisions about prototypes during product development. These are principles inform decisions about what types of prototypes to build and about how to incorporate prototypes into the development plan.

Analytical prototypes are generally more flexible than physical prototypes. As an analytical prototype is a mathematical approximation of the product it will generally contain parameters that can be varied in order to represent design alternatives. In most cases, changing a parameter in an analytical prototype is easier than changing an attribute of a physical prototype. It also allows larger changes than could be made in a physical prototype.

Physical prototypes are required to detect unanticipated phenomena. A physical prototype often exhibits unanticipated phenomena completely unrelated to the original objective of the prototype. Physical prototypes intended to investigate purely geometric issues will also have thermal and optical properties.

Some of the incidental properties of physical prototypes may manifest themselves in the final product. In these cases, a physical prototype can serve as a tool for detecting unanticipated detrimental phenomena that may arise in the final product. Analytical prototypes in contrast can never reveal phenomena that are not part of the underlying analytical model on which the prototype is based.

A prototype may reduce the risk of costly iterations. In many situations, the outcome of a test may dictate whether a development task will have to be-repeated. For example, if a molded part fits poorly with its mating parts, the mold may have to be rebuilt.

The anticipated benefits of a prototype in reducing risks must be weighed against the time and money required to build and evaluate the prototype. Products which .are high in risk or uncertainty, due to high costs of failure, new technology, or the revolutionary nature of the product, will benefit from such prototypes. On the other hand, products for which failure costs are low and the technology if well known do not derive as much risk reduction benefit from prototyping.

A prototype may expedite other development steps. Sometimes the addition of a short prototyping phase may allow a subsequent activity to be completed more quickly than if the prototype were not built. The existence of a physical model of a geometrically complex part allows the mold designer to more quickly visualize and design the mold.

A Prototype may restructure task dependencies. It is possible to complete some of the tasks concurrently by building a prototype. For example, a software test may depend on the existence of a physical circuit. Instead of waiting for the production version of the printed circuit board to use in the test, it is possible to fabricate a prototype (e.g.) a wire-wrapped board and use it for the test while the production of the printed circuit board. proceeds.

## 16.5 CONCURRENT ENGINEERING

When new and competitive products are introduced, there are chances that it may not be a success story. There may be cases of defective parts that either malfunctioned or those that would go bad. These are due to engineering failures. The engineers working on technical points failed to detect the error at the design stage, at tooling, production, testing and assembly stages. This results in sunk investments, and more important than money the loss of confidence among consumers.

The communication gaps and the willingness to cooperate among various departments are the main problems in product failure. 'Working with other departments' seems to be very difficult. In a typical enterprise, manufacturing process involves various departments with clearly defined functions and roles. The design department create a new product design,

which is followed by the tooling and production departments. Then there are the approving authorities. If a problem is detected, then design department has to redesign it. If error is discovered after some production is through then rectification becomes even more costly.

For example a design engineer may design a product without considering its manufacturability. A materials engineer may not inform the design or production engineer about new materials hence competitive and innovative products may not be designed and produced. The costs involved both direct and indirect are quite high in such cases.

**What is concurrent engineering?**

The traditional work culture in design, development and production activities was not enough. A new competitive method was needed to minimise time-loss, minimise unnecessary expenses and increase interdepartmental cooperation. This approach was called concurrent engineering. Other names are collaborative engineering, team engineering, integrated systems design and shared engineering.

It is "the systematic approach to the integrated, concurrent design of products and related processes, including manufacturing and support". The aim is to reduce the product development cycle time through proper integration of activities and processes across departments. Every element of product life cycle from conception to sales, including quality, cost, schedule and user requirements have to be dealt with.

Dean and Unal (1992), define CE as getting the right people together at the right time to identify and resolve design problem. Concurrent engineering is designing for assembly, availability, cost, customer satisfaction, maintainability, manageability, manufacturability, operability, performance, quality, risk, safety, schedule, social acceptability, and all other attributes of the product.

**Concurrent Engineering includes concurrent design, which is the simultaneous**

- Design of the product
- Design of the evaluation of the product
- Design of the prototyping of the product
- Design of the test of the product
- Design of the production of the product
- Design of the deployment of the product
- Design of the operation of the product
- Design of the support of the product
- Design of the evolution of the product • Design of the retirement of the product, and
- Design of the management of the product

*Source:* MM The Industry Magazine: Nov. 1999 P. 16.

CE becomes effective when there is proper communication between the designee and end-users. In CE customers are of two types internal and external. Internal customers are the members of the CE staff, for the intermediate products in the product development cycle. By careful monitoring of the design process, errors are avoided or detected before hand. The design process is integrated in the sense that sharing information is very important, resulting in coordination and cooperation during redesigns and modifications. CE has grown in popularity due to availability of tools and complex technologies making integrated design possible.

The advantage of CE is that all the staff members involved are made to think in a holistic manner instead of focussing on just his job in hand. This along with the use of matured IT technologies, not only saves costs, but also avoids product recall, after launching and repeated redesigning during development process.

**Steps to build cooperation with other departments**

- Adopt a common language to easy understanding by every one - Learning to speak and using a common language to manage problems from identification through to resolution has been crucial to successful cross-functional team efforts.

- Maintain a "clear" focus on the goal – The key to gaining cooperation of other departments is getting everyone to focus on a single identifiable end goal, which everyone has in common.

- Create a cross-functional review board is a step in the right direction - Involve other departments, especially marketing, sales, and purchasing besides engineering, to create a unified new product development environment.

- Focus on the `internal customer' changes the cooperative spirit - Get departments to work together by focusing on both internal and external customer satisfaction.

- Project tracking helps to alleviate the pain of change - Changing specification or design displays without notifying every team, and particularly the engineering team can be disastrous.

- Conflict resolution can be a major initiative, in itself - The multitude of experiences and perceptions that of different teams can cause troublesome conflicts within the teams at times.

- Develop plans to better coordinate resources - While design engineers can be dedicated to a project, the resources from purchasing, tooling, and industrial engineering and other disciplines can be spread over many programs to generate more detailed project plans to better predict resource needs.

**Source: MM The Industry Magazine: Nov. 1999, P. 15.**

**Top 10 ways to prepare for 21st century design challenges**

- How can engineering teams change their cultures to help meet the "better-faster-cheaper" needs of the 21st century? Here is an unofficial list of techniques, based on recommendations from Cincinnati Milacron and the University of Michigan's Office for the Study of Automotive Transportation.
- Define your customer - The design of any machine flows from the seeds of the customer. Knowing your customer makes it easier to define your machine specs.
- Clearly define product requirements - Too often, engineers lose valuable time because the machine requirements are not clearly defined from the outset.
- Use common processes - Do not use one method for one department and a different method for another. Math tools, for example, should be common across the organization.
- Encourage lateral flow of people through an organization - Boundaries, such as those between manufacturing, engineering, and purchasing, slow progress. Erase boundaries by encouraging employees to cross them.
- Plug into networks - Do not engineer in isolation. Do not always engineer from scratch. Another department may be working on a component similar to yours. If so, draw on that work.
- Staff quickly - Once a program is approved, staff it quickly and attack it aggressively.
- Use modular product architecture - Modular architecture enables a team to break a design into its component parts and assign it to more individuals who can work in parallel.
- Know your competition - Know how your product fits relative to your customer and your competition.
- Maintain math skill competency - In the coming decades, engineers who refuse to learn math/software skills will be left behind.
- Choose the right leadership - In the era of concurrent engineering, managers need to choose leaders who work well with other departments.

**Source MM The Industry Magazine: Nov. 1999 P. 18.**

## 16.6 SUMMARY

In the present unit the basic processes of developing physical product and testing have been introduced. Product architecture refers to the basic structure of the product which provides functionality to the consumer, which made up of number of modules are chunks. The next step is to develop industrial design for incorporating the manufacturing requirements in- to the product. Prototyping follows this stage in this stage analog or physical models are developed for evaluation.

## 16.7 SELF-ASSESSMENT QUESTIONS

1). Discuss the scope and relevance of Product Architecture. What are its implications and how would firms benefit by adopting this concept?

2). Describe the steps involved in Industrial Design Development.

3). What do you understand by the term "Prototype"? Discuss the various kinds and their Bases for classification.

4). Write an essay on `Concurrent Engineering'.

## 16.8 FURTHER READINGS

Clark K B and S C Wheelwright, (1993) Managing New Product and Process Development: Text and Cases, The Free Press, New York.

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