Product Design and Development

Module-1

Product Development

Basic Terms in Product Design and Development

- Product-A term used to describe all goods, services, and knowledge sold.

  or

  A product is something is sold by an enterprise to its customers.

- Product Development-It is the set of activities, beginning with the perception of a market Opportunity and ending in the production ,sales and delivery of product.

Product Development

- The economic success of most firms depends on their ability to identify the needs of customers and to quickly create products that meet these needs and can be produced at low cost. Achieving these goals is not solely a marketing problem, nor is it solely a design problem or a manufacturing problem; it is a product development problem involving all of these functions.

- Product Development is the organization and Management of people and the information they develop in the evaluation of product.

Design-Design is to formulate a plan to satisfy a particular need and to create something with a physical reality

General Procedure in Machine Design

- Need or Aim
- Synthesis
- Analysis of Forces
- Material Selection
- Design of Machine elements
- Modifications
- Detailed Drawing
- Production

Product Design versus Design

- A Design Process is a set of all Technical Activities.
- Product Development Process that Work to meet marketing and business case vision.
- From the customers feedback analyze the needs/requirements and by the market opportunities specify the Specifications and that specifications send to designers. The whole process is called Product Developments.
- Specifications can be send to Designers. Designers will finalize the product Specifications it converted final product by performing operations and that product to meet customers Specifications. The whole process is called Product Design.

Characteristics of Successful Product Development

- From the perspective of the investors in a for-profit enterprise, successful product development results in products that can be produced and sold profitably, yet profitability is often difficult to assess quickly and directly. Five more specific dimensions, all of which ultimately relate to profit, are commonly used to assess the performance of a product development effort:
- Product quality: How good is the product resulting from the development effort? Does it satisfy customer needs? Is it robust and reliable? Product quality is ultimately reflected in market share and the price that customers are willing to pay

  Product cost: What is the manufacturing cost of the product? This cost includes spending on capital equipment and tooling as well as the incremental cost of producing each unit of the product. Product cost determines how much profit accrues to the firm for a particular sales volume and a particular sales price.
- Development time: How quickly did the team complete the product development
- Development cost: How much did the firm have to spend to develop the product? Development cost is usually a significant fraction of the investment required to achieve the profits.
- Development capability: Are the team and the firm better able to develop future products as a result of their experience with a product development project? Development capability is an asset the firm can use to develop products more effectively and economically in the future.

Who Designs and Develops Products?

- Product development is an interdisciplinary activity requiring contributions from nearly all the functions of a firm; however, three functions are almost always central to a product development project:
- Marketing: The marketing function mediates the interactions between the firm and its customers. Marketing also typically arranges for communication between the firm and its customers, sets target prices, and oversees the launch and promotion of the product.
- Design: The design function plays the lead role in defining the physical form of the product to best meet customer needs. In this context, the design function includes engineering design (mechanical, electrical, software, etc.) and industrial design (aesthetics, ergonomics, user interfaces).

Manufacturing: The manufacturing function is primarily responsible for designing, operating, and/or coordinating the production system in order to produce the product. Broadly defined, the manufacturing function also often includes purchasing, distribution, and installation. This collection of activities is sometimes called the supply chain

The Challenges of Product Development:

- Trade-offs: An airplane can be made lighter, but this action will probably increase manufacturing cost. One of the most difficult aspects of product development is recognizing, understanding, and managing such trade-offs in a way that maximizes the success of the product.
- Dynamics: Technologies improve, customer preferences evolve competitors introduce new products.
- Time pressure: Any one of these difficulties would be easily manageable by itself given plenty of time, but product development decisions must usually be made quickly and without complete information.
- Economics: Developing, producing, and marketing a new product requires a large investment. To earn a reasonable return on this investment, the resulting product must be both appealing to customers and relatively inexpensive to produce.
- Creation: The product development process begins with an idea and ends with the production of a physical artifact. When viewed both in its entirety and at the level of individual activities, the product development process is intensely creative.
- Satisfaction of societal and individual needs: All products are aimed at satisfying needs of some kind. Individuals interested in developing new products can almost always find institutional settings in which they can develop products satisfying what they consider to be important needs.

- Team diversity: Successful development requires many different skills and talents. As a result, development teams involve people with a wide range of different training, experience, perspectives, and personalities.
- Team spirit: Product development teams are often highly motivated, cooperative groups. The team members may be colocated so they can focus their collective energy on creating the product. This situation can result in lasting camaraderie among team members.

The Product Development Process

A process is a sequence of steps that transforms a set of inputs into a set of outputs.

A product development process is the sequence of steps or activities that an enterprise employs to conceive, design, and commercialize a product.

Some organizations define and follow a precise and detailed development process, while others may not even be able to describe their process. Furthermore, every organization employs a process at least slightly different from that of every other organization. In fact, the same enterprise may follow different processes for each of several different types of development projects.

A well-defined development process is useful for the following reasons:

- Quality assurance: A development process specifies the phases a development project will pass through and the checkpoints along the way. When these phases and checkpoints are chosen wisely, following the development process is one way of assuring the quality of the resulting product.
- Coordination: A clearly articulated development process acts as a master plan that defines the roles of each of the players on the development team.
- This plan informs the members of the team when their contributions will be needed and with whom they will need to exchange information and materials.
- Planning: A development process includes milestones corresponding to the completion of each phase
- Management: A development process is a benchmark for assessing the performance of an ongoing development effort. By comparing the actual events to the established process, a manager can identify possible problem areas.
- Improvement: The careful documentation and ongoing review of an organization’s development process and its results may help to identify opportunities for improvement.

Steps in Generic product Development Process

- 0. Planning: The planning activity is often referred to as "phase zero" because it precedes the project approval and launch of the actual product development process. This phase begins with opportunity identification guided by corporate strategy and includes assessment of technology developments and market objectives. The output of the planning phase is the project mission statement, which specifies the target market for the product, business goals, key assumptions, and constraints.
- 1. Concept development: In the concept development phase, the needs of the target market are identified, alternative product concepts are generated and evaluated, and one or more concepts are selected for further development and testing. A concept is a description of the form, function, and features of a product and is usually accompanied by a set of specifications.
- 2. System-level design: The system-level design phase includes the definition of the product architecture, decomposition of the product into subsystems and components, and preliminary design of key components. Initial plans for the production system and final assembly are usually defined during this phase as well. The output of this phase usually includes a geometric layout of the product, a functional specification of each of the product's subsystems.
- Detail design: The detail design phase includes the complete specification of the geometry, materials, and tolerances of all of the unique parts in the product and the identification of all of the standard parts to be purchased from suppliers. The output of this phase is the control documentation for the product—the drawings or computer files describing the geometry of each part and its production tooling, the specifications of the purchased parts, and the process plans for the fabrication and assembly of the product.
- 4. Testing and refinement: The testing and refinement phase involves the construction and evaluation of multiple preproduction versions of the product. Early (alpha) prototypes are usually built with production-intent parts—parts with the same geometry and material properties as intended for the production version of the product but not necessarily fabricated with the actual processes to be used in production. Alpha prototypes are tested to determine whether the product will work as designed and whether the product satisfies the key customer needs. Later (beta) prototypes are usually built with parts supplied by the intended production processes but may not be assembled using the intended final assembly process. Beta prototypes are extensively evaluated internally and are also typically tested by customers in their own use environment. The goal for the beta prototypes is usually to answer questions about performance and reliability in order to identify necessary engineering changes for the final product.
- Setting final specifications: The target specifications set earlier in the process are revisited after a concept has been selected and tested. At this point, the team must commit

to specific values of the metrics reflecting the constraints inherent in the product concept, limitations identified through technical modeling, and trade-offs between cost and performance

- Modeling and prototyping: Every stage of the concept development process involves various forms of models and prototypes.
- **Adapting the Generic Product Development Process**
- The generic process is most like the process used in a market-pull situation: a firm begins product development with a market opportunity and then uses whatever available technologies are required to satisfy the market need

  (i.e., the market "pulls" the development decisions).
- Technology-Push Products
- In developing technology-push products, the firm begins with a new proprietary technology and looks for an appropriate market in which to apply this technology. example-Gore-Tex rainwear
- Platform Products
- A platform product is built around a preexisting technological subsystem (a technology platform). Examples of such platforms include the Intel chipset in a personal computer, the Apple iPhone operating system.
- Process-Intensive Products
- Examples of process-intensive products include semiconductors, foods, chemicals, and paper. For these products, the production process places strict constraints on the properties of the product, so that the product design cannot be separated, even at the concept phase, from the production process design. In many cases, process-intensive products are produced in very high volumes and are bulk.
- Customized Products
- Examples of customized products include switches, motors, batteries, and containers. Customized products are slight variations of standard configurations and are typically developed in response to a specific order by a customer

High-Risk Products

The product development process addresses many types of risk. These include technical risk (Will the product function properly?), market risk (Will customers like what the team develops?), and budget and schedule risk (Can the team complete the project on time and within budget?). High-risk products are those that entail unusually large uncertainties related to the technology or market so that there is substantial technical or market risk.

Quick-Build Products

For the development of some products, such as software and many electronics products, building and testing prototype models is such a rapid process that the design-build-test cycle can be repeated many times. In fact, teams can take advantage of rapid iteration to achieve a more flexible and responsive product development process, sometimes called a spiral product development process.

Complex Systems Larger-scale products such as automobiles and airplanes are complex systems comprising many interacting subsystems and components.

Product Cost Analysis

The cost of product development is roughly proportional to the number of people on the project team and to the duration of the project. In addition to expenses for development effort, a firm will almost always have to make some investment in the tooling and equipment required for production. This expense is often as large as the rest of the product development budget; however, it is sometimes useful to think of these expenditures as part of the fixed costs of production.

The cost of Production

Fixed Cost (FC): Cost that are spent and cannot be changed in the period of time under consideration.

Variable Cost (VC): Costs that change as output changes.

Total Cost = Fixed Cost (FC) + Variable Cost (VC)

Average Total Cost or Average Cost (ATC): Is just the cost of producing a unit of a product. Let Q be the quantity supplied or produced. As its name suggest, it is calculated as $ATC = TC/Q = (FC + VC) / Q$.

Average Fixed Cost (AFC): Is just the fixed cost involved in producing a unit of a product. $AFC = FC / Q$.

Average Variable Cost (AVC): Is just the variable cost involved in producing a unit of a product. $AVC = VC / Q$.

The following relationship follows: TC = FC + VC

Which implies that TC / Q = (FC + VC) / Q

Which gives ATC = AFC + AVC

Marginal Cost (MC) which is the cost involved in the production of an additional unit of a product.

In other words, MC = Change in Total Cost / Change in Quantity Produced

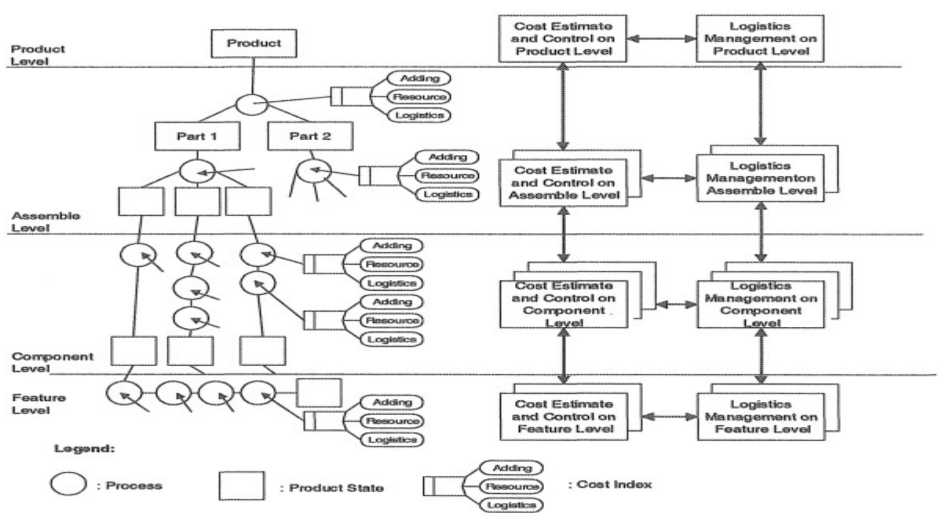
$$= \Delta \text{ TC} / \Delta \text{ Q}$$

Profit = Total Revenue – Total Cost

COST INDEX STRUCTURE

To estimate and control the manufacture cost and logistics cost of a product development, a Cost Index Structure was developed and illustrated in Figure 1. In accordance with the Product Production Structure, the Cost Index Structure adopts the same hierarchy of the Product Production Structure.

a manufacturing process will associated with a cost index. A cost index includes three generic data classes, viz. Adding, Resource and Logistics, which are associated with possible three costs of a manufacturing process as mentioned in previous section. 'Adding' means adding cost to a manufacturing process. It is used to pay for the possible test and reworks due to the difficulty or uncertainty of the process. The difficulty or uncertainty of a process is determined by the design of a product, part, component or feature, e.g. geometry, surface finishing or treatment requirements, special tolerance and machining requirements etc.



Product Production Structure, these cost data classes are written in EXPRESS of STEP so that they can be accessed and retrieved by different computer software systems.

Cost optimization means a selection among alternative designs, manufacturing processes, manufacturing resources, inventories, suppliers, partners, and subcontractors, or combinations of these alternatives with a lowest cost or total costs. Manufacturing process optimization, e.g. to find a shortest path for a CNC cutting, and operations optimization

Generative Cost Estimate Model

Generative cost estimate method is a pipeline method. With· the Cost Index Structure as shown in Figure 1 and the input data from all the other systems as well as the price and cost data from the costing knowledge base The Cost Estimate and Optimal Control system can calculate the data or instances of the cost index associated with a process from bottom level up to the top level of the Cost Index Structure. The cost index of punching a hole on a sheet metal (a process on the feature level), for example, can be determined by calculating Adding cost, Resource Cost and Logistics cost. As mentioned before, the adding cost is decided according to the difficulty of the process, i.e. punching a hole on a sheet metal for this example, and it is the sum of the costs of the possible tests and reworks.

The resource cost for this example will be calculated by multiplying the standard cost rates of the used manufacturing resources (e.g. punch machine, tool and machine operator) to the used times of these manufacturing resources. The standard cost rates were recorded in the Costing Knowledge base and the used times can be provided by the Manufacturing Process.

Planning and Optimization subsystem. The Logistics cost is determined according to whether this process needs to take a material or component into consideration and how and from where this material or component can be provided.

To avoid the duplicated cost data in these cost indexes, only the
first process, which is among a group of sequential processes to be carried out on a blank or a sheet metal, will take the logistics cost of the blank or sheet metal into account. All the other succeeding processes will not take the logistics cost of this blank or sheet metal into account in their cost indexes under the Logistics, or a zero (0) will be assigned to the Logistics. However, if a succeeding process needs to add a new material or component, under the Logistics of its cost index, the logistics cost of this new material or component will be estimated and recorded.

When all the cost indexes have fixed data or instances, the production cost of a component, part or product can be calculated by the Cost Estimate and Optimal Control subsystem through adding up all the cost data in the cost indexes associated with these processes which are under and linked (directly or indirectly) to the component, part or product in the Cost Index Structure.

Variant and Knowledge based Cost Estimate Model

As implied by the discussions made in previous sub-section, the Generative Cost Estimate Model can only be used to estimate the costs of these standard components and processes. For those non-standard or 'new' components and processes which are required by the product design to address particular customer requirements, the variant and knowledge based cost estimate model need to be employed. This method estimates the cost of a component or process through searching and comparing the similarities between the developing product and the products which were made in the past.

The Product Production Structures of these past-made products were recorded in a Design/Manufacturing Knowledge base . The cost indexes are part of the Product Production Structure of a product and hence they must also be record in the Design/Manufacturing Knowledge base.

Through searching this Design/Manufacturing Knowledge base, the Cost Estimate and Optimal Control subsystem may find the cost index of a process,

which is a part of a past-made product production structure and is similar to the process of the new product. The Cost Estimate and Optimal Control subsystem search for a similar process by following a GT (group technology) coding system .

Module-II

Product specifications

<u>What Are Specifications?</u>

Customer needs are generally expressed in the “language of the customer.” The primary customer needs for the suspension fork are listed in Exhibit 6-2. Customer needs such as “the suspension is easy to install” or “the suspension enables high-speed descents on bumpy trails” are typical in terms of the subjective quality of the expressions. However, while such expressions are helpful in developing a clear sense of the issues of interest to customers.

For this reason,

development teams usually establish a set of specifications, which spell out in precise, measurable detail what the product has to do. Product specifications do not tell the team how to address the customer needs, but they do represent an unambiguous agreement on what the team will attempt to achieve in order to satisfy the customer needs. For example, in contrast to the customer need that “the suspension is easy to install,” the corresponding specification might be that “the average time to assemble the fork to the frame is less than 75 seconds.”

product specifications to mean the precise description of what the product has to do. Some firms use the terms “product requirements” or “engineering

characteristics” in this way. Other firms use “specifications” or “technical specifications "to refer to key design variables of the product such as the oil viscosity or spring constant of the suspension system. These are just differences in terminology. For clarity, let us be

EXHIBIT 6-2 Customer needs for the suspension fork and their relative importance (shown in a convenient spreadsheet format).

No.		Need	Imp.
1	The suspension	reduces vibration to the hands.	3
2	The suspension	allows easy traversal of slow, difficult terrain.	2
3	The suspension	enables high-speed descents on bumpy trails.	5
4	The suspension	allows sensitivity adjustment.	3
5	The suspension	preserves the steering characteristics of the bike.	4
6	The suspension	remains rigid during hard cornering.	4
7	The suspension	is lightweight.	4
8	The suspension	provides stiff mounting points for the brakes.	2
9	The suspension	fits a wide variety of bikes, wheels, and tires.	5
10	The suspension	is easy to install.	1
11	The suspension	works with fenders.	1
12	The suspension	instills pride.	5
13	The suspension	is affordable for an amateur enthusiast.	5
14	The suspension	is not contaminated by water.	5
15	The suspension	is not contaminated by grunge.	5
16	The suspension	can be easily accessed for maintenance.	3
17	The suspension	allows easy replacement of worn parts.	1
18	The suspension	can be maintained with readily available tools.	3
19	The suspension	lasts a long time.	5
20	The suspension	is safe in a crash.	5

precise about a few definitions. A specification (singular) consists of a metric and a value. For example, “average time to assemble” is a metric, while “less than 75 seconds” is the value of this metric.

When Are Specifications Established?

In an ideal world, the team would establish the product specifications once early in the development process and then proceed to design and engineer the product to exactly meet those specifications. For some products, such as soap or soup, this approach works quite well; the technologists on the team can reliably concoct a formulation that satisfies almost any reasonable specifications. However, for technology-intensive products this is rarely possible. For such products, specifications are established at least twice.

Immediately after identifying the customer needs, the team sets target specifications.

These specifications represent the hopes and aspirations of the team, but they are established before the team knows what constraints the product technology will place on what can be achieved. The team’s efforts may fail to meet some of these specifications and may exceed others, depending on the product concept the team eventually selects. For this reason, the target specifications must be refined after a product concept has been selected. The team revisits the specifications while assessing the actual technological constraints and the expected production costs. To set the final specifications, the team must frequently make hard trade-offs among different desirable characteristics of the product.

For simplicity, we present a two-stage process for establishing specifications, but we note that in some organizations specifications are revisited many times throughout the development process.

The two stages in which specifications are established are shown as part of the concept development process in Exhibit 6-3. Note that the final specifications are one of the key elements of the development plan, which is usually documented in the project’s contract book. The contract book specifies what the team agrees to achieve, the project schedule, the required resources, and the economic implications for the business. The list of product specifications is also one of the key information systems used by the team throughout the development process.

This chapter presents two methods: the first is for establishing the target specifications and the second is for setting the final specifications after the product concept has been selected.

Establishing Target Specifications

Target specifications are established after the customer needs have been identified but before product concepts have been generated and the most promising one(s) selected. An arbitrary setting of the specifications may not be technically feasible.

For example, in designing a suspension fork, the team cannot assume in advance that it will be able to achieve simultaneously a mass of 1 kilogram, a manufacturing cost of $30, and the best descent time on the test track, as these are three quite aggressive specifications. Actually meeting the specifications established at this point is contingent upon the details of the product concept the team eventually selects. For this reason, such preliminary specifications are labeled "target specifications."

The process of establishing the target specifications contains four steps:

- Prepare the list of metrics.
- Collect competitive benchmarking information.
- Set ideal and marginally acceptable target values.
- Reflect on the results and the process.

Prepare the List of Metrics

The most useful metrics are those that reflect as directly as possible the degree to which the product satisfies the customer needs. The relationship between needs and metrics is central to the entire concept of specifications. The working assumption is that a translation from customer needs to a set of precise, measurable specifications is possible.

A good way to generate the list of metrics is to contemplate each need in turn and to consider what precise, measurable characteristic of the product will reflect the degree to which the product satisfies that need.

In the ideal case, there is one and only one metric for each need. In practice, this is frequently not possible.

For example, consider the need that the suspension be "easy to install." The team may conclude that this need is largely captured by measuring the time required for assembly of the fork to the frame. However, note the possible subtleties in this translation. Is assembly time really identical to ease of installation? The installation could be extremely fast but require an awkward and painful set of finger actions, which ultimately may lead to worker injury or dealer frustration. Because of the imprecise nature of the translation process, those establishing the specifications should have been directly involved in identifying the customer needs. In this way the team can rely on its understanding of the meaning of each need statement derived from firsthand interactions with customers

Metrics should be complete. Ideally each customer need would correspond to a single metric, and the value of that metric would correlate perfectly with satisfaction of that need. In practice, several metrics may be necessary to completely reflect a single customer need.

Metrics should be dependent, independent, variables. Designers use many types of variables in product development; some are dependent, such as the mass of the fork, and some are independent, such as the material used for the fork. In other words, designers cannot control mass directly because it arises from other independent decisions the designers will make, such as dimensions and materials choices.

Metrics should be practical. metrics will be directly observable or analyzable properties of the product that can be easily evaluated by the team

Some needs cannot easily be translated into quantifiable metrics..

The metrics should include the popular criteria for comparison in the marketplace**.**

Collect Competitive Benchmarking Information

Unless the team expects to enjoy a total monopoly, the relationship of the new product to competitive products is paramount in determining commercial success. While the team will have entered the product development process with some idea of how it wishes to compete in the marketplace, the target specifications are the language the team uses to discuss and agree on the detailed positioning of its product relative to existing products, both its own and competitors'. Information on competing products must be gathered to

support these positioning decisions.

The benchmarking chart is conceptually very simple. For each competitive product, the values of the metrics are simply entered down a column. Gathering these data can be very time consuming, involving (at the least) purchasing, testing, disassembling, and estimating the production costs of the most important competitive products. However, this investment of time is essential, as no product development team can expect to succeed without

having this type of information.

Set Ideal and Marginally Acceptable Target Values

In this step, the team synthesizes the available information in order to actually set the target values for the metrics. Two types of target value are useful: an ideal value and a marginally acceptable value. The ideal value is the best result the team could hope for. The marginally acceptable value is the value of the metric that would just barely make the product commercially viable.

Both of these targets are useful in guiding the subsequent stages of concept generation and concept selection, and for refining the specifications after the product concept has been selected.

Reflect on the Results and the Process

The team may require some iteration to agree on the targets. Reflection after each iteration helps to ensure that the results are consistent with the goals of the project. Questions to consider include:

• Are members of the team “gaming”? For example, is the key marketing representative insisting that an aggressive value is required for a particular metric in the hopes that by setting a high goal, the team will actually achieve more than if his or her true, and more lenient, beliefs were expressed?

• Should the team consider offering multiple products or at least multiple options for the product in order to best match the particular needs of more than one market segment, or will one “average” product suffice?

• Are any specifications missing? Do the specifications reflect the characteristics that will dictate commercial success?

Once the targets have been set, the team can proceed to generate solution concepts.

Setting the Final Specifications

Specifications that originally were only targets expressed as broad ranges of values are now refined and made more precise.

Finalizing the specifications is difficult because of trade-offs—inverse relationships between two specifications that are inherent in the selected product concept. Trade-offs frequently occur between different technical performance metrics and almost always occur between technical performance metrics and cost. For example, one trade-off is between brake mounting stiffness and mass of the fork. Because of the basic mechanics of the fork

structure, these specifications are inversely related, assuming other factors are held constant. Another trade-off is between cost and mass. For a given concept, the team may be able to reduce the mass of the fork by making some parts out of titanium instead of steel.

Unfortunately, decreasing the mass in this way will most likely increase the manufacturing cost of the product. The difficult part of refining the specifications is choosing how such trade-offs will be resolved.

Here, we propose a five-step process:

1. Develop technical models of the product.

2. Develop a cost model of the product.

3. Refine the specifications, making trade-offs where necessary.

4. Flow down the specifications as appropriate.

5. Reflect on the results and the process.

Develop technical models of the product.

A technical model of the product is a tool for predicting the values of the metrics for a particular set of design decisions. We intend the term models to refer to both analytical and physical approximations of the product.

performance can be expected from a particular choice of design variables, without costly physical experimentation.

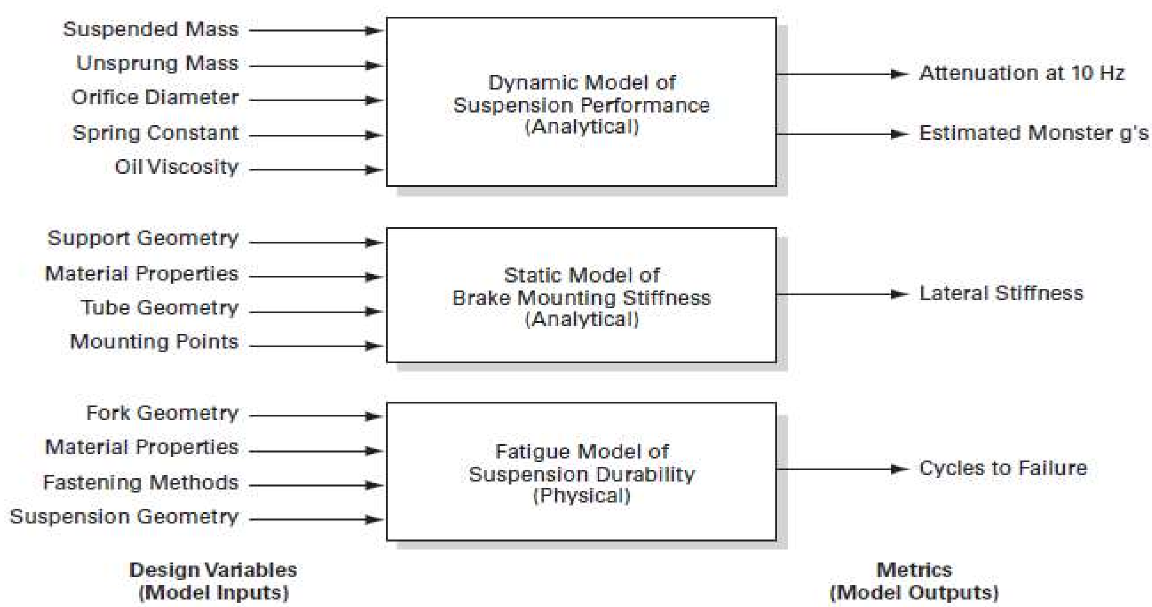


EXHIBIT 6-9 Models used to assess technical feasibility. Technical models may be analytical or physical approximations of the product concept.

Note that a technical model is almost always unique to a particular product concept. One of the models illustrated in Exhibit 6-9 is for an oil-damped suspension system; the model would be substantially different if the team had selected a concept employing a rubber suspension element. Thus, the modeling step can only be performed after the concept has been chosen.

Develop a Cost Model of the Product

The goal of this step of the process is to make sure that the product can be produced at the target cost. The target cost is the manufacturing cost at which the company and its distribution partners can make adequate profits while still offering the product to the end customer at a competitive price.

For most products, the first estimates of manufacturing costs are completed by drafting a bill of materials (a list of all the parts) and estimating a purchase price or fabrication cost for each part.

At this point in the development process the team does not generally know all of the components that will be in the product, but the team nevertheless makes an attempt to list the components it expects will be required. While early estimates generally focus on the cost of components, the team will usually make a rough estimate of assembly and other manufacturing costs (e.g., overhead) at this point as well.

Efforts to develop these early cost estimates involve soliciting cost estimates from vendors and estimating the production costs of the components the firm will make itself. This process is often facilitated by a purchasing expert and a production engineer.

A useful way to record cost information is to list figures for the high and low estimates of each item. This helps the team to understand the range of uncertainty in the market.

Refine the Specifications, Making Trade-Offs Where Necessary

Once the team has constructed technical performance models where possible and constructed a preliminary cost model, these tools can be used to develop final specifications. Finalizing specifications can be accomplished in a group session in which feasible combinations of values are determined through the use of the technical models and then the cost implications are explored. In an iterative fashion, the team converges on the specifications that will most favorably position the product relative to the competition, will best satisfy the customer needs, and will ensure adequate profits.

One important tool for supporting this decision-making process is the competitive map. An example competitive map is shown in Exhibit 6-11. This map is simply a scatter plot of the competitive products along two dimensions selected from the set of metrics and is sometimes called a trade-off map.

The map displayed in Exhibit 6-11 shows estimated manufacturing cost versus score on the Monster test. The regions defined by the marginal and ideal values of the specifications are shown on the map. This map is particularly useful in showing that all of the high-performance suspensions (low Monster scores) have

high estimated manufacturing costs. Armed with technical performance models and a cost model, the team can assess whether or not it will be able to “beat the trade-off ” exhibited in the competitive map.

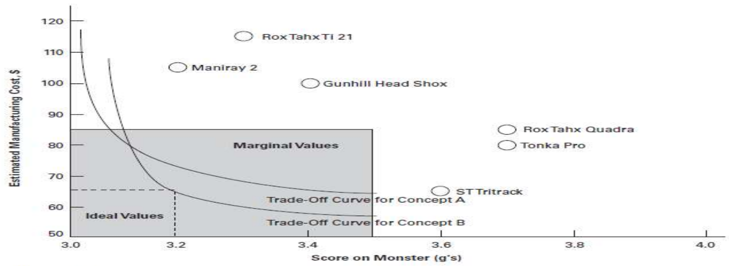


EXHIBIT 6-11 A competitive map showing estimated manufacturing cost versus score on the Monster test. Trade-off curves for two suspension concepts are also drawn on this map.

Flow Down the Specifications as Appropriate

This chapter focuses on the specifications for a relatively simple component designed by a single, relatively small development team. Establishing specifications takes on additional importance and is substantially more challenging when developing a highly complex product consisting of multiple subsystems designed by multiple development teams. In such a context, specifications are used to define the development objectives of each of the subsystems as well as for the product as a whole. The challenge in this case is to flow down the overall specifications to specifications for each subsystem.

For example, the overall specifications for an automobile contain metrics like fuel economy, 0–100 kilometer/hour acceleration time, and turning radius. However, specifications must also be created for the several dozen major subsystems that make up the automobile, including the body, engine, transmission, braking system, and suspension.

The specifications for the engine include metrics like peak power, peak torque, and fuel consumption at peak efficiency. One challenge in the flow-down process is to ensure that the subsystem specifications in fact reflect the overall product specifications—that if specifications for the subsystems are achieved, the overall product specifications will be achieved. A second challenge is to ensure that certain specifications for different subsystems are equally difficult to meet. That is, for example, that the mass specification for the engine is not inordinately more difficult to meet than is the mass specification for the body. Otherwise,

the cost of the product will likely be higher than necessary.

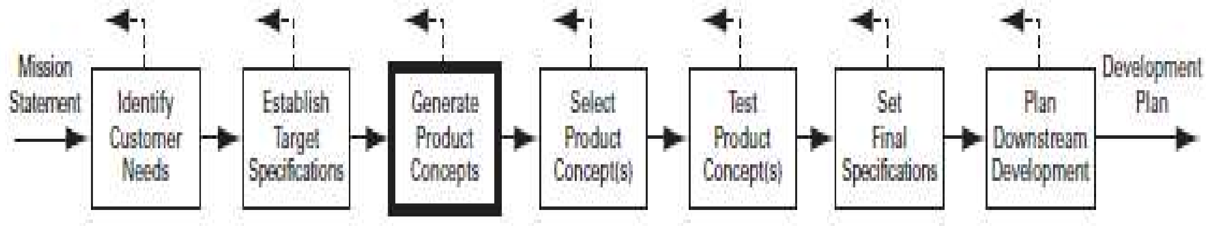
Reflect on the Results and the Process

As always, the final step in the method is to reflect on the outcome and the process. Some questions the team may want to consider are:

- Is the product a winner? The product concept should allow the team to actually set the specifications so that the product will meet the customer needs.

and excel competitively If not, then the team should return to the concept generation.

- How much uncertainty is there in the technical and cost models? If competitive success is dictated by metrics around which much uncertainty remains, the team may wish to refine the technical or cost models in order to increase confidence in meeting the specifications
- Is the concept chosen by the team best suited to the target market, or could it be best applied in another market (say, the low end or high end instead of the middle)? The selected concept may actually be too good. If the team has generated a concept that is dramatically superior to the competitive products, it may wish to consider employing the concept in a more demanding, and potentially more profitable, market segment.
- Should the firm initiate a formal effort to develop better technical models of some aspect of the product's performance for future use?
- Sometimes the team will discover that it does not really understand the underlying product technology well enough to create useful performance models. In such circumstances, an engineering effort to develop better understanding and models may be useful in subsequent development projects.
- **Concept Generation**
- A product concept is an approximate description of the technology, working principles, and form of the product. It is a concise description of how the product will satisfy the customer needs. A concept is usually expressed as a sketch or as a rough three-dimensional model and is often accompanied by a brief textual description. The degree to which a product satisfies customers and can be successfully commercialized depends to a large measure on the quality of the underlying concept. A good concept is sometimes poorly implemented in subsequent development phases, but a poor concept can rarely be manipulated to achieve commercial success. Fortunately, concept generation is relatively inexpensive and can be done relatively quickly in comparison to the rest of the development process. For example, concept generation had typically consumed less than 5 percent of the budget and 15 percent of the development time.
- The concept generation process begins with a set of customer needs and target specifications and results in a set of product concepts from which the team will make a final selection. The relation of concept generation to the other concept development activities is shown in Exhibit 7-2. In most cases, an effective development team will generate hundreds of concepts, of which 5 to 20 will merit serious consideration during the concept selection activity.

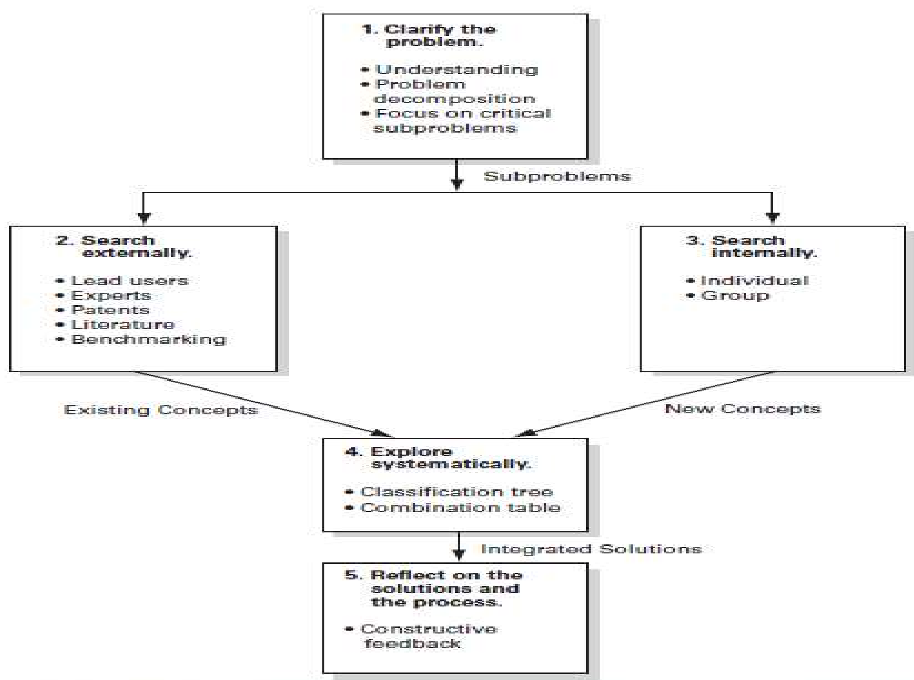


Good concept generation leaves the team with confidence that the full space of alternatives has been explored. Thorough exploration of alternatives early in the development process greatly reduces the likelihood that the team will stumble upon a superior concept late in the development process or that a competitor will introduce a product with dramatically better performance than the product under development.

Five-Step Method

This chapter presents a five-step concept generation method. The method, outlined in Exhibit 7-3, breaks a complex problem into simpler subproblems. Solution concepts are then identified for the subproblems by external and internal search procedures. Classification trees and concept combination tables are then used to systematically explore the space of solution concepts and to integrate the subproblem solutions into a total solution. Finally, the team takes a step back to reflect on the validity and applicability of the results, as well as on the process used.

EXHIBIT 7-3
The five-step concept generation method.



MODULE-III

Product concepts

Product configuration

Product configuration is an activity of customizing a product to meet the needs of a customer.

Configurators are used to guide the user through the product definition process and serve as an important tool for choice navigation.

"Product configurators allow the customer to get the exact product they need or desire".

Benefits of Using a Product Configurator

Specific benefits to using a configurator include:

- Better turn-around to customer requests
- More accurate information to the customer and internal organization
- Customer differentiation through individuality
- Better knowledge of customers' needs
- Less finished goods inventory to cover expected configurations
- Less expediting to adapt a specific request for a customer
- Reduced engineering time to develop a custom product
- Reduced order entry errors and improved customer service/customer loyalty
- Latest and greatest version of products being offered

A medical supply company retained a product design firm to develop a reusable syringe with precise dosage control for outpatient use. One of the products sold by a competitor is shown in Figure. To focus the development effort, the medical supply company identified two major problems with its current product: cost (the existing model was made of stainless steel) and accuracy of dose metering. The company also requested that the product be tailored to the physical capabilities of the elderly, an important segment of the target market. To summarize the needs of its client and of the intended end users, the team established seven criteria on which the choice of a product concept would be based:

• Ease of handling.

• Ease of use.

• Readability of dose settings.

• Dose metering accuracy.

• Durability.

• Ease of manufacture.

• Portability.

The team described the concepts under consideration with the sketches shown. Although each concept nominally satisfied the key customer needs, the team was faced with choosing the best concept for further design, refinement, and production.

The need to select one syringe concept from many raises several questions:

• How can the team choose the best concept, given that the designs are still quite abstract?

• How can a decision be made that is embraced by the whole team?

• How can desirable attributes of otherwise weak concepts be identified and used?

• How can the decision-making process be documented

Concept Selection Is an Integral Part of the Product Development Process

Early in the development process the product development team identifies a set of customer needs. By using a variety of methods, the team then generates alternative solution concepts in response to these needs. Concept selection is the process of evaluating concepts with respect to customer needs and other criteria, comparing the relative strengths and weaknesses of the concepts, and selecting one or more concepts for further investigation, testing, or development. Exhibit 8-2 illustrates how the concept selection activity is related to the other activities that make up the concept development phase of the product development process

While many stages of the development process benefit from unbounded creativity and divergent thinking, concept selection is the process of narrowing the set of concept alternatives under consideration. Although concept selection is a convergent process, it is frequently iterative and may not produce a dominant concept immediately. A large set of concepts is initially winnowed down to a smaller set, but these concepts may subsequently be combined and improved to temporarily enlarge the set of concepts under consideration.

Through several iterations a dominant concept is finally chosen. Exhibit 8-4 illustrates the successive narrowing and temporary widening of the set of options under consideration during the concept selection activity.

All Teams Use Some Method for Choosing a Concept

Whether or not the concept selection process is explicit, all teams use some method to choose among concepts.

• **External decision:** Concepts are turned over to the customer, client, or some other external entity for selection.

• **Product champion:** An influential member of the product development team chooses a concept based on personal preference.

• **Intuition:** The concept is chosen by its feel. Explicit criteria or trade-offs are not used. The concept just seems better.

• **Multivoting:** Each member of the team votes for several concepts. The concept with the most votes is selected.

• **Web-based survey:** Using an online survey tool, each concept is rated by many people to find the best ones.

• **Pros and cons:** The team lists the strengths and weaknesses of each concept and makes a choice based upon group opinion.

• **Prototype and test:** The organization builds and tests prototypes of each concept, making a selection based upon test data.

• **Decision matrices:** The team rates each concept against prespecified selection criteria, which may be weighted.

A Structured Method Offers Several Benefits

A structured concept selection process helps to maintain objectivity throughout

the concept phase of the development process and guides the product development team through a critical, difficult, and sometimes emotional process. Specifically, a structured concept selection method offers the following potential benefits:

• **A customer-focused product:** Because concepts are explicitly evaluated against

customer-oriented criteria, the selected concept is likely to be focused on the customer.

• **A competitive design:** By benchmarking concepts with respect to existing designs, designers push the design to match or exceed their competitors' performance along key dimensions.

• **Better product-process coordination:** Explicit evaluation of the product with respect to manufacturing criteria improves the product's manufacturability

and helps to match the product with the process capabilities of the firm.

• **Reduced time to product introduction:** A structured method becomes a common language among design engineers, manufacturing engineers, industrial designers, marketers, and project managers, resulting in decreased ambiguity, faster communication, and fewer false starts.

• **Effective group decision making:** Within the development team,organizational philosophy and guidelines, willingness of members to participate, and team member experience may constrain the concept selection process. A structured method encourages decision making based on objective criteria and minimizes the likelihood that arbitrary or personal factors influence the product concept.

• **Documentation of the decision process:** A structured method results in a readily understood archive of the rationale behind concept decisions. This record is useful for assimilating new team members and for quickly assessing the impact of changes in the customer needs or in the available alternatives.

We present a two-stage concept selection methodology, The first stage is called concept screening and the second stage is called concept scoring. Each is supported by a decision matrix that is used by the team to rate, rank, and select the best concept(s). Although the method is structured, we emphasize the role of group insight to improve and combine concepts.

Screening is a quick, approximate evaluation aimed at producing a few viable alternatives. Scoring is a more careful analysis of these relatively few concepts

in order to choose the single concept most likely to lead to product success.

During concept screening, rough initial concepts are evaluated relative to a common reference concept using the screening matrix. At this preliminary stage, detailed quantitative comparisons are difficult to obtain and may be misleading, so a coarse comparative rating system is used. After some alternatives are eliminated, the team may choose to move on to concept scoring and conduct more detailed analyses and finer quantitative evaluation of the remaining concepts using the scoring matrix as a guide.

Throughout the screening and scoring process, several iterations may be performed, with new alternatives arising from the combination of the features of several concepts. Both stages, concept screening and concept scoring, follow a six-step process that leads the team through the concept selection activity. The steps are:

- Prepare the selection matrix.
- Rate the concepts.
- Rank the concept
- Combine and improve the concepts.
- Select one or more concepts.
- Reflect on the results and the process.

Concept Screening

The purposes of this stage are to narrow the number of concepts quickly and to improve the concepts.

Prepare the Selection Matrix

	Concepts						
Selection Criteria	A Master Cylinder	B Rubber Brake	C Ratchet	D (Reference) Plunge Stop	E Swash Ring	F Lever Set	G Dial Screw
Ease of handling	0	0	–	0	0	–	–
Ease of use	0	–	–	0	0	+	0
Readability of settings	0	0	+	0	+	0	+
Dose metering accuracy	0	0	0	0	–	0	0
Durability	0	0	0	0	0	+	0
Ease of manufacture	+	–	–	0	0	–	0
Portability	+	+	0	0	+	0	0
Sum +'s	2	1	1	0	2	2	1
Sum 0's	5	4	3	7	4	3	5
Sum –'s	0	2	3	0	1	2	1
Net Score	2	–1	–2	0	1	0	0
Rank	1	6	7	3	2	3	3
Continue?	Yes	No	No	Combine	Yes	Combine	Revise

EXHIBIT 8-5 The concept-screening matrix. For the syringe example, the team rated the concepts against the reference concept using a simple code (+ for "better than," 0 for "same as," – for "worse than") in order to identify some concepts for further consideration. Note that the three concepts ranked "3" all received the same net score.

If the team is considering more than about 12 concepts, the multivote technique may be used to quickly choose the dozen or so concepts to be evaluated with the screening matrix. Multivoting is a technique in which members of the team simultaneously vote for three to five concepts by applying "dots" to the sheets describing their preferred concepts.

Rate the Concepts

A relative score of "better than" (+), "same as" (0), or "worse than" (–) is placed in each cell of the matrix to represent how each concept rates in comparison to the reference concept relative to the particular criterion. It is generally advisable to rate every concept on one criterion before moving to the next criterion. However, with a large number of concepts, it is faster to use the opposite approach—to rate each concept completely before moving on to the next concept.

Rank the Concepts

After rating all the concepts, the team sums the number of “better than,” “same as,” and “worse than” scores and enters the sum for each category in the lower rows of the matrix. From our example in Exhibit 8-5, concept A was rated to have two criteria better than, five the same as, and none worse than the reference concept. Next, a net score can be calculated by subtracting the number of “worse than” ratings from the “better than” ratings.

Once the summation is completed, the team rank-orders the concepts. Obviously, in general those concepts with more pluses and fewer minuses are ranked higher. Often at this point the team can identify one or two criteria that really seem to differentiate the concepts.

Combine and Improve the Concepts

Having rated and ranked the concepts, the team should verify that the results make sense and then consider if there are ways to combine and improve certain concepts. Two issues to consider are:

- Is there a generally good concept that is degraded by one bad feature? Can a minor modification improve the overall concept and yet preserve a distinction from the other concepts?
- Are there two concepts that can be combined to preserve the “better than” qualities while annulling the “worse than” qualities?

Combined and improved concepts are then added to the matrix, rated by the team, and ranked along with the original concepts. In our example, the team noticed that concepts D and F could be combined to remove several of the “worse than” ratings to yield a new concept, DF, to be considered in the next round. Concept G was also considered for revision. The team decided that this concept was too bulky, so the excess storage space was removed while retaining the injection technique. These revised concepts are shown in Exhibit 8-6.

Select One or More Concepts

Once the team members are satisfied with their understanding of each concept and its relative quality, they decide which concepts are to be selected for further

refinement and analysis. Based upon previous steps, the team will likely develop a clear sense of which are the most promising concepts. The number of concepts selected for further review will be limited by team resources (personnel, money, and time). In our example, the team selected concepts A and E to be considered along with the revised concept G+ and the new concept DF. Having determined the concepts for further analysis, the team must clarify which issues need to be investigated further before a final selection can be made.

The team must also decide whether another round of concept screening will be performed or whether concept scoring will be applied next. If the screening matrix is not seen to provide sufficient resolution for the next step of evaluation and selection, then the concept-scoring stage with its weighted selection criteria and more detailed rating scheme would be used.

Reflect on the Results and the Process

All of the team members should be comfortable with the outcome. If an individual is not in agreement with the decision of the team, then perhaps one or more important criteria are missing from the screening matrix, or perhaps a particular rating is in error, or at least is not clear. An explicit consideration of whether the results make sense to everyone reduces the likelihood of making a mistake and increases the likelihood that the entire team will be solidly committed to the subsequent development activities.

		Concept							
		A (Reference) Master Cylinder		DF Lever Stop		E Swash Ring		G+ Dial Screw+	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Ease of handling	5%	**3**	0.15	3	0.15	4	0.2	4	0.2
Ease of use	15%	**3**	0.45	4	0.6	4	0.6	3	0.45
Readability of settings	10%	2	0.2	**3**	0.3	5	0.5	5	0.5
Dose metering accuracy	25%	**3**	0.75	3	0.75	2	0.5	3	0.75
Durability	15%	2	0.3	5	0.75	4	0.6	**3**	0.45
Ease of manufacture	20%	**3**	0.6	3	0.6	2	0.4	2	0.4
Portability	10%	**3**	0.3	3	0.3	3	0.3	3	0.3
	Total Score	2.75		3.45		3.10		3.05	
	Rank	4		1		2		3	
	Continue?	No		Develop		No		No	

EXHIBIT 8-7 The concept-scoring matrix. This method uses a weighted sum of the ratings to determine concept ranking. While concept A serves as the overall reference concept, the separate reference points for each criterion are signified by **bold** rating values.

Concept Scoring

Concept scoring is used when increased resolution will better differentiate among competing concepts. In this stage, the team weighs the relative importance of the selection criteria and focuses on more refined comparisons with respect to each criterion. The concept scores are determined by the weighted sum of the ratings. Exhibit 8-7 illustrates the scoring matrix used in this stage. In describing the concept scoring process, we focus on the differences relative to concept screening.

Step 1: Prepare the Selection Matrix

As in the screening stage, the team prepares a matrix and identifies a reference concept. In most cases a computer spreadsheet is the best format to facilitate ranking and sensitivity analysis. The concepts that have been identified for analysis are entered on the top of the matrix. The concepts have typically been refined to some extent since concept screening and may be expressed in more detail. In conjunction with more detailed concepts, the team may wish to add more detail to the selection criteria. The use of hierarchical relations is a useful way to illuminate the criteria. For the syringe example, suppose the team decided that the criterion “ease of use” did not provide sufficient detail to help distinguish among the remaining concepts. “Ease of use” could be broken down, as shown in Exhibit 8-8, to include “ease of injection,” “ease of cleaning,” and “ease of loading.” The level of criteria detail will depend upon the needs of the team; it may not be necessary to expand the criteria at all. After the criteria are entered, the team adds importance weights to the matrix. Several different schemes can be used to weight the criteria, such as assigning an importance value from 1 to 5, or allocating 100 percentage points among them, as the team has done in Exhibit 8-7. There are marketing techniques for empirically determining weights from customer data, and a thorough process of identifying customer needs may result in such weights.

Step 2: Rate the Concepts

As in the screening stage, it is generally easiest for the team to focus its discussion by rating all of the concepts with respect to one criterion at a time. Because of the need for additional resolution to distinguish among competing concepts, a finer scale is now used. We recommend a scale from 1 to 5:

Relative Performance Rating

Much worse than reference 1

Worse than reference 2

Same as reference 3

Better than reference 4

Much better than reference 5

single reference concept can be used for the comparative ratings, as in the screening stage; however, this is not always appropriate. Unless by pure coincidence the reference concept is of average performance relative to all of the criteria, the use of the same reference concept for the evaluation of each criterion will lead to “scale compression” for some of the criteria. For example, if the reference concept happens to be the easiest concept to manufacture, all of the remaining concepts will receive an evaluation of 1, 2, or 3 (“much worse than,” “worse than,” or “same as”) for the ease-of-manufacture criterion,

compressing the rating scale from five levels to three levels.

To avoid scale compression, it is possible to use different reference points for the

various selection criteria. Reference points may come from several of the concepts under consideration, from comparative benchmarking analysis, from the target values of the product specifications, or other means. It is important that the reference point for each criterion be well understood to facilitate direct one-to-one comparisons. Using multiple reference points does not prevent the team from designating one concept as the overall reference for the purposes of ensuring that the selected concept is competitive relative to this benchmark. Under such conditions the overall reference concept will simply not receive a neutral score.

Exhibit 8-7 shows the scoring matrix for the syringe example. The team believed that the master cylinder concept was not suitable as a reference point for two of the criteria, and other concepts were used as reference points in these cases.

Step 3: Rank the Concepts

Once the ratings are entered for each concept, weighted scores are calculated by multiplying the row scores by the criteria weights. The total score for each concept is the sum of the weighted scores:

Step 4: Combine and Improve the Concepts

As in the screening stage, the team looks for changes or combinations that improve concepts. Although the formal concept generation process is typically completed before concept selection begins, some of the most creative refinements and improvements occur during the concept selection process as the team realizes the inherent strengths and weaknesses of certain features of the product concepts.

Step 5: Select One or More Concepts

The final selection is not simply a question of choosing the concept that achieves the highest ranking after the first pass through the process. Rather, the team should explore this initial evaluation by conducting a sensitivity analysis. Using a computer spreadsheet, the team can vary weights and ratings to determine their effect on the ranking.

By investigating the sensitivity of the ranking to variations in a particular rating

the team members can assess whether uncertainty about a particular rating has a large impact on their choice. In some cases they may select a lower-scoring concept about which there is little uncertainty instead of a higher-scoring concept that may possibly prove unworkable or less desirable as they learn more about it. Based on the selection matrix, the team may decide to select the top two or more concepts. These concepts may be further developed, prototyped, and tested to elicit customer feedback.

The team may also create two or more scoring matrices with different weightings to yield the concept ranking for various market segments with different customer preferences. It may be that one concept is dominant for several segments. The team should also consider carefully the significance of differences in concept scores. Given the resolution of the scoring system, small differences are generally not significant. For the syringe example, the team agreed that concept DF was the most promising and would be likely to result in a successful product.

Module-IV

Product Architecture

What Is Product Architecture?

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. For a printer, some of the functional elements are "store paper" and "communicate with host computer." Functional elements are usually described in schematic form before they are reduced to specific technologies, components, or physical working principles.

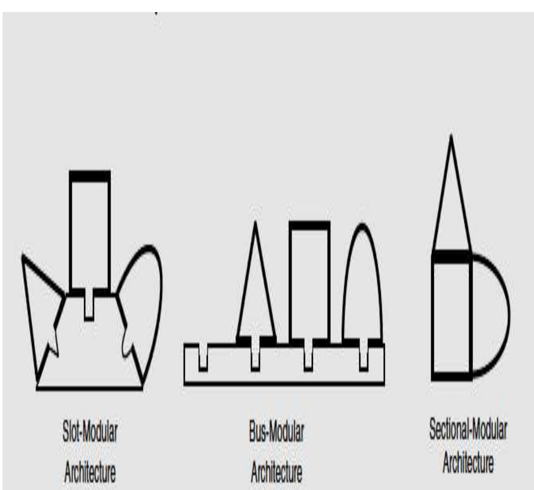
The physical elements of a product are the parts, components, and subassemblies that ultimately implement the product's functions. The physical elements become more defined as development progresses. Some physical elements are dictated by the product concept, and others become defined during the detail design phase. For example, the Desk Jet embodies a product concept involving a thermal ink delivery device, implemented by a print cartridge

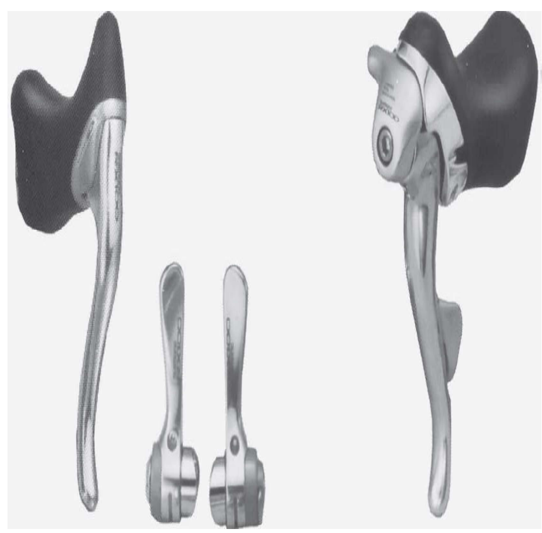
Types of Modularity

Slot-modular architecture

Bus-modular architecture

Sectional-modular architecture





Implications of the Architecture

- Product Change

- Product Variety
- Component Standardization
- Product Performance
- Manufacturability
- Product Development Management

Establishing the Architecture

1. Create a schematic of the product.

2. Cluster the elements of the schematic.

3. Create a rough geometric layout.

4. Identify the fundamental and incidental interactions

Related System-Level Design Issues

- Defining Secondary Systems
- Establishing the Architecture of the Chunks
- Creating Detailed Interface Specifications
- **Establishing the Architecture**
- Because the product architecture will have profound implications for subsequent product development activities and for the manufacturing and marketing of the completed product, it should be established in a cross-functional effort by the development team. The end result of this activity is an approximate geometric layout of the product, descriptions of the major chunks, and documentation of the key interactions among the chunks. We recommend a four-step method to structure the decision process, which is illustrated using the DeskJet printer example. The steps are:
- 1. Create a schematic of the product.
- 2. Cluster the elements of the schematic.
- 3. Create a rough geometric layout.
- 4. Identify the fundamental and incidental interactions
- **Step 1: Create a Schematic of the Product**
- A schematic is a diagram representing the team's understanding of the constituent elements of the product. A schematic for the DeskJet is shown in Exhibit 10-6. At the end of the concept development phase, some of the elements in the schematic are physical

concepts, such as the front-in/front-out paper path. Some of the elements correspond to critical components, such as the print cartridge the team expects to use. However, some of the elements remain described only functionally.

- The schematic should reflect the team's best understanding of the state of the product, but it does not have to contain every imaginable detail
- Step 2: Cluster the Elements of the Schematic
- The challenge of step 2 is to assign each of the elements of the schematic to a chunk. One possible assignment of elements to chunks is shown in Exhibit 10-7, where nine chunks are used. Although this was the approximate approach
taken by the DeskJet team, there are several other viable alternatives. At one extreme, each element could be assigned to its own chunk, yielding 15 chunks.
To determine when there are advantages to clustering, consider these factors, which echo the implications discussed in the previous section:
- Geometric integration and precision
- Function sharing
- Capabilities of vendors
- Similarity of design or production technology
- Localization of change
- Accommodating variety
- Enabling standardization
- Portability of the interfaces

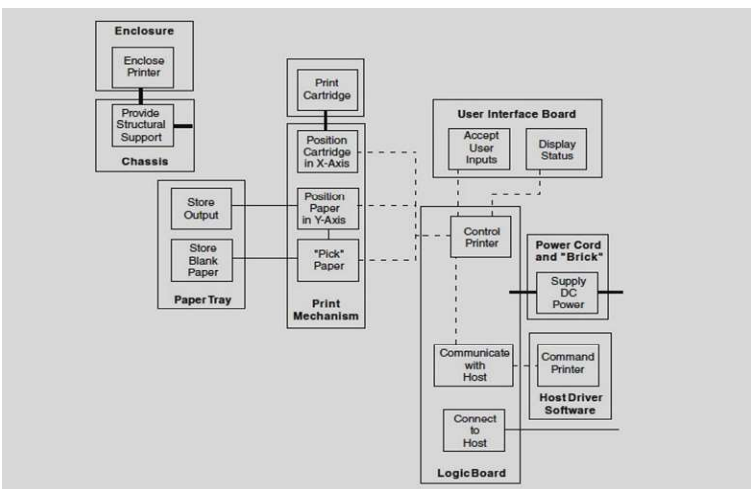
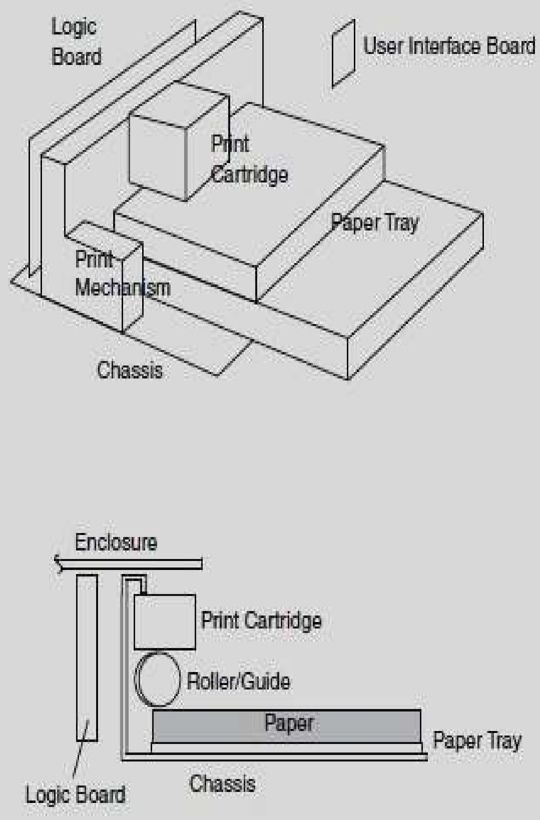


EXHIBIT 10-7 Clustering the elements into chunks. Nine chunks make up this proposed architecture for the DeskJet printer.

Step 3: Create a Rough Geometric Layout

A geometric layout can be created in two or three dimensions, using drawings, computer models, or physical models (of cardboard or foam, for example). Exhibit 10-8 shows a geometric layout of the DeskJet printer, positioning the major chunks. Creating a geometric layout forces the team to consider whether the geometric interfaces among the chunks are feasible and to work out the basic dimensional relationships among the chunks. By considering a cross section of the printer, the team realized that there was a fundamental trade-off between how much paper could be stored in the paper tray and the height of the machine. In this step, as in the previous step, the team benefits from generating several alternative layouts and selecting the best one. Layout decision criteria are closely related to the clustering issues in step 2. In some cases, the team may discover that the clustering derived in step 2 is not geometrically feasible and thus some of the elements would have to be reassigned to other chunks

EXHIBIT 10-8
Geometric layout of the printer.



Step 4: Identify the Fundamental and Incidental Interactions

Most likely a different person or group will be assigned to design each chunk. Because the chunks interact with one another in both planned and unintended ways, these different groups will have to coordinate their activities and exchange information. In order to better manage this coordination process, the team should identify the known interactions between chunks during the system-level design phase.

There are two categories of interactions between chunks. First, fundamental interactions are those corresponding to the lines on the schematic that connect the chunks to one another. For example, a sheet of paper flows from the paper tray to the print mechanism. This interaction is planned, and it should be well understood, even from the very earliest schematic, as it is fundamental to the system's operation. Second, incidental interactions are those that arise because of the particular physical implementation of functional elements or because of the geometric arrangement of the chunks.

For example, vibrations induced by the actuators in the paper tray could interfere with the precise location of the print cartridge in the x-axis.

Related System-Level Design Issues

The four-step method for establishing the product architecture guides the early system level design activities, but many more detailed activities remain. Here we discuss some of the issues that frequently arise during subsequent system-level design activities and their implications for the product architecture.

DefiningSecondarySystems

The schematic in Exhibit 10-6 shows only the key elements of the product. There are many other functional and physical elements not shown, some of which will only be conceived and detailed as the system-level design evolves. These additional elements make up the secondary systems of the product. Examples include safety systems, power systems, status monitors, and structural supports. Some of these systems, such as safety systems, will span several chunks. Fortunately, secondary systems usually involve flexible connections such as wiring and tubing and can be considered after the major architectural decisions have been made.

EstablishingtheArchitectureoftheChunks

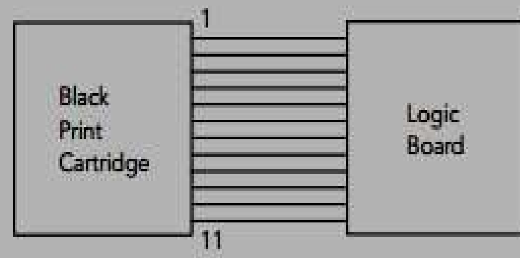
Some of the chunks of a complex product may be very complex systems in their own right. For example, many of the chunks in the DeskJet printer involve dozens of parts. Each of these chunks may have its own architecture—the scheme by which it is divided into smaller chunks. This problem is essentially identical to the architectural challenge posed at the level of the entire product. Careful consideration of the architecture of the chunks is nearly as important as the creation of the architecture of the overall product. For example, the print cartridge consists of the sub functions store ink and deliver ink for each of four colors of ink. Several architectural approaches are possible for this chunk, including, for example, the use of independently replaceable reservoirs for each ink color.

CreatingDetailedInterfaceSpecifications

As the system-level design progresses, the fundamental interactions indicated by lines on the schematic in Exhibit 10-6 are specified as much more detailed collections of signals, material flows, and exchanges of energy. As this refinement occurs, the specification of the interfaces between chunks should also be clarified. For example, Exhibit 10-14 shows an overview of a possible Specification of an interface between a black print cartridge and a logic board for a printer. Such interfaces represent the "contracts" between chunks and are often detailed in formal specification documents.

EXHIBIT 10-14
Specification of interface between black print cartridge and logic board.

Line	Name	Properties
1	PWR-A	+12VDC, 5mA
2	PWR-B	+5VDC, 10mA
3	STAT	TTL
4	LVL	100KΩ-1MΩ
5	PRNT1	TTL
6	PRNT2	TTL
7	PRNT3	TTL
8	PRNT4	TTL
9	PRNT5	TTL
10	PRNT6	TTL
11	GND	



Module-V
Product Improvement

Maintainability Defined

• Maintainability is considered as inherent to the system design, regarding the ease, accuracy, safety, and economy of maintenance tasks.

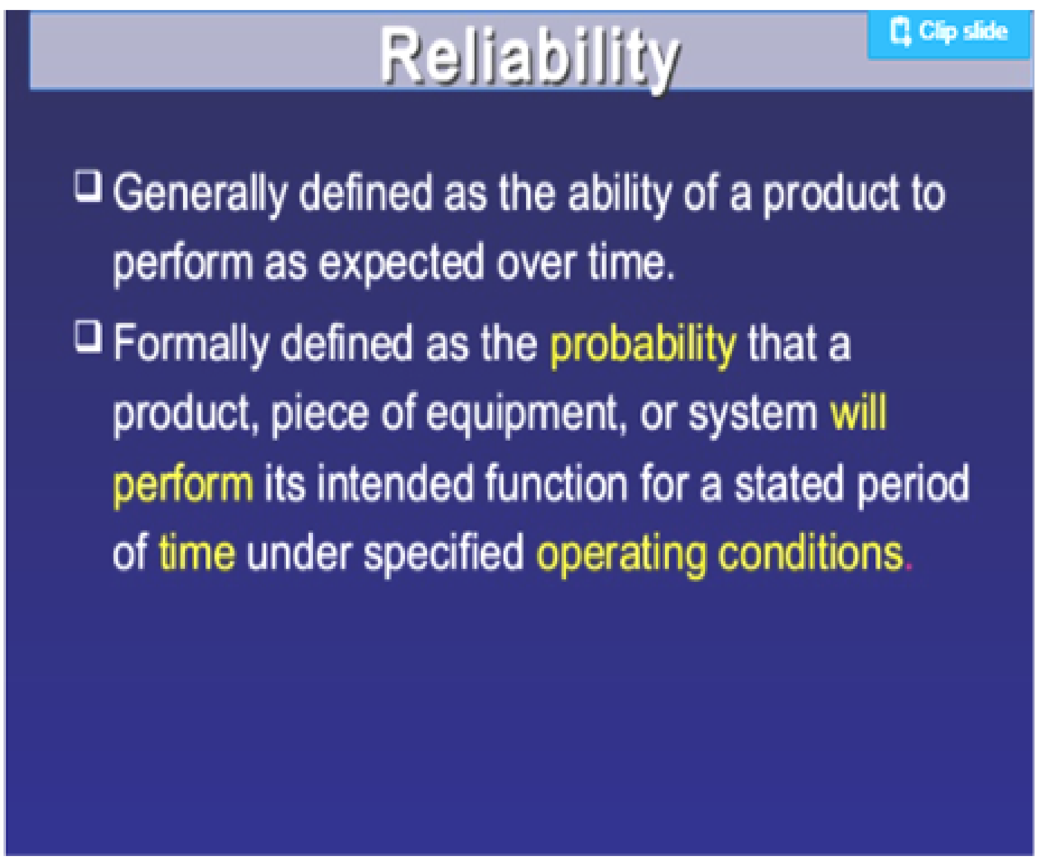
• The purpose of maintainability is to improve effectiveness and efficiency of maintenance.

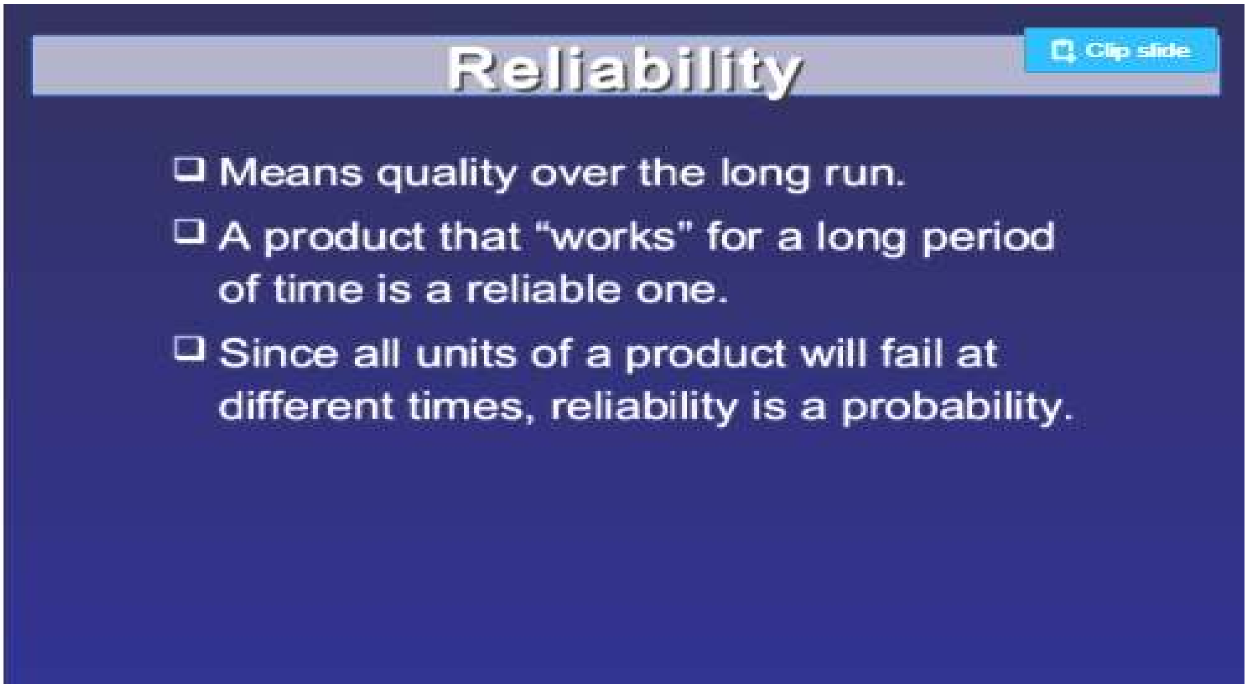
• Design for Maintainability (DfM) is the first step of an effective maintenance program, linking maintenance goals and desired outcomes to the design process.

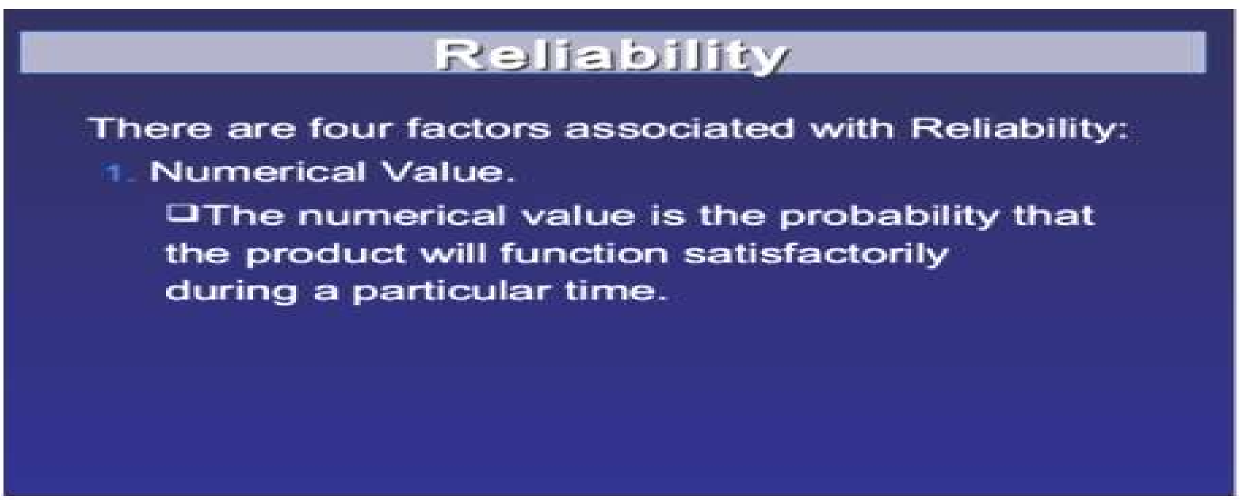
Why DfM?

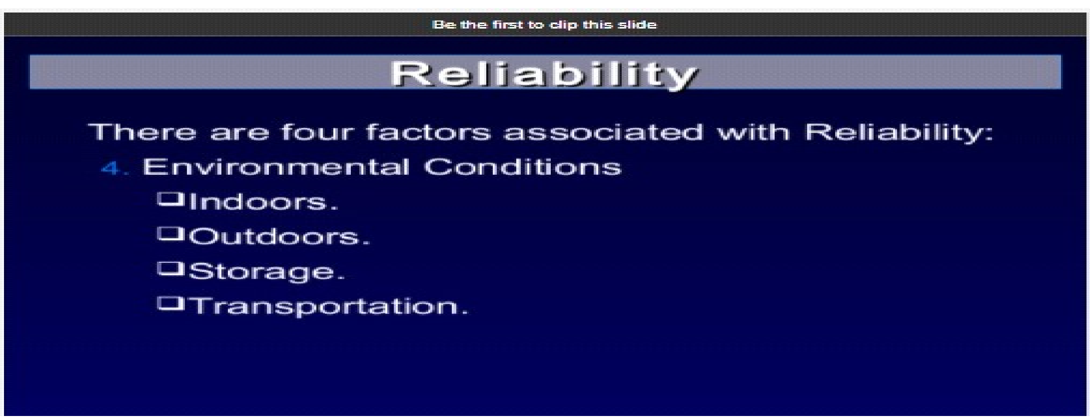
• Design for Maintainability emphasizes the importance of timely integration of design and construction knowledge with operations and maintenance (O&M) experiences into project designs at an early stage.

• Implementing DfM decreases the risk of § Reliability and Uptime being impacted § Total Life Cycle Costs increasing significantly § Inability of building use as originally intended




Clip slide
Reliability
❑ Means quality over the long run.
❑ A product that "works" for a long period of time is a reliable one.
❑ Since all units of a product will fail at different times, reliability is a probability.


Reliability
There are four factors associated with Reliability:
1. Numerical Value.
❑The numerical value is the probability that the product will function satisfactorily during a particular time.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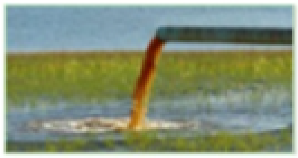
Reliability
There are four factors associated with Reliability:
4. Environmental Conditions
❑Indoors.
❑Outdoors.
❑Storage.
❑Transportation.

Environmental Impacts

Global Warming

Resource depletion

Solid waste



Water pollution

Air pollution

Land degradation

Design for Environment (DFE)

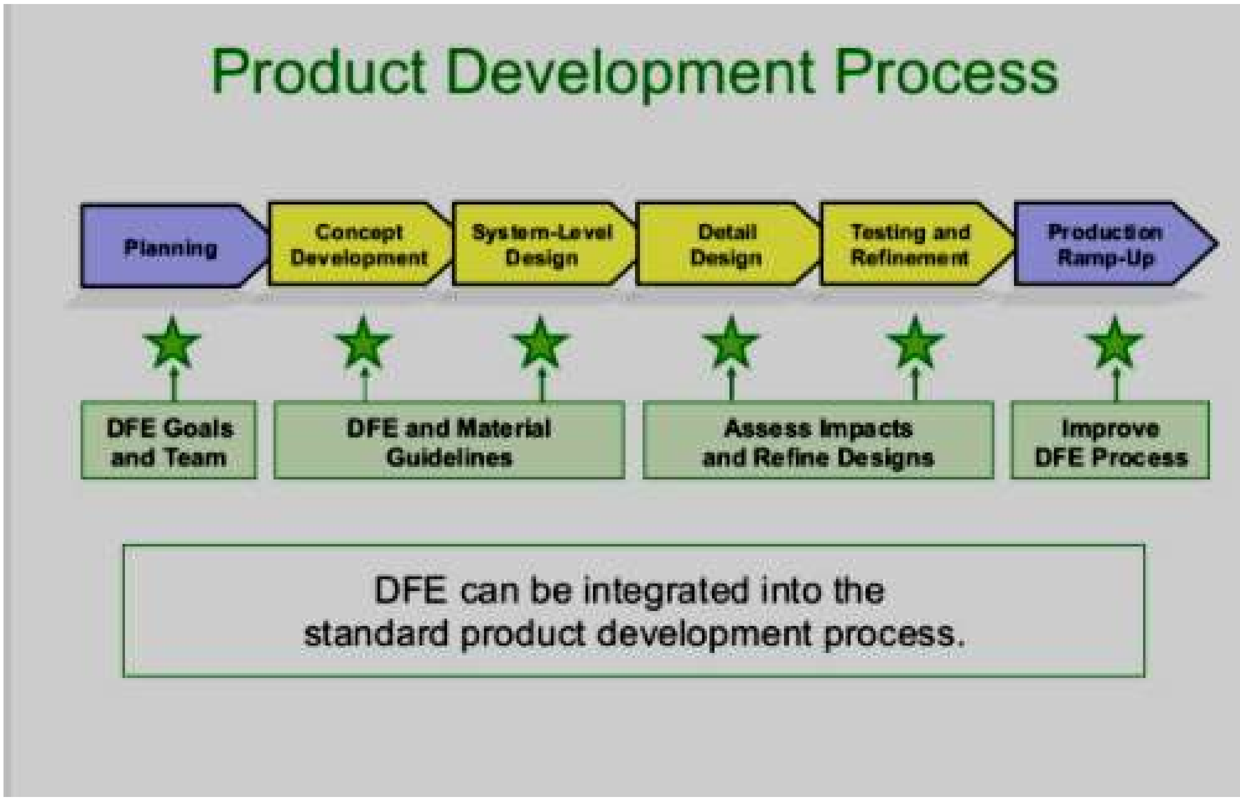
Design for Environment (DFE) is a method to minimize or eliminate environmental impacts of a product over its life cycle.

Effective DFE practice maintains or improves product quality and cost while reducing environmental impacts.

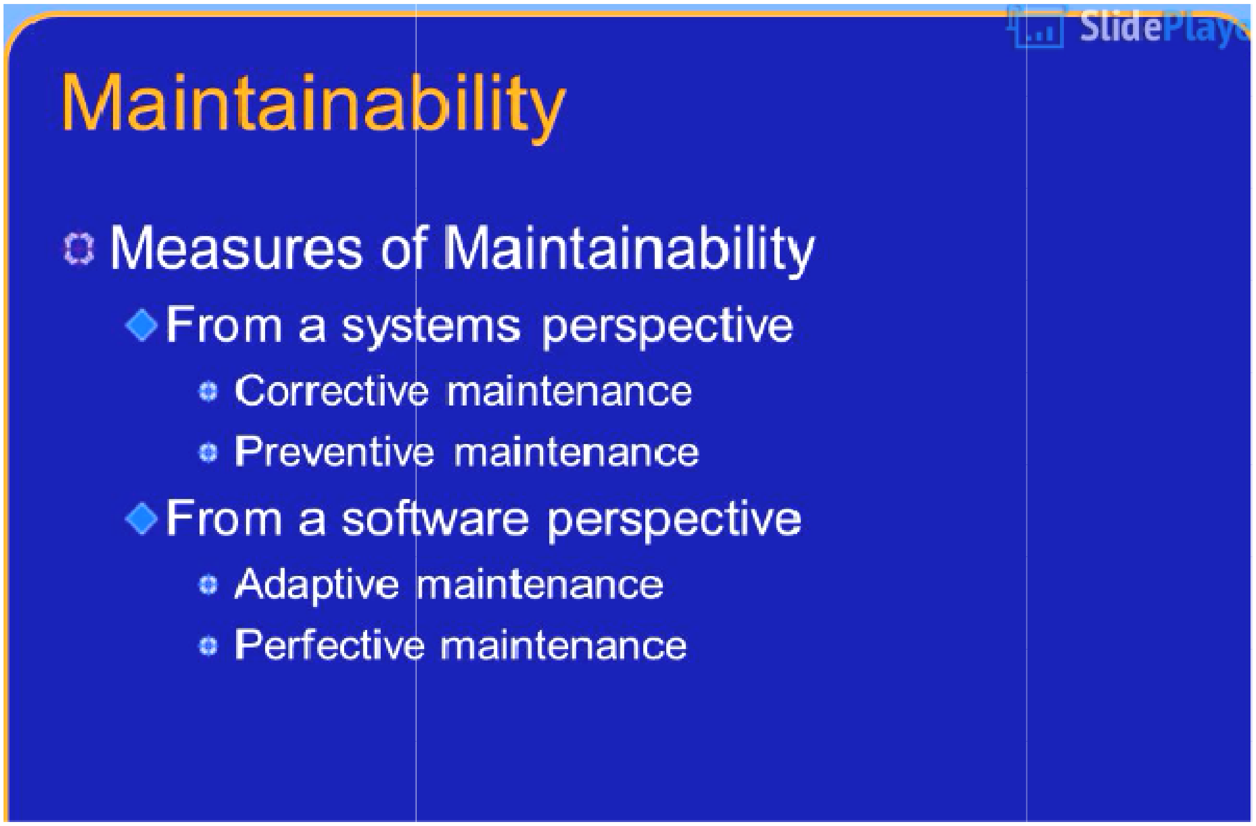
DFE expands the traditional manufacturer's focus on the production and distribution of its products to a closed-loop life cycle.

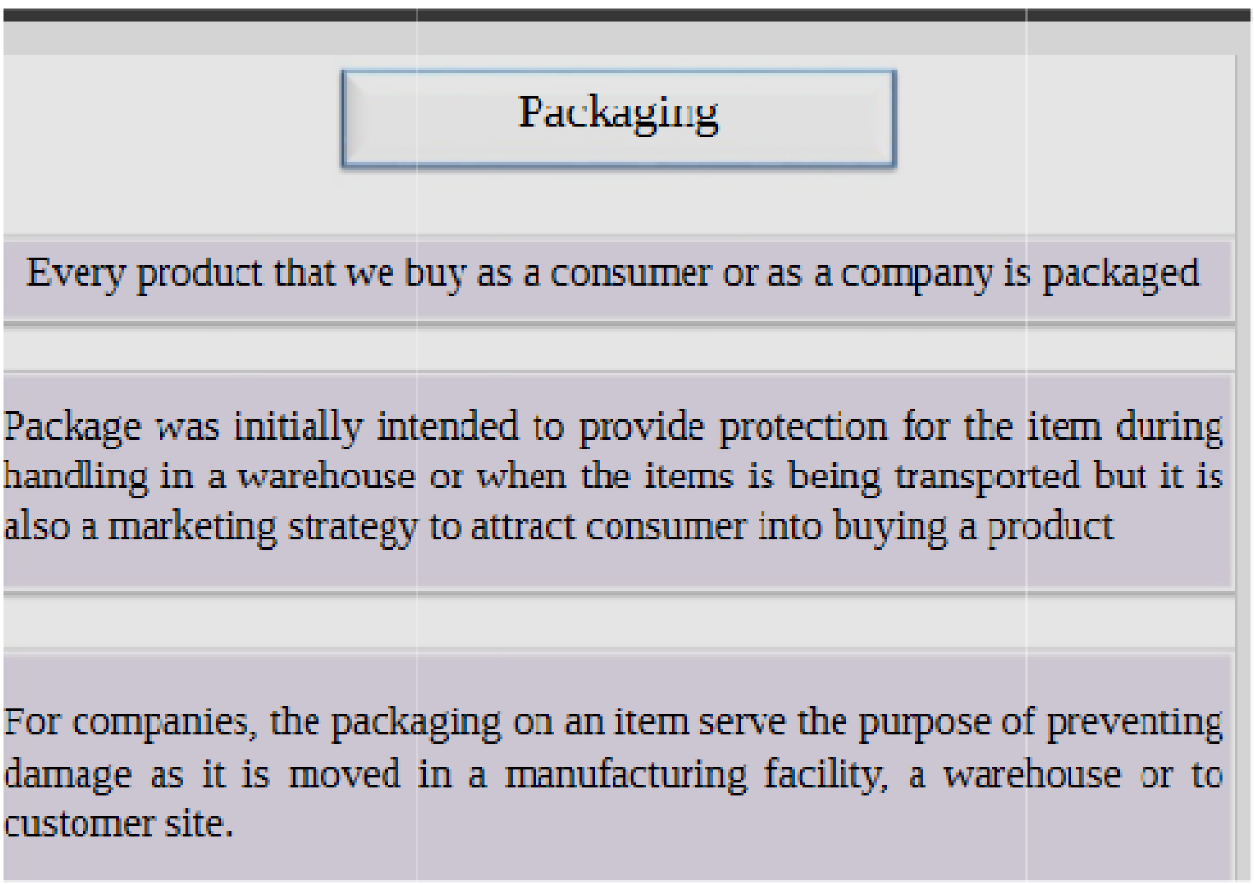
Life-Cycle Assessment (LCA)

- Quantifies environmental impact over product life cycle
- Steps in LCA analysis:
  1. Prepare proposed design options
  2. Identify life cycle, including recycling and disposal
  3. Identify all materials and energy sources used
  4. Identify outputs and waste streams
  5. Quantify impacts of each material, energy, waste


Product Development Process
Planning
Concept Development
System-Level Design
Detail Design
Testing and Refinement
Production Ramp-Up
DFE Goals and Team
DFE and Material Guidelines
Assess Impacts and Refine Designs
Improve DFE Process
DFE can be integrated into the standard product development process.


Maintainability
Definition
Maintainability, as a characteristic of design, can be defined on the basis of a combination of the following factors:
Maintenance times
Maintenance frequency
Maintenance cost
The above three factors are dependant on the fact that the system is operated and maintained in accordance with prescribed procedures and resources.
Maintainability
2


SlidePlayer
Maintainability
Measures of Maintainability
From a systems perspective
Corrective maintenance
Preventive maintenance
From a software perspective
Adaptive maintenance
Perfective maintenance


Packaging
Every product that we buy as a consumer or as a company is packaged
Package was initially intended to provide protection for the item during handling in a warehouse or when the items is being transported but it is also a marketing strategy to attract consumer into buying a product
For companies, the packaging on an item serve the purpose of preventing damage as it is moved in a manufacturing facility, a warehouse or to customer site.

Industrial Packaging

Industrial packaging that used to safely move the items from vendor to the customer of from manufacturing facility to the distribution centre and retailers. This is usually external packaging and is normally discarded before the items reach the consumer.

Secondary packaging like cartons, Corrugated boxes, wooden enclosure, etc, are typical examples of industrial packaging.

Impact of packaging

There are two main areas within a company that have the biggest influence on packaging. Consumers and Warehousing and logistics.

The marketing function wants packaging that is extremely attractive to the consumer so much so that they will purchase the item. In this case, packaging can be complex, fragile, and sometimes difficult to move

The logistics function has the job of moving items to the warehouse, within the warehouse, and to the distribution centre and then on the retail stores. The retail stores need to display the items in their original package and sometimes in their secondary packing for bulk buyers. The shape of packaging is important to the logistics department as they would prefer items that are regular in size and shape, so that they are easier to move and store

Impact of packaging

The logistics function will require external industrial package that will protect the product, and its internal packaging, from any damage while moving items in the warehouse or moving items to and from the warehouse.

The external packaging must be able to protect items from weather conditions, tampering, damage from material handling, handling and contamination.

The logistics function also need to make sure that the external packaging is able to allow stacked storage on pallets without damaging the items.

What is Product Liability?

Product liability is the branch of law in which manufacturers, distributors, suppliers, retailers, and others who make products available to the public are held responsible for the injuries those products cause. Although the word "product" has broad connotations, product liability as an area of law is traditionally limited to products in the form of tangible personal property.