**FACTORS TO CONSIDER IN PRODUCT DESIGN**

Here are some additional factors that need to be considered during the product design stage.

**Design for Manufacture**

When we think of product design we generally first think of how to please the customer.However, we also need to consider how easy or difficult it is to manufacture the product. Otherwise, we might have a great idea that is difficult or too costly tomanufacture. **Design for manufacture (DFM)** is a series of guidelines that we should follow to produce a product easily and profitably. DFM guide line include the following:

1. Minimize parts.

2. Design parts for different products.

3. Use modular design.

4. Avoid many tools.

5. Simplify operations.

DFM guidelines focus on two issues:

1. **Design simplification** means reducing the number of parts and features ofthe product whenever possible. A simpler product is easier to make, costsless, and gives us higher quality.

2. **Design standardization** refers to the use of common and interchangeable parts. By using interchangeable parts we can make a greater variety of products with less inventory and significantly lower cost and provide greater flexibility.

**Product Life Cycle**

Another factor in product design is the stage of the life cycle of the product. Mostproducts go through a series of stages of changing product demand called the**product life cycle**. Therefore, a product life cycle is a series of stages that products pass through in their lifetime, characterized by changing product demands There are typically four stages of the product life cycle: introduction, growth, maturity, and decline. Products in the introductory stage are not well defined and neither is their market.Often all the “bugs” have not been worked out and customers are uncertain aboutthe product. In the growth stage, the product takes hold and both product and marketcontinue to be refined. The third stage is that of maturity, where demand levels offand there are usually no design changes. The product is predictable at this stage andso is its market. Many products, such as toothpaste, can stay in this stage for manyyears. Finally, there is a decline in demand, because of new technology, better productdesign, or market saturation.

The first two stages of the life cycle can collectively be called the early stages ofthe product life cycle because the product is still being improved and refined, and themarket is still in the process of being developed*.* The last two stages of the life cyclecan be referred to as the later stages because here the product and market are bothwell defined.Understanding the stages of the product life cycle is important for product designpurposes, such as knowing at which stage to focus on design changes. Also, whenconsidering a new product, the expected length of the life cycle is critical in order toestimate future profitability relative to the initial investment. The product life cyclecan be quite short for certain products, as seen in the computer industry. For otherproducts it can be extremely long, as in the aircraft industry. A few products, such aspaper, pencils, nails, milk, sugar, and flour, do not go through a life cycle. However, almostall products do and some may spend a long time in one stage.

**Concurrent Engineering**

Concurrent engineering is an approach that brings together multifunction teams in the early phase of product design in order to simultaneously design the product and the process. This is an approach that brings many people together in the early phase of product design in order to simultaneously design the product and the process. This type of approach has been found to achieve a smooth transition from the design stage to actual production in a shorter amount of development time with improved quality results.

The old approach to product and process design was to first have the designersof the idea come up with the exact product characteristics. Once their design wascomplete they would pass it on to operations who would then design the productionprocess needed to produce the product. This was called the “over-the-wall” approach, because the designers would throw their design “over-the-wall” to operations whothen had to decide how to produce the product.

There are many problems with the old approach. First, it is very inefficient and costly. For example, there may be certain aspects of the product that are not criticalfor product success but are costly or difficult to manufacture, such as a dye color thatis difficult to achieve. Since manufacturing does not understand which features arenot critical, it may develop an unnecessarily costly production process with costspassed down to the customers. Because the designers do not know the cost of theadded feature, they may not have the opportunity to change their design or may do somuch later in the process, incurring additional costs. Concurrent engineering allowseveryone to work together so these problems do not occur.

A second problem is that the “over-the-wall” approach takes a longer amount oftime than when product and process design work together. When product and process design work together much of the work is done in parallelrather than in sequence. In today’s markets, new product introductions are expectedto occur faster than ever. Companies do not have the luxury of enough time tofollow a sequential approach and then work the “bugs” out. They may eventually get agreat product, but by then the market may not be there!

The third problem is that the old approach does not create a team atmosphere,which is important in today’s work environment. Rather, it creates an atmospherewhere each function views its role separately in a type of “us versus them” mentality.With the old approach, when the designers were finished with the designs, they consideredtheir job done. If there were problems, each group blamed the other. Withconcurrent engineering the team is responsible for designing and getting the productto market. Team members continue working together to resolve problems with theproduct and improve the process

**Remanufacturing**

The concept of using componentsof old products in the production of new ones is referred to as remanufacturing which is a concept that has been gaining increasing importance, as our societybecomes more environmentally conscious and focuses on efforts such as recyclingand eliminating waste. In addition to the environmental benefits, there are significantcost benefits because remanufactured products can be half the price of theirnew counterparts. Remanufacturing has been quite popular in the production ofcomputers, televisions, and automobiles.

**PROCESS SELECTION**

Though product design isvery important for a company, it cannot be done separately from the **selection of the**

**process.** When you look at different types of companies,

it may seem like there are hundreds of different types of processes. Some aresmall, like your local Starbuck’s, and some are very large, like a Ford Motor Companyplant. Some produce standardized “off-the-shelf” products, like Pepperidge Farm’sfrozen chocolate cake, and some work with customers to customize their product, like

a gourmet bakery that makes cakes to order. Though there seem to be large differences between the processes of companies, many companies have certain processingcharacteristics in common.

 All processes can be grouped into two broad categories: (i) Intermittent operations and

(II) Continuous operations.

These two categories differ in almost every way. Once we understand these differences, it is possible to identify organizations based on the categoryof process they use.

**Intermittent Operations**

**Intermittent operations** are used to produce many differentproducts with varying processing requirements in lower volumes. Examples are anauto body shop, a tool and dye shop, or a health-care facility. Because different productshave different processing needs, there is no standard route that all products takethrough the facility. Instead, resources are grouped by function and the product isrouted to each resource as needed. To be able to produce products with different processing requirements, intermittent operations tend to be labor intensive rather than capital intensive. Workers need to be able to perform different tasks depending on the processing needs of theproducts produced. Often we see skilled and semiskilled workers in this environment with a fair amount of worker discretion in performing their jobs. Workers need to be flexible and able to perform different tasks as needed for the different products thatare being produced. Equipment in this type of environment is more general purpose to satisfy different processing requirements. Automation tends to be less common, becauseautomation is typically product specific. Given that many products are beingproduced with different processing requirements, it is usually not cost efficient to investin automation for only one product type. Finally, the volume of goods producedis directly tied to the number of customer orders.

**Continuous Operations**

**Continuous operations** are used to produce one or a few

Standardized products in high volume. Examples are a typical assembly line, cafeteria,or automatic car wash. Resources are organized in a line flow to efficiently accommodateproduction of the product. Note that in this environment it is possible to arrangeresources in a line because there is only one type of product. This is directly the oppositeof what we find with intermittent operations.

To efficiently produce a large volume of one type of product these operationstend to be capital intensive rather than labor intensive. An example is “mass production”operations, which usually have much invested in their facilities and equipmentto provide a high degree of product consistency. Often these facilities rely on automationand technology to improve efficiency and increase output rather than on laborskill. The volume produced is usually based on a forecast of future demands ratherthan on direct customer orders.

**Differences between Intermittent and Continuous Operations**

The most common differences between intermittent and continuous operations relate to two dimensions:

 (1) The amount of product volume produced, and

 (2) Thedegree of product standardization.

Product volume can range from making a single unique product one at a time to producing a large number of products at the same time.

Product standardization refers to a lack of variety in a particular product. Examplesof standardized products are Fruit-of-the-Loom white undershirts, calculators, toasters, and television sets. The type of operation used, including equipmentand labor, is quite different if a company produces one product at a time to customerspecifications instead of mass production of one standardized product.

**The Continuum of Process Types**

Dividing processes into two fundamental categoriesof operations is helpful in our understanding of their general characteristics. Tobe more detailed, we can further divide each category according to product volumeand degree of product standardization as follows. Intermittent operations can be divided into:

1. *project processes* and
2. *batch processes.*

Continuous operations can be dividedinto

1. *line processes* and
2. *continuous processes.*

**Project processes** are used to make one-at-a-time products exactly to customerspecifications. These processes are used when there is high customizationand low product volume, because each product is different. Examplescan be seen in construction, shipbuilding, medical procedures, creation ofartwork, custom tailoring, and interior design. With project processes thecustomer is usually involved in deciding on the design of the product. Theartistic baker you hired to bake a wedding cake to your specifications uses aproject process.

\_ **Batch processes** are used to produce small quantities of products in groupsor batches based on customer orders or product specifications. The volumesof each product produced are still small and there can still be a high degreeof customization. Examples can be seen in bakeries, education, and printingshops. The classes you are taking at the university use a batch process.

**Line processes** are designed to produce a large volume of a standardizedproduct for mass production. With line processes the product that is producedis made in high volume with little or no customization. Think of atypical assembly line that produces everything from cars, computers, televisionsets, shoes, candy bars, even food items.

**Continuous processes** operate continually to produce a very high volume ofa fully standardized product. Examples include oil refineries, water treatmentplants, and certain paint facilities. The products produced by continuousprocesses are usually in continual rather than discrete units, such as liquid orgas. Also, these facilities are usually highly capital intensive and automated.

Note that both project and batch processes have low product volumes and offercustomization. The difference is in the volume and degree of customization. Projectprocesses are more extreme cases of intermittent operations compared to batchprocesses. Also, note that both line and continuous processes primarily produce large volumes of standardized products. Again, the difference is in the volume and degreeof standardization. Continuous processes are more extreme cases of high volume andproduct standardization than are line processes.

**Process Decisions**

**Vertical Integration** A major strategic decision involving process selection relates tothe amount of vertical integration of the company.

**Vertical integration** refers to thesegments in the chain from acquisition of raw materials to final delivery of finishedproducts that the company owns. Some companies are highly vertically integrated,and own their own raw material facilities, manufacturing plants, and fleets of trucksfor delivery to customers. An example is Dole Pineapple, which owns and controlsmost of the canned pineapple production from pineapple farms to the processingplant. Other companies choose the opposite strategy, and use outside suppliers of materials

and subassemblies and distributors of their products.

There are two types of vertical integration strategies. One is called **backward integration,** where a company owns or acquires sources of supply, raw materials, or subassemblies. **Forward integration,** on the other hand, is integration in the oppositedirection, where a company owns facilities closer to the customer, such as distributionchannels, warehouses, and retail locations. Both of these strategies have their advantagesand disadvantages. Both have the advantage of control over the quality, consistency,and delivery of raw materials and finished products. A disadvantage, however,can be cost. Often it can be much cheaper to use outside suppliers and third parties toperform certain tasks, like distribution and delivery, because these outside companiesalready have the resources, equipment, and “know-how” needed to perform these tasks.

**Make-or-Buy Decisions** An important decision that relates to vertical integration isthe **make-or-buy decision.** Make or buy is a type of backward integration decision,where the company decides whether to purchase certain materials or tasks or perform the operations itself. Often this is called *outsourcing*. Many companies routinely outsourcecertain services, such as janitorial services, repair, security, payroll, or records management. Outsourcing has been a big trend for companies over the past few years. The keyfor a company is to outsource activities that are not considered critical to its business strategy. Having someone else perform noncritical tasks allows a company to givemore focus to its strategic decisions. For example, the trend in the auto industry hasbeen to outsource many of the functions historically performed inside, such as quality control of incoming materials or package design. Outsourcing allows the automakers to focus more on product and process design, which are much more critical to theirsuccess. The importance of outsourcing is evidenced by the growth of companies thatperform many noncritical tasks for other firms. For example, Grainger IndustrialSupply is a company that performs purchasing and inventory control of noncritical

items for companies such as American Airlines and Procter & Gamble, which frees upthese companies to focus on what they do best.Many factors must be considered in the make-or-buy decision. They include the

following:

1. **Strategic impact.** Probably the most important factor in the make-or-buydecision is the strategic impact of outsourcing certain tasks. Once tasks areoutsourced, a company usually has much less control over them. Customersmay not be as satisfied with the product. Also, outsourcing certain tasks nowmakes it more difficult to bring them back at a later date due to cost and lossof expertise. Companies need to identify functions that are critical and noncriticalto their success, as identified through the company’s business strategy. Critical functions that have strategic impact should not be outsourced.Noncritical functions, on the other hand, should be outsourced wheneverpossible in order to free up the company to focus on its main tasks.

2. **Available capacity.** A factor in favor of making products in-house is availablecapacity. Capacity refers to the output capability of a facility, such as thenumber of products it can produce over a period of time. If a company hasavailable capacity, as well as skills and equipment required, it is often a goodbusiness decision to produce the items in-house.

3. **Expertise.** When considering outsourcing, a company should evaluatewhether it has the expertise necessary to perform a job or the costs necessaryto acquire the expertise. In many cases it is more efficient to hire somebodyelse who is proficient in performing certain tasks. For example, many companieswill hire outside advertising firms for large promotions and advertising campaigns.

4. **Quality considerations.** quality is an importantcompetitive priority and needs to be given consideration when making themake-or-buy decision. By making products in-house the firm has more controlover quality. However, if special expertise is required the company maynot be able to achieve the level of quality available from an outside expert. Inthat case it may be better to outsource.

5. **Speed.** Specialized suppliers can often provide parts more quickly than themanufacturer can produce. This is especially important for products thathave fluctuating or unpredictable demands. Suppliers can also be more flexiblein accommodating rapid design changes.

6. **Cost.** The last factor to consider is the cost of manufacturing the item inhouseversus buying it from the outside. However, cost should not be themost important factor and needs to be balanced with the other factors discussed.

A more expensive alternative that is strategically sound can prove tobe a far better alternative in the long run.

**Designing Processes**

**Process Flow Analysis**

**Process flow analysis** is a tool for evaluating an operation interms of the sequence of steps from inputs to outputs with the goal of improving its design.One of the most important tools in process flow analysis is a process flowchart.

A **process flowchart** is used for viewing the flow of the processes involved in producing theproduct. It is a very useful tool for seeing the totality of the operation and for identifyingpotential problem areas. There is no exact format for designing the chart. The flowchartcan be very simple or very detailed.

The points in the process for potential problems are indicated. Management can thentake care to monitor these problem areas. The chart could be even more detailed, including information such as frequency of errors or approximate time to complete a task.Another way of using a process flowchart is to overlay it on a facility layout tovisually represent movement through the physical plant or store.

**Process Reengineering**

**Reengineering** means redesigning the company’s processes. Reengineering is a drastic measure of analyzing the company’s processes and redevelopingthem from scratch. The process requires teamwork from many areas of the companyand good communication. Hard questions need to be asked and old ways of doing things questioned. Reengineering is usually applied to the core processes of a company,such as filling customer orders. Reengineering can produce dramatic improvements inquality, cost, and customer service.

However, it does not alwayswork. Reengineering is a radical measure that focuses on drastic changes rather than incremental changes. It usually means layoffs or shifts in job duties and a very differentway of doing things for the company’s employees. Reengineering is usually appliedas a last resort for companies that are either in trouble or foresee trouble in the future.

When other measures for a company have failed, reengineering may be the last resort.

**MANUFACTURING TECHNOLOGY DECISIONS**

Advancements in technology have had the greatest impact on process design decisions.Technological advances have enabled companies to produce products faster, with better quality, at a cheaper rate. Many processes that were not imaginable only afew years ago have been made possible through the use of technology. In this sectionwe look at some of the greatest impacts technology has had on process design.

**Automation**

An important decision in designing processes is deciding whether the firm should automate,to what degree, and the type of automation that should be used.

**Automation** is machinery that is able to perform work without human operators. Automation can be a single machine or an entire factory. Although there are tremendous advantages toautomation, there are also disadvantages. Companies need to consider these carefullybefore making the final decision.

Automation has the advantage of product consistency and ability to efficiently produce large volumes of product. With automated equipment the last part made in the day will be exactly like the first one made. Because automation brings consistency,quality tends to be higher and easier to monitor. With automation, production can flow uninterrupted throughout the day, without breaks for lunch, and there is no fatigue factor. However, automation does have its disadvantages. First, automation is typically very costly. These costs can be justified only through a high volume of production. Second, automation is typically not flexible in accommodating product and process changes. Therefore,

Automation would probably not be good for products in the early stages of their lifecycle or for products with short life cycles. Automation needs to be viewed as another capital investment decision and financial payback is critical. For all these reasons automationis typically less present in intermittent than in continuous operations.

DIFFERENT TYPES OF AUTOMATION.

**Automated Material Handling**

Material handling devices are used to move and store products. Historically the primary method of moving products used conveyors in the form of belts or chains. Today’smaterial handling devices can read bar codes that tell them which location to goto and are capable of moving in many directions. One such device is an **automatedguided vehicle (AGV)**. This is a small battery-driven truck that moves materials from one location to the other. The AGV is not operated by a human and takes its directions from either an on-board or central computer. Even AGVs have become more sophisticated

over time. The older models followed a cable that was installed under thefloor. The newer models follow optical paths and can go anywhere there is aisle space.

One of the biggest advantages of AGVs is that they can pretty much go anywhere,as compared to traditional conveyor belts. Managers can use them to move materials wherever they are needed; avoiding huge piles of inventory in one area. Another type of automated material handling are **automated storage and retrieval**

**system (AS/RSs)**, which are basically automated warehouses. AS/RSs useAGVs to move material and computer-controlled racks and storage bins. The storage

bins can typically rotate like a carousel, so that the desired storage bin is available foreither storage or retrieval. All this is controlled by a computer that keeps track of theexact location and quantity of each item. The computer controls how much will bestored or retrieved in a particular area. AS/RSs can have great advantages over traditionalwarehouses. Though they are much more costly to operate, they are also muchmore efficient and accurate.

**Computer-Aided Design (CAD)**

**Computer-aided design (CAD)** is a system that uses computer graphics to design new products. Gone are the days of drafting designs by hand. Today’s powerful desk-top computers combined with graphics software allow the designer to create drawingson the computer screen and then manipulate them geometrically to be viewed fromany angle.With CAD the designer can rotate the object, split it to view the inside, andmagnify certain sections for closer view.CAD can also perform other functions. Engineering design calculations can be performed to test the reactions of the design to stress and evaluate strength of materials.

This is called **computer-aided engineering (CAE)**. For example, the designer cantest how different dimensions, tolerances, and materials respond to different conditions

such as rough handling or high temperatures. The designer can use the computerto compare alternative designs and determine the best design for a given set of

conditions. The designer can also perform cost analysis on the design, evaluating theadvantages of different types of materials. Another advantage of CAD is that it can be linked to manufacturing. Through CAD the link of product design to process selection is made easy. **Computer-aided manufacturing (CAM)** is theprocess of controlling manufacturing through computers. Since the product designsare stored in the computer database, the equipment and tools needed can easily besimulated to match up with the processing needs. Efficiencies of various machinechoices and different process alternatives can be computed.As you can imagine, there are numerous advantages to CAD. It has dramatically

increased the speed and flexibility of the design process. Designs can be made on thecomputer screen and printed out when desired. Electronic versions can be shared bymany members of the organization for their input. Also, electronic version can bearchived and compared to future versions. The designer can catalogue features basedon their characteristics—a very valuable feature. As future product design are beingconsidered, the designer can quickly retrieve certain features from past designs andtest them for inclusion in the design being currently developed. Overall, it is estimatedthat CAD can speed up the design process by up to 50%.

**Flexible Manufacturing Systems (FMS)**

A **flexible manufacturing system (FMS)** is a type of automation system that provides the flexibility of intermittent operations with the efficiency of continuous operations.

As you can see by the definition, this is a *system* of automated parts not only one machine. An FMS consists of groups of computer-controlled machines and/or robots, automated handling devices for moving, loading, and unloading, and a computer control center. Based on the instructions from the computer control center, parts and materials are automatically moved to appropriate machines or robots. The machinesperform their tasks and the parts are then moved to the next set of machines with the parts automatically loaded and unloaded. The routes taken by each product aredetermined with the goal of maximizing efficiency of the operation. Also, the FMS“knows” when one machine is down due to maintenance or if there is a backlog ofwork on a machine, and it will automatically route the materials to an available machine. Flexible manufacturing systems are still fairly limited in the variety of productsthat they handle. Usually they can only produce similar products from the same family.

Flexible manufacturing systems are not very widespread. One of the primary reasonsis their high cost. A decision to use an FMS needs to be long term and strategic,requiring a sizable financial outlay.

**Robotics**

When most of us think of robots we think of something like the robot from the oldtelevision show “Lost In Space,” which resembles humans. However, in manufacturinga robot is usually nothing more than a mechanical arm with a power supply and acomputer control mechanism that controls the movements of the arm. The arm canbe used for many tasks, such as painting, welding, assembly, loading, and unloading of

machines. Robots are excellent for physically dangerous jobs such as working with radioactiveor toxic materials. Also, robots can work 24 hours a day to produce a highly

consistent product.Robots range in their degree of sophistication. Some robots are fairly simpleand follow a repetitive set of instructions. Other robots follow complex instructions,and some can be programmed to recognize objects and even make simple decisions.

One type of automation that is similar to simple robotics is the **numerically controlled**

**(NC) machine**: NC machines are controlled by a computer and can do a varietyof tasks such as drilling, boring, or turning parts of different sizes and shapes. Factories

of the future will most likely be composed of a number of robots and NC machines working together. The use of robots has not been very widespread in U.S. firms. However, this isan area that can provide a competitive advantage for a company. Cost justificationshould not only consider reduction in labor costs but also the increased flexibility ofoperation and improvement in quality. The cost of robots can vary greatly and depends

on the robots’ size and capabilities. Generally, it is best for a company to considerpurchasing multiple robots or forms of automation to spread the costs of mainmaintenanceand software support. Also, the decision to purchase automation such asrobotics needs to be a long-term strategic decision that considers the totality of theproduction process. Otherwise, the company may have one robot working 24 hours aday and piling up inventory while it waits for the other processes to catch up.Robots can be used to improveoperations of almost any business even literal “operations.”Recently robots have begun tobe used in performing certainmedical surgeries.

**Computer-Integrated Manufacturing**

**Computer-integrated manufacturing (CIM)** is a term used to describe the integrationof product design, process planning, and manufacturing using an integrated

computer system. Computer-integrated manufacturing systems vary greatly in theircomplexity. Simple systems might integrate computer-aided design (CAD) with some

numerically controlled machines (NC machines). A complex system, on the otherhand, might integrate purchasing, scheduling, inventory control, and distribution, inaddition to the other areas of product design.The key element of CIM is the integration of different parts of the operationprocess to achieve greater responsiveness and flexibility. The purpose of CIM is to improvehow quickly the company can respond to customer needs of product designand availability, as well as quality, productivity, and improve overall efficiency.