

**CHAPTER 4 (Product and Service Design)**

**Product Design Process – The Elements**

- 1) **Product Approval Committee**
  - Top management oversees and directs the development activities
- 2) **Core Teams**
  - Cross functional teams designed to plan and lead the projects
- 3) **Phase Reviews**
  - Approve, modify or cancel the project at certain milestones
- 4) **Structured Development Process**
  - Use project management techniques to schedule, execute and control

**Product Design Process – The Phases**

- 1) **Idea Generation**
  - ... And "primary assessment" (scoping)
- 2) **Build a Business Case**
  - Market and competitor analysis
- 3) **Development**
  - Translate the "voice of the customer"
- 4) **Testing and Validation**
- 5) **Launch**

**Stage-Gate Model**

- Gate 1: Idea Screen**
  - Does the idea merit any work?
- Gate 2: Second Screen**
  - Does the idea justify the investigation?
- Gate 3: Decision to Develop**
  - Is the business case sound?
- Gate 4: Decision to Test**
  - Should to project go to external testing?
- Gate 5: Decision to Launch**
  - Is it ready for commercial launch?

**Sources of Ideas for Projects**

- Employees (Marketing, R&D)
- Customers (Surveys, Focus Groups)
- Competition (Reverse Engineering)
- Suppliers

**Searching for New Product Ideas**

- 1) Listening to Market Complaints
- 2) Gaps in the Market
- 3) Exploring Market Niches
- 4) Using New Technology
- 5) Creating New Market Spaces

**Issues in Product Design**

- 1) Life Cycles
- 2) Standardization
- 3) Mass Customization
- 4) Reliability
- 5) Robust Design
- 6) Legal and Ethical Issues
- 7) Design for Environment
- 8) Concurrent Engineering
- 9) Computer-Aided Design (CAD)
- 10) Design for Manufacturing & Assembly
- 11) Component Commonality

**1) Life Cycles**

- 1<sup>st</sup> – **Incubation** (item intro., low demand)
- 2<sup>nd</sup> – **Growth** (design improvements)
- 3<sup>rd</sup> – **Maturity** (demand levels off)
- 4<sup>th</sup> – **Saturation** (decline in demand)
- 5<sup>th</sup> – **Decline**

**2) Standardization**

- "Extent to which there is an absence of variety in a product, service or process"
- Advantages** – Economies of scale, reduced training costs and time
- Disadvantages** – Limits range of consumer appeal

**3) Design for Mass Customization**

- "A strategy of producing standardized goods or services, but incorporating some degree of customization"
- Two options** for Mass Customization:
  - 1) **Delayed Differentiation** – "Producing, but not completing, a product until customer preferences are known"
    - Example: Restaurants producing salads
  - 2) **Modular Design** – "Parts are subdivided into modules which are easily replaced or interchanged"

**4) Reliability**

- "The ability of a product, part or system to perform its intended function under a prescribed set of conditions"
- Ways to Improve Reliability**
  - System Design - Component Design
  - Product / Assembly Techniques
  - Testing - User Education
  - Redundancy / Backup
  - Preventive Maintenance Procedures

**5) Robust Design**

- "Design that can function over a broad range of conditions"
- Controllable factors** are materials, dimensions and form of processing
- Uncontrollable factors** are user's control (length of use, maintenance, settings, etc)
- Taguchi Approach**
  - "Easier to create robust design than to control environmental factors"
  - Central feature** is **Parameter Design**
    - Determines factors that are controllable and not controllable
    - Determines optimal levels of factors relative to major product advances

**6) Legal and Ethical Issues**

- Legal issues** such as:
  - Changes in FDA, EPA HPA
  - Patent violations
  - Product liability related to injuries
- Ethical issues** such as:
  - Releasing products with defects
  - Environmental issues

**7) Design for Environment**

- "Incorporating the 3 R's (reduce, reuse, recycle) into product design"
- Remanufacturing** – "Refurbishing used products by replacing worn-out or defective components"
- Design for Disassembly** – "Design so that used products can be easily taken apart"
- Recycling** – "Recovering materials for future use"

**8) Concurrent Engineering**

- "Bringing engineering design, manufacturing, marketing and purchasing staff together early in the design phase"

**9) Computer-Aided Design (CAD)**

- "Product design using computer graphics"
- Increases prod. of designers by 3-10 times

**10) Design for Manufacturing and Assembly**

- Design for Manufacturing** – "Considering organization's manufacturing capabilities when designing a product"
- Design for Assembly** – "Focuses on reducing the number of parts in a product and on assembly methods and sequence"

**11) Component Commonality**

- "Multiple products that have a high degree of similarity can share components"

**Key Differences between Goods and Services**

- 1) Services are **intangible**
- 2) Services are **created and delivered** at the same time
- 3) Services are **customized** vary in length
- 4) Services have **low barriers** to entry
- 5) **Location** important to service design

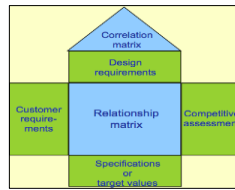
**Design Guidelines**

- 1) Have a **single** unifying theme
- 2) Make sure the system has **capability** to handle variability in service requirements
- 3) Include design features and checks for reliable and consistent **quality**
- 4) Design the system to be **user-friendly**

**Quality Function Deployment**

- "An approach that integrates the 'voice of the customer' into product design"
- AKA – House of Quality** (Weights customer requirements on the basis of importance)

**House of Quality**



**CHAPTER 4S (Product Reliability)**

**Product Reliability**

- "The ability of a product, part or system to perform its intended function under a prescribed set of conditions"

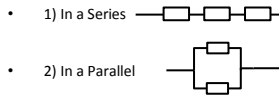
**Failure**

- "Situation in which a product, part or system does not perform as intended"

**Normal Operating Conditions**

- "The set of conditions under which an item's reliability is specified"
- R = Probability of success

**Two Types of Reliability**



**1) Reliability in a Series**

- $R = R_1 \times R_2 \times R_3$
- \* System fails if **any** component fails \*

**2) Reliability in a Parallel**

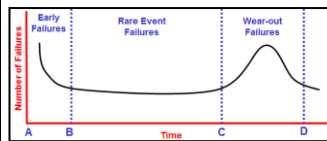
- $R = R_1 + (1 - R_1)(R_2)$  (one failing)
- OR**
- $R = 1 - (1 - R_1)(1 - R_2)$  (both failing)
- \* System fails if **all** components fails \*

**Reliability along the Time Dimension**

- "Probability that the system/component will function for a given length of time"
- Early Failures** – **Negative exponential** dist.
- Rare Event Failures** – **Poisson** distribution
- Wear-Out Failures** – **Normal** distribution

**Failure Rate / Hour**

- $F/Hr = \frac{\# \text{ of Failures}}{\text{Total Operations Hours (A + B)}}$
- Where...**
- A** = (Total Products – # of Failures) x (Total Operations Hours)
- B** = (Failure pt. 1) x (Failure pt. 2)



**Probability of Failure**

- Exponential Distribution** (avg. = MTTF)
- T = length of service **before** failure
- $P(\text{Failure before 't'}) = 1 - (e^{-\frac{t}{MTTF}})$
- $P(\text{No failure before 't'}) = e^{-\frac{t}{MTTF}}$

**Probability of Failure due to Wear-Out**

- Normal Distribution**
- $Z = \frac{(T) - (\text{Mean Wear-Out Time})}{(\text{Standard Deviation of Wear-Out Time})}$
- $Z = \frac{(T) - (\mu)}{(\sigma)}$
- Z = failure **before** "x" years
- 1 - Z = failure **after** "x" years
- Potential question...**
- If asked to provide a failure prob. of 10%
- Z value of 90% and solve for "T"

**Availability**

- "The fraction of time that a system / component is expected to be operational"
- MTBF** = Mean Time between Failure
- MTRR** = Mean Time to Repair
- $\text{Availability} = \frac{MTBF}{MTBF + MTRR}$

**CHAPTER 5 (Strategic Capacity Planning)**

**Capacity**

- "The upper limit on the load that an operating unit can handle"

**Importance of Long-Term Capacity**

- Impacts ability to meet future demands
- Affects operating costs
- Major determinant of initial costs
- Affects competitiveness

**Measuring Capacity**

- Design Capacity** – "Maximum obtainable output under ideal conditions"
- Effective Capacity** – "Maximum capacity given delays, product mix, scheduling difficulties and other realities"
- Actual Output (AO)** – "Rate of output actually that is actually achieved"
  - AO is **always** ≤ Effective Capacity

**Efficiency and Utilization**

- Efficiency** =  $\frac{\text{Actual Output}}{\text{Effective Capacity}}$
- Utilization** =  $\frac{\text{Actual Output}}{\text{Design Capacity}}$

**Factors Influencing Capacity**

- 1) **Facilities**
  - Floor space, layout
- 2) **Products or Services**
  - A limited menu in a restaurant
- 3) **Human**
  - Training, skills and experience
- 4) **Planning and Operational**
  - Quality control, inventory, shifts per day
- 5) **External**
  - Pollution standards, paper work

**Capacity Planning Process**

- 1) Forecast demand 1-5 years ahead
- 2) Determine capacity requirements
- 3) Measure current capacity and decide how to bridge the gap
- \* 3A) Generate feasible alternatives
- \* 3B) Evaluate alternatives considering **economic** and **non-economic** aspect
- \* 3C) Choose the best alternative and implement it

**\*3B) Considerations**

- Economic Considerations**
  - Cost, useful life, compatibility, revenue
- Non-Economic Considerations**
  - Public opinion, employee reactions

**\*3B) Evaluation Techniques:**

- 1) Break-Even Analysis
- 2) Payback Period
- 3) Net Present Value

**1) Break-Even Analysis (Legend)**

- v = Variable Cost per Unit
- r = Revenue per Unit
- Q = Volume of Output
- Q<sub>BE</sub> = Break Even Volume

**1) Break-Even Analysis**

- TC = FC + VC
- VC = Q \* v
- TR = Q \* r
- P = TR - TC
- P = (Q \* r) - (FC + Q \* v)
- Q<sub>BE</sub> = FC / (r - v)

**Make or Buy Question**

- The quantity that one would be **indifferent** between making or buying...
- $Q = \frac{FC}{(VC \text{ of Buying} - VC \text{ of Making})}$  **OR**
- FC + VC (Making) = FC + VC (Buying)
- "Making" is preferred when x >

**2) Payback Period**

**3) Net Present Value**

**Further Financial Analysis**

- Cash Flow** = Cash Inflow – Cash Outflow
- Present Value** = Sum of the current values of all future cash flows

**Optimal Operating Level**

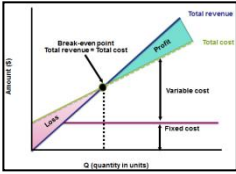
- Is a function of **size of production unit**
- (Different for **small, medium, large** plant)

**Economies of Scale**

- **Economies of Scale – Advantages** related to larger-scale production
- \* **Examples include:**
  - Fixed costs spread over more units
  - Volume purchase discounts

**Diseconomies of Scale**

- **Diseconomies of Scale – Disadvantages** related to larger-scale production
- \* **Examples include:**
  - Worker fatigue, equipment breakdown



**CHAPTER 6 (Process Design & Facility Layout)**

**Process Design**

- “Determining the form and function of how goods or services are produced”

**Process Types**

- From **high** to **low** equipment flexibility
- **1) Job Shop**
  - Small scale (appliance repair, ER)
- **2) Batch**
  - Moderate volume (bakery, theatre)
- **3) Repetitive (Assembly Line)**
  - High volume (automobiles, carwash)
- **4) Continuous**
  - Very high volume (steel production)

**Process Flowcharting**

- “The use of a diagram to present the major elements of a process”

**Process Flowcharting Symbols**

- **Tasks or Operations**
  - Installing engine in car
- **Decision Points**
  - Which wrench to use
- **Storage Areas or Queues**
  - People waiting in line
- **Flows of Materials or Cust.**
  - Mechanic selecting a tool

**Strategic Importance of Layout Decisions**

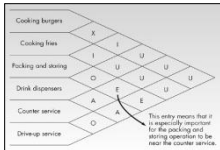
- Higher utilization of space, equip., people
- Improved flow of information
- Improved employee morale
- Improved customer interaction
- Flexibility

**Activity Relationship Chart**

- “Certain activities should be in proximity to each other to maximize the process”

**Glossary:**

- A – Absolutely Necessary
- E – Especially Important
- I – Important
- O – Ordinary OK
- U – Unimportant
- X – Undesirable



**From-To Chart**

- “Chart displaying the relationship (often geographic) between two locations”

From \ To	Sows	Millng	Drills	Loftes	Sanders
Sows	18	40	30	65	24
Millng	18	38	75	16	30
Punch press	40	38	32	38	12
Drills	30	75	22	50	40
Loftes	65	16	38	50	65
Sanders	24	30	12	40	60

**Types of Layout**

- 1) **Fixed Position Layout**
- 2) **Product Layout**
- 3) **Process Layout**
- 4) **Group Technology Layout**
- 5) **Warehouse Layout**

**1) Fixed Position Layout**

- “Addresses the layout requirements of large, bulky projects”
- **Example** – Ships, buildings
- **AKA** – Job Shop
- **AKA** – Functional Layout

**2) Product Layout**

- “Machines are organized to conform to sequences of operations required to produce the product”
- **Example** – Assembly lines
- **AKA** – Flow-Shop Layout
  - Used for repetitive or continuous proces.
  - Adv. (easy to use, low cost per unit)
  - Dis. (high equipment costs, dull work)

**3) Process Layout**

- “Deals with low-to-medium volume productions with a high-variety”
- **Example** – Machine shop, forklifts
- **AKA** – Job Shop
- **AKA** – Functional Layout
  - Adv., (lower maintenance costs)
  - Dis., (high setup costs, difficult schedule)

**4) Group Technology Layout**

- “A special arrangement of machinery and equipment to focus on production of a single product or related products”
- **AKA** – Cellular Layout

**5) Warehouse Layout**

- “Must consider frequency of orders, size of orders and correlation between items”
- **Example** – Grocer warehouse

**Assembly-Line Balancing**

- “Designing assembly lines to minimize the imbalances between machines or personnel while meeting required output”
- \* Must assign **all tasks** to a series of workstations to ensure that:
  - 1) **Duration of work** at each workstation is **always ≤ the cycle time**
  - 2) Unassigned time across all workstations is **minimized**

**Cycle Time**

- **Workstation Cycle Time** – “Time between successive units coming off the end of the assembly line”
- The **cycle time** is always determined by the workstation taking the **longest time**

**Cycle Time Calculations**

- **Workstation Cycle Time (C)**  
 $C = \frac{\text{Production time per day (OT)}}{\text{Required output per day (D)}}$
- **Theoretical Min. # of Workstations (N<sub>min</sub>)**  
 $N_{min} = \frac{\text{Sum of task times (T)}}{\text{Cycle time (C)}}$
- **Efficiency** =  $\frac{\text{Sum of task times(T)}}{\text{Actual # of workstations (Na * C)}}$
- **Output Capacity**
- **Output Cap.** =  $\frac{\text{Production time per day (OT)}}{\text{Cycle time (C)}}$

**Assembly-Line Balancing (Types of Questions)**

- The Precedence Diagram
- The Bottleneck
- Determine Cycle Time
- Determine Theoretical Min. # of Work.

**Steps for Loading Workstations**

- 1) Make assignments to workstations in **order** (beginning with station 1)
- 2) Keep assigning to a workstation and ensure that **precedence** is maintained
- 3) Ensure total work assigned to the workstation is **always ≤ the cycle time**
- 4) Use either **(A) Largest Number of Successors Rule** or **(B) Largest Time Rule**
- 5) After each assignment, **update the time left** at the workstation
- 6) Continue until **all tasks** have been assigned to workstations
- 7) Calculate **total idle time**

**4) Use of the Two Rules**

- **A) Largest Number of Successors Rule**  
 “Assign tasks in order of the largest number of following tasks”
- **B) Longest Time Rule**  
 “Assign task in order of longest task time”
- Ties are broken by using the **other rule**

**7) Calculate Total Idle Time**

- **% Idle Time** =  $\frac{\text{Sum of idle times per unit}}{\text{Actual x Cycle time}}$
- **Efficiency** = 100% – (% Idle Time)

**CHAPTER 7 (Work Measurement)**

**Job Design**

- “Specifying content and method of a job”
- 1) Efficiency Approach
- 2) Behavioural Approach

**1) Efficiency Approach**

- Focuses on worker specialization
- **Specialization** – “Focus on narrowing the scope of a specific job”

**2) Behavioural Approach**

- “Attempt job enrichment, rotation, etc.”

**Methods Analysis**

- “Breaks down the job into a sequence of tasks and elements and improves it”
- **Uses** process and worker-machine charts
- **Motion Study** – “Systematic study of human motions used to perform a task”

**Working Conditions**

- Temp., illumination, ergonomics, safety

**Work Measurement**

- “Determining how long it should take to complete a job”

**Three Methods to Measure Work**

- 1) Stopwatch
- 2) Predetermined Element Times
- 3) Work Sampling

**A) Stopwatch Time Study**

**Stopwatch Time Study**

- “Development of a time standard based on observations of one worker taken over a number of cycles”
- **Two key parts are:**
  - 1) Determine the # of cycles to observe
  - 2) Compute the standard time

**1) Determine # of Cycles to Observe (legend)**

- z = # of normal st. dev. for desired conf.
- Do (% / 200) to find value for normal
- s = Sample standard deviation
- a = Desired accuracy proportion
- $\bar{x}$  = Sample mean
- e = Accuracy amount (max. accept. error)

**1) Determine # of Cycles to Observe**

•  $n = \left(\frac{zs}{\alpha e}\right)^2$  or  $n = \left(\frac{zs}{e}\right)^2$

**2) Compute the Standard Time (steps)**

- **1<sup>st</sup>** – Calculate the **Observed Time (OT)**
- **2<sup>nd</sup>** – Calculating the **Normal Time (NT)**
- **3<sup>rd</sup>** – Calculate the **Standard Time (ST)**

**2) Compute the Standard Time**

- **1<sup>st</sup>:** **OT = average of all observed times**
- **2<sup>nd</sup>:** **NT = OT \* PR**
  - PR = performance rating
  - PR < 1 (worker is **slower** than the norm)
  - PR > 1 (worker is **faster** than the norm)
- **3<sup>rd</sup>:** **ST = NT \* AF**
  - AF = 1 + Allowance % (job time)
  - AF = (1 / 1 - Allowance %) (time in day)
- “**Job Time**” used when different tasks have **different** allowances
- “**Time in Work Day**” used when different tasks have **similar** allowances

**Assembly-Line Balancing (Types of Questions)**

- The Precedence Diagram
- The Bottleneck
- Determine Cycle Time
- Determine Theoretical Min. # of Work.

**B) Predetermined Element Times**

**Predetermined Element Times**

- “Published data based on extensive research on element times”
- **Not testable**

**Two Types of Charts**

- 1) Methods Time Measurement (MTM)
- 2) Time Measurement Unit (TMU)

**C) Work Sampling**

**Work Sampling**

- “A technique for estimating the proportion of time that a worker or machine spends on each activity or is idle”

**Work Sampling (legend)**

- z = # of normal st. dev. for desired conf.
- a = maximum acceptable error proportion
- $\hat{p}$  = Sample proportion
- $\hat{p} = \frac{\# \text{ of occurrences}}{\text{sample size}}$
- $\hat{p}$  is assumed to 0.5 if not given

**Work Sampling**

•  $a = \sqrt{\frac{\hat{p}(1-\hat{p})}{n}}$  or  $n = \left(\frac{z}{a}\right)^2 \hat{p}(1-\hat{p})$

**CHAPTER 8 (Location Planning & Analysis)**

**Formal Location Decision Process**

- 1) Identify the important factors
- 2) Gather information on important sites
- 3) Make a short list
- 4) Site visits and meetings
- 5) Evaluate and make selection

**Factors in Location (Country)**

- 1) Political risks, government rules
- 2) Cultural and economic issues
- 3) Location of markets
- 4) Labor availability, productivity
- 5) Availability of supplies, comm., energy
- 6) Exchange rates, currency risks

**Factors in Location (Region)**

- 1) Attractiveness of regions
- 2) Labor availability, costs
- 3) Costs and availability of utilities
- 4) Environmental regulations
- 5) Government incentives
- 6) Proximity to raw materials
- 7) Land and construction costs

**Factors in Location (Site)**

- 1) Site size and cost
- 2) Air, rail, road and water systems
- 3) Zoning restrictions
- 4) Nearness of services needed
- 5) Environmental impact issues

**Evaluating Location Alternatives**

- 1) Location Break-Even Analysis
- 2) Transportation Method
- 3) Factor Rating
- 4) Centre of Gravity Method
- 5) Voronoi Polygons Method

**1) Location Break-Even Analysis**

- Identify **dominated** locations
- Determine **lowest** total costs

**2) Transportation Method**

- **Not testable**

**3) Factor-Rating Method**

- Choose location with **highest** wtd. score

**4) Centre-of-Gravity Method**

- “Determine the location that will **minimize** total distribution cost”
- $\bar{x} = \frac{\sum x_i Q_i}{\sum Q_i}$
- $\bar{y} = \frac{\sum y_i Q_i}{\sum Q_i}$

**5) Voronoi Polygons Method**

- **Not testable**