Chapter 4

Product Design

Russell and Taylor
Operations and Supply Chain Management, 8th Edition
Lecture Outline

- **Design Process** – Slide 4
- **Rapid Prototyping and Concurrent Design** – Slide 11
- **Technology in Design** – Slide 27
- **Design Quality Reviews** – Slide 29
- **Design for Environment** – Slide 33
- **Quality Function Deployment** – Slide 36
- **Design for Robustness** – Slide 45
Learning Objectives

• Explain the importance of the product design process and provide an overview of each step of the process
• Calculate the reliability and availability of a product or service
• Understand the technologies involved in designing new products and their related production processes
• Utilize techniques for analyzing design failures and eliminating unnecessary design features
• Explain why and how each step of the product lifecycle can be changed for improved environmental stewardship, and provide examples of programs that support green efforts
• Use quality function deployment as a design tool
Design Process

• Effective design can provide a competitive edge
  • matches product or service characteristics with customer requirements
  • ensures that customer requirements are met in the simplest and least costly manner
  • reduces time required to design a new product or service
  • minimizes revisions necessary to make a design workable
Design Process

• Product design
  • defines appearance of product
  • sets standards for performance
  • specifies which materials are to be used
  • determines dimensions and tolerances
Design Process
Idea Generation

• Company’s own R&D department
• Customer complaints or suggestions
• Marketing research
• Suppliers

• Salespersons in the field
• Factory workers
• New technological developments
• Competitors
Idea Generation

- Perceptual Maps
  - visual comparison of customer perceptions
- Benchmarking
  - comparing product/process against best-in-class
- Reverse engineering
  - dismantling competitor’s product to improve your own product
Perceptual Map of Breakfast Cereals

- Cocoa Puffs
- Rice Krispies
- Cheerios
- Wheaties
- Shredded Wheat
Feasibility Study

- Market analysis
- Economic analysis
- Technical/strategic analyses
- Performance specifications
Rapid Prototyping and Concurrent Design

- Testing and revising a preliminary design model
- Build a prototype
  - form design
  - functional design
  - production design
- Test prototype
- Revise design
- Retest
Concurrent Design

(a) Sequential design: Walls between functional areas

- Product concept
- Performance specs
- Design specs
- Manufacturing specs

- Customers
- Marketing personnel
- Design engineer
- Manufacturing engineer
- Production personnel

(b) Concurrent design: Walls broken down

Design team
Form and Functional Design

• Form Design
  • how product will look?

• Functional Design
  • how product will perform?
    • reliability
    • maintainability
    • usability
Computing Reliability

Components in series

0.90 0.90
Computing Reliability

Components in series

\[0.90 \times 0.90 = 0.81\]
Computing Reliability

Components in parallel

0.90
R₂

0.95
R₁
Computing Reliability

Components in parallel

\[ 0.95 + 0.90(1 - 0.95) = 0.995 \]
System Reliability
System Reliability

\[ 0.90 \]

\[ 0.98 \]

\[ 0.92 \]

\[ 0.98 \]

\[ 0.98 \times 0.99 \times 0.98 = 0.951 \]
System Availability (SA)

\[
SA = \frac{MTBF}{MTBF + MTTR}
\]

where:
MTBF = mean time between failures
MTTR = mean time to repair
## System Availability

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<tr>
<th>PROVIDER</th>
<th>MTBF (HR)</th>
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<td>A</td>
<td>60</td>
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<td>36</td>
<td>2.0</td>
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<td>C</td>
<td>24</td>
<td>1.0</td>
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\[
SA_A = \]
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SA_B = \]
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SA_C = \]
## System Availability

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<tr>
<td>C</td>
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\[
SA_A = \frac{60}{60 + 4} = .9375 \text{ or } 94\%
\]

\[
SA_B = \frac{36}{36 + 2} = .9473 \text{ or } 95\%
\]

\[
SA_C = \frac{24}{24 + 1} = .96 \text{ or } 96\%
\]
Usability

- Ease of use of a product or service
  - ease of learning
  - ease of use
  - ease of remembering how to use
  - frequency and severity of errors
  - user satisfaction with experience
Production Design

• How the product will be made
  • Simplification
    • reducing number of parts, assemblies, or options in a product
  • Standardization
    • using commonly available and interchangeable parts
  • Modular Design
    • combining standardized building blocks, or modules, to create unique finished products
  • Design for Manufacture (DFM)
    • Designing a product so that it can be produced easily and economically
Design Simplification

(a) Original design
Assembly using common fasteners

(b) Revised design
One-piece base and elimination of fasteners
Plastic inserts allow spindle to be assembled from above; integral base and brackets eliminate need for screws, washers, and nuts

(c) Final design
Design for push-and-snap assembly
Flexible design feature permits spindle to be snapped into place

84 seconds to assemble
12 seconds to assemble
4 seconds to assemble
Final Design and Process Plans

• Final design
  • detailed drawings and specifications for new product or service

• Process plans
  • workable instructions
    • necessary equipment and tooling
    • component sourcing recommendations
    • job descriptions and procedures
    • computer programs for automated machines
Technology in Design

• Computer Aided Design (CAD)
  • assists in creation, modification, and analysis of a design
  • computer-aided engineering (CAE)
    • tests and analyzes designs on computer screen
  • computer-aided manufacturing (CAD/CAM)
    • ultimate design-to-manufacture connection
  • product life cycle management (PLM)
    • managing entire lifecycle of a product
  • collaborative product design (CPD)
Collaborative Product Design (CPD)

- A software system for collaborative design and development among trading partners
- With PML, manages product data, sets up project workspaces, and follows life cycle of the product
- Accelerates product development, helps to resolve product launch issues, and improves quality of design
- Designers can
  - conduct virtual review sessions
  - test “what if” scenarios
  - assign and track design issues
  - communicate with multiple tiers of suppliers
  - create, store, and manage project documents
Design Quality Review

• Review designs to prevent failures and ensure value
  • Failure mode and effects analysis (FMEA)
    • a systematic method of analyzing product failures
  • Fault tree analysis (FTA)
    • a visual method for analyzing interrelationships among failures
  • Value analysis (VA)
    • helps eliminate unnecessary features and functions

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## FMEA for Potato Chips

<table>
<thead>
<tr>
<th>Failure Mode</th>
<th>Cause of Failure</th>
<th>Effect of Failure</th>
<th>Corrective Action</th>
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<tr>
<td>Stale</td>
<td>low moisture content, expired shelf life, poor packaging</td>
<td>tastes bad, won’t crunch, thrown out, lost sales</td>
<td>add moisture, cure longer, better package seal, shorter shelf life</td>
</tr>
<tr>
<td>Broken</td>
<td>too thin, too brittle, rough handling, rough use, poor packaging</td>
<td>can’t dip, poor display, injures mouth, choking, perceived as old, lost sales</td>
<td>change recipe, change process, change packaging</td>
</tr>
<tr>
<td>Too Salty</td>
<td>outdated receipt, process not in control, uneven distribution of salt</td>
<td>eat less, drink more, health hazard, lost sales</td>
<td>experiment with recipe, experiment with process, introduce low salt version</td>
</tr>
</tbody>
</table>
Fault Tree Analysis (FTA)

Chip breaking

Too brittle
- More moisture
- Fewer ridges
- Adjust frying procedures

Too thin
- Increase thickness
- Reduce size

Key:
- and
- or
- XXX undesirable solution
- XXX acceptable solution

Amount of heat
- Solved

Length of time
- Solved
Value Analysis (VA)

- Eliminate unnecessary features and functions
- Used by multifunctional design teams
- Define essential functions of an item
- Determine the value of the functions
- Determine the cost of providing the functions
- Compute Value/Cost ratio
- Design team works to increase the ratio
Design for Environment and Extended Producer Responsibility

• Design for environment
  • designing a product from material that can be recycled
  • design from recycled material
  • design for ease of repair
  • minimize packaging
  • minimize material and energy used during manufacture, consumption and disposal

• Extended producer responsibility
  • holds companies responsible for their product even after its useful life
Design for Environment

**INPUT**
Sourcing
- Less material
- Recycled material
- Organic material
- Non-toxic material
- Renewable material
- Durable material
- Nearby supplier

**TRANSFORMATION**
Manufacturing
- Less energy to process
- Less waste
- No harmful by-products
- Less inventory
- Renewable resources
- Less packaging
- Less transport

**OUTPUT**
Consumption
- Energy efficient
- Longer life
- Easy to repair
- recyclable
- Easy to disassemble
- Useful
- Does no harm

Options:
- RE-USE
- RECYCLE
- DISCARD
Green Areas

• Green Sourcing
  • use less material
  • use recycled if possible
• Green Manufacture
  • is energy from renewable sources
  • amount of waste produced
• Green Consumption
  • product’s use of energy
  • is product recyclable and maintainable
• Recycling and Re-Use
  • design products to be recycled or re-used
  • save energy and money
Quality Function Deployment (QFD)

- Translates voice of customer into technical design requirements
- Displays requirements in matrix diagrams
  - first matrix called “house of quality”
  - series of connected houses
House of Quality

1. Customer requirements
2. Competitive assessment
3. Design characteristics
4. Relationship matrix
5. Trade-off matrix
6. Target values

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## Competitive Assessment of Customer Requirements

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<tr>
<th>Customer Requirements</th>
<th>Competitive Assessment</th>
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<tr>
<td>Presses quickly</td>
<td>9</td>
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<tr>
<td>Removes wrinkles</td>
<td>8</td>
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<tr>
<td>Doesn’t stick to fabric</td>
<td>6</td>
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<tr>
<td>Provides enough steam</td>
<td>8</td>
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<tr>
<td>Doesn’t spot fabric</td>
<td>6</td>
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<tr>
<td>Doesn’t scorch fabric</td>
<td>9</td>
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<tr>
<td>Heats quickly</td>
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<td>Automatic shut-off</td>
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<tr>
<td>Quick cool-down</td>
<td>3</td>
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<tr>
<td>Doesn’t break when dropped</td>
<td>5</td>
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<tr>
<td>Doesn’t burn when touched</td>
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<tr>
<td>Not too heavy</td>
<td>8</td>
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### From Customer Requirements to Design Characteristics

<table>
<thead>
<tr>
<th>Customer Requirements</th>
<th>Energy needed to press</th>
<th>Weight of iron</th>
<th>Size of soleplate</th>
<th>Material used in soleplate</th>
<th>Number of holes</th>
<th>Size of soleplate</th>
<th>Flow of water from holes</th>
<th>Time required to reach 450°F</th>
<th>Time to go from 450°F to 100°F</th>
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Tradeoff Matrix

- Energy needed to press
- Weight of iron
- Size of soleplate
- Thickness of soleplate
- Material used in soleplate
- Number of holes
- Size of holes
- Flow of water from holes
- Time required to reach 450°
- Time to go from 450° to 100°
- Protective cover for soleplate
- Automatic shutoff
## Targeted Changes in Design

<table>
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<tr>
<th>Objective measures</th>
<th>Units of measure</th>
<th>Energy needed to press</th>
<th>Weight of iron</th>
<th>Size of soleplate</th>
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Completed House of Quality

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Key:
SS = Silverstone
MG = Mirrorglide
T = Titanium

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4-42
A Series of Connected QFD Houses

- Customer requirements
- House of quality
- Product characteristics
  - A-1
- Product characteristics
  - A-2
- Part deployment
- Part characteristics
- Process planning
  - A-3
- Process characteristics
  - A-4
- Operations
- Operating requirements

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4-43
Benefits of QFD

- Promotes better understanding of customer demands
- Promotes better understanding of design interactions
- Involves manufacturing in design process
- Provides documentation of design process
Design for Robustness

• Robust product
  • designed to withstand variations in environmental and operating conditions

• Robust design
  • yields a product or service designed to withstand variations

• Controllable factors
  • design parameters such as material used, dimensions, and form of processing

• Uncontrollable factors
  • user’s control (length of use, maintenance, settings, etc.)
Design for Robustness

• Tolerance
  • allowable ranges of variation in the dimension of a part

• Consistency
  • consistent errors are easier to correct than random errors
  • parts within tolerances may yield assemblies that are not within limits
  • consumers prefer product characteristics near their ideal values
Taguchi’s Quality Loss Function

- Quantifies customer preferences toward quality
- Emphasizes that customer preferences are strongly oriented toward consistently
- Design for Six Sigma (DFSS)