Lecture Module:

Problem Understanding & Design Specification
Key Concepts

- Design is a Problem Solving Process
- Multiple Phases of Design
- Customer Requirements
- Intrinsic requirements
- Problem understanding forms
- Functions vs Constraints
- Design Specifications & Target performance metrics
Outline

1. Review understanding of Design
   - Characteristics, types, process
2. Phases of Design
3. Customer requirements
   - Seeding questions; Needs/Wants; Target Markets
4. Design Objectives/Requirements
5. Product Functions
6. Design Specifications
7. Quality Function Deployment
8. Summary
2. Phases of Design

A. Customer/Product Requirements
B. Design Specification
C. Conceptual Design
   I. Concept Generation
   II. Concept Evaluation
D. Detail Design
E. Prototyping
F. Design Finalization
   I. Specification for Production
     ◆ Manufacturing
     ◆ Usable Life
     ◆ End of Life

PRODUCT LIFECYCLE

Start

Concurrent
NOT Linear

End
3. Customer Requirements

Key Concepts:

Seeding questions: Where can I sell product? What is target Market?, Why will people buy it? Why is it important?

Customer side: Needs, Wants, Desires
Product side: Features, Benefits, Quality

Design process is most successful iff. customers’ “quality function” is embedded in the product

QFD - Quality Function Deployment:
Design process originated in Japan to rigorously ensure customer-centric product development
4. DT2 - Problem Understanding Form

- Ensures evaluation of all Customer Requirements
- Establishes relationships between Customer Requirements and Design Requirements using Relationship Matrix
  - *Customer WHATS into Design HOWS*

**Analysis:**
- *Blank Row* – customer requirement not met; Engineer doesn’t care
- *Blank Column* – design requirement that customer doesn’t want
  - *Be aware of intrinsic requirements*

**Relationship Matrix**

<table>
<thead>
<tr>
<th>Relationship</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong</td>
<td>9</td>
</tr>
<tr>
<td>Medium</td>
<td>3</td>
</tr>
<tr>
<td>Weak</td>
<td>1</td>
</tr>
<tr>
<td>None</td>
<td>0</td>
</tr>
</tbody>
</table>
5. Product Functions

What is a Product Function

- Actions the product must be capable of DOING
- Abstract formulation of task

What it is NOT

- A specific solution path - eg. “Turn Light On”
- A Constraint – eg. “Be smaller than…”

Approach:

- Drill down to the “Hows”
5. DT3 Example: Active-Safety Car Seat

- Consider the design of active-safety seats to increase occupant safety
- Use a Function Tree to establish/identify the product functions
5. DT3 Example: Active-Safety Car Seat

Close, but not quite there...

- Provide Active Safety
  - Be Comfortable
    - Change shape to conform to Human Body
  - Move During Crash
    - Sense Crash
  - Reduce Injuries
    - Follow Desired Trajectory
    - Increase Bottom Angle
    - Prevent Passenger from Hitting Roof
5. DT3 Example: Active-Safety Car Seat

Technically accurate, but not only solution

Active Safety Car-Seat
- Be Comfortable
  - Conform to User Shape
  - Maintain cushioning
- Constrain occupant
- Reduce Injuries
  - Sense Collision
  - Adjust Occ. motion
    - Rotate seat rails up
    - Increase head space
6. Design Specifications

What is a Design Specification

• Numerical target (TPM) or constraint
• Derived from Design Standard, Design Constraint (V.o.C), or Design Analysis

Specification Categories

• Geometric
• Kinematics
• Dynamics
• Energy
• Costs
• Material
• Signals
• Safety
• Ergonomics
• Schedules
• Assembly
• Transportation
• Operation
• Quality Control
• Recycling
DT4 – Design Specification Sheet/List

- List of Design Specifications, Source, Design responsibility
- Tracks versioning by including date of modification or spec change
- Specifications arranged by category

<table>
<thead>
<tr>
<th>Change</th>
<th>D/W</th>
<th>Requirements</th>
<th>Issued:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>For: CUP OF COFFEE</td>
<td></td>
</tr>
<tr>
<td>10/4/95</td>
<td>10/4/95</td>
<td>Cup Of Coffee</td>
<td>1st Hoq From Class</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Energy:</td>
<td>NIST STD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Serving Temperature, 140 °F</td>
<td>FDA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Material:</td>
<td>1st HOQ From Class</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Color Std, NIST # ?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-Poisonous, &lt; X₁, X₂, ...mg/l</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Brewed Coffee Should Yield &lt; Y mg/l Coffee</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grounds When Filtered</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Safety:</td>
<td>FDA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-Poisonous, &lt; X₁, X₂, ...mg/l</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Signals:</td>
<td>NIST STD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Color Std, NIST # ?</td>
<td>1st HOQ From Class</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Smells Jury, 95% Consensus</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Taste Jury, 95% Consensus</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Costs:</td>
<td>1st HOQ From Class</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minimize Price</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Quality Control</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Color Std, NIST # ?</td>
<td>NIST STD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Smells Jury, 95% Consensus</td>
<td>1st HOQ From Class</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Taste Jury, 95% Consensus</td>
<td></td>
</tr>
</tbody>
</table>
Quality Function Deployment

- QFD is a planning tool
  - translates customer needs into appropriate product development requirements
  - identifies the significant items on which to focus time, product improvement efforts, and other resources

- QFD is not
  - a quality control strategy

Casual-wear in Japan [Photo from Dr. Singhose]
5. DT5 – House of Quality

- Primary design tool in QFD
- Ensures comprehensive understanding of design task and product requirements
- Builds on P.U.F by adding “rooms” for:
  - Design Trade-off & Analysis Identification
  - Technical Importance identifies key design requirements for product non-subjectively
  - Customer Competitive Assessment
  - Technical Competitive Assessment
  - Design Target Specification

Correlation Matrix

Design Requirements

Customer Requirements Importance

Relationship Matrix

TPMs

Technical Competitive Assessment

Customer Comp. Assessment

Absolute
\[ \sum 1 \quad \sum n \quad \sum R \]

Relative
\[ \sum 1/\sum R \quad \sum n/\sum R \]
5. H.o.Q Matrices

**Relationship Matrix:**
- Relates Customer Requirements to Design requirements
- **WHATS to HOWS**
- Symbolic Entries with larger weighting scale

<table>
<thead>
<tr>
<th>Relationship</th>
<th>Symbol</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong</td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>Medium</td>
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<td>3</td>
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<td>1</td>
</tr>
<tr>
<td>None</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

**Correlation Matrix:**
- Relates Design Requirements to Design requirements
- **Hows to HOWS**
- Clearly identifies design trade-offs
- Demonstrates areas for optimization efforts

**Co-Relationship**

| Strong Positive |                |
| Positive        |                |
| Negative        |                |
| Strong Negative |                |

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5. H.o.Q Example

Product: A cup of coffee

Customer Requirements:
Be Hot, Taste Good, Smell Good, Stimulating, Look like Coffee, No Grounds, Reasonable Cost

Product Requirements:
Non-Toxic

<table>
<thead>
<tr>
<th>What</th>
<th>How</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot</td>
<td>Serving temperature (Hot)</td>
</tr>
<tr>
<td>Taste</td>
<td>Taste jury (Taste)</td>
</tr>
<tr>
<td>Smell</td>
<td>Smell jury (Smell)</td>
</tr>
<tr>
<td>Stimulating</td>
<td>Measure caffeine level (Stimulating)</td>
</tr>
<tr>
<td>Color</td>
<td>Color standard (Color)</td>
</tr>
<tr>
<td>Grounds</td>
<td>Filter &amp; weigh (Grounds)</td>
</tr>
<tr>
<td>Not poisonous</td>
<td>Measure LD 50 (Limit poison)</td>
</tr>
<tr>
<td>Cost</td>
<td>Price ($)</td>
</tr>
</tbody>
</table>
Technical Importance

Absolute

\[ \Sigma 1 : \quad 8 \times 9 + 3 \times 6 + 9 \times 9 + 10 \times 1 = 181 \]

Relative

\[ \Sigma R \]

181 + 132 + 54 + 99 + 18 + 108 \ldots \n
\ldots + 90 = 682

\[ \Sigma 1/\Sigma R \]

181 / 682 = 0.27
5. H.o.Q – Design Understanding Analysis

- House of Quality is a comprehensive summary of the understanding of a design task.
- HoQ exposes areas for detailed analysis and additional evaluation

H.o.Q Analysis:
- Identify Blank rows and columns
- Compare customer vs technical competitive surveys
  - Identify and Resolve conflicts
  - Identify advantages (marketing points)
- Confirm target performance metrics
- Identify areas for detailed design optimization
  - Strong negative correlations
- Target direction indicators
5. HoQ – Detailed Example

Product: Car door

Customer requirements?
5. HoQ – Detailed Example

Product: Car door

<table>
<thead>
<tr>
<th>Operating Efforts</th>
<th>Human Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Door</td>
<td>Window</td>
</tr>
<tr>
<td>Lock</td>
<td>Lock/ latch</td>
</tr>
<tr>
<td>Door Effort</td>
<td>Window Effort</td>
</tr>
<tr>
<td>Lock Effort</td>
<td>Lock Effort</td>
</tr>
<tr>
<td>Door Effort</td>
<td>Target Area</td>
</tr>
<tr>
<td>Lock Effort</td>
<td>Target Area</td>
</tr>
<tr>
<td>Door Effort</td>
<td>4 minute test</td>
</tr>
</tbody>
</table>

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8. Summary

A. Customer/Product Requirements
   *Problem understanding, Initial Analysis*
   
   DT1 – Objectives Tree    DT2 – Problem Understanding Form

B. Design Specification
   *Target Performance Metrics, Design Constraints*
   
   DT3 – Function tree    DT4 – Design Spec. Sheet
   
   DT5 – House of Quality (QFD)

C. Conceptual Design
   I. Concept Generation
   II. Concept Evaluation

D. Detail Design

E. Prototyping

F. Design Finalization
   I. Specification for Production