Phases of Design

Customer
Understand the Design Process

Specification Development
Specification of Information

Conceptual Design
Specification of a Principle
Functional Decomposition
Generate Concepts
Concept Evaluation
Concept Selection
Preliminary Design/Embodiment

Detail Design

Specification of Production
Process Planning

Manufacture
Who is the Customer for this System?

- airlines
- passengers
- flight attendants
- pilots
- ground crew
- TSA
- air traffic control
- FAA
- and many others....
Customer needs are found by asking, observing, and testing

- Focus Groups
- One-on-One Interviews
- Ethnography (culture)
- Empathic design (feelings)
- Many others...

https://www.coolcamping.co.uk/features/35-the-rise-rise-of-inflatable-tents

Three Types of Quality/Features

Basic:
• Expected or assumed (threshold attributes)
• Typical of “invisible” products
• Functions of products

Performance:
• One dimensional
• Most market research

Excitement:
• Pleasant surprises or customer delights
• Unexpected
Customer needs are specific, positive, and solution-neutral

<table>
<thead>
<tr>
<th>Guideline</th>
<th>Customer Statement</th>
<th>Need Statement</th>
<th>Need Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What Not How</strong></td>
<td>“Why don’t they put a hook at the end of the outlet hose?”</td>
<td>The outlet hose has a hook to connect to water containers.</td>
<td>The WF easily transfers water into a variety of different containers</td>
</tr>
<tr>
<td><strong>Specificity</strong></td>
<td>“I often times drop the water filter on rocks.”</td>
<td>The WF is rugged.</td>
<td>The WF operates normally after repeated dropping.</td>
</tr>
<tr>
<td><strong>Positive Not Negative</strong></td>
<td>“the WF is difficult to hold.”</td>
<td>The WF is not difficult to hold.</td>
<td>The WF is easy to hold</td>
</tr>
<tr>
<td><strong>Product Attribute</strong></td>
<td>“I need to attach a virus filter to the WF.”</td>
<td>A virus filter can be attached to the WF</td>
<td>WF accommodates a virus filter</td>
</tr>
<tr>
<td><strong>Avoid “Must” &amp; “Should”</strong></td>
<td>“The water should taste good.”</td>
<td>The WF should deliver good tasting water</td>
<td>The WF delivers good tasting water</td>
</tr>
</tbody>
</table>

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8
## Customer Needs (e.g., Page Turner)

<table>
<thead>
<tr>
<th>Question</th>
<th>Customer Statement</th>
<th>Interpreted Need</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical uses</td>
<td>• Independent use by student</td>
<td>• Operable by person with disabilities</td>
<td>(must) 4</td>
</tr>
<tr>
<td>Likes</td>
<td>• Portable, Mobile</td>
<td>• Portable</td>
<td>(good) 3</td>
</tr>
<tr>
<td></td>
<td>• Auditory sound provided when page is turned</td>
<td>• Signals when performing desired actions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Adjustable stand for different book sizes</td>
<td>• Adjusts to different book sizes</td>
<td></td>
</tr>
<tr>
<td>Dislikes</td>
<td>• Used so much that we wore it out</td>
<td>• Lightweight</td>
<td>(good) 3</td>
</tr>
<tr>
<td></td>
<td>• Heavy</td>
<td>• Repairable by staff</td>
<td>(good) 3</td>
</tr>
<tr>
<td></td>
<td>• Need consistent page turning</td>
<td>• Easily replaceable parts</td>
<td>(must) 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Predictable page turning</td>
<td>(must) 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Low failure rate</td>
<td>(must) 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Long mean time between failures</td>
<td>(should) 2</td>
</tr>
<tr>
<td>Suggested</td>
<td>• Built in delay for multiple button pushes</td>
<td>• Turns variety of page types</td>
<td>(should) 2</td>
</tr>
<tr>
<td>Improvements</td>
<td>• Be able to turn newspaper pages</td>
<td>• Accounts for accidental, repeat button pushes</td>
<td>(good) 3</td>
</tr>
<tr>
<td></td>
<td>• Be able to turn scrapbook pages</td>
<td>• Operable by multiple persons</td>
<td>(must) 4</td>
</tr>
<tr>
<td></td>
<td>• Multiple students can share</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
From Customer Needs to Specifications

Engineering Requirements and Specifications Translate Voice of the Customer to Technology

TABLET DEVICE COMPARISON

<table>
<thead>
<tr>
<th>Model</th>
<th>Display Size (inches)</th>
<th>Weight (g)</th>
<th>Resolution (pPI)</th>
<th>Camera</th>
<th>Connectivity</th>
<th>Battery Life (h)</th>
<th>Processor</th>
<th>RAM</th>
<th>Storage</th>
<th>OS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samsung Galaxy Tab 3</td>
<td>10.1 diagonal</td>
<td>600g</td>
<td>1366x768</td>
<td>8MP rear</td>
<td>Bluetooth: 2.1, Wi-Fi</td>
<td>9.5</td>
<td>Snapdragon 802</td>
<td>2GB</td>
<td>16GB or 32GB</td>
<td>Android 4.4</td>
</tr>
<tr>
<td>Motorola XOOM</td>
<td>10.1 diagonal</td>
<td>730g</td>
<td>1280x800</td>
<td>5MP</td>
<td>Bluetooth: 3.0, Wi-Fi</td>
<td>10</td>
<td>Tegra 3</td>
<td>2GB</td>
<td>32GB</td>
<td>Android 3.2</td>
</tr>
<tr>
<td>BlackBerry Playbook</td>
<td>7-inch diagonal</td>
<td>400g</td>
<td>1366x768</td>
<td>5MP</td>
<td>Bluetooth: 3.0, Wi-Fi</td>
<td>9.5</td>
<td>Snapdragon 802</td>
<td>2GB</td>
<td>16GB or 32GB</td>
<td>BlackBerry OS 7.0</td>
</tr>
<tr>
<td>Apple iPad 2</td>
<td>7.7-inch diagonal</td>
<td>661g</td>
<td>Retina</td>
<td>8MP</td>
<td>Bluetooth: 3.0, Wi-Fi</td>
<td>9.5</td>
<td>A5</td>
<td>1GB</td>
<td>16GB, 32GB, 64GB</td>
<td>iOS 4.3</td>
</tr>
<tr>
<td>Samsung Galaxy Tab 2</td>
<td>7.0 diagonal</td>
<td>385g</td>
<td>1280x800</td>
<td>5MP</td>
<td>Bluetooth: 2.1, Wi-Fi</td>
<td>10</td>
<td>Exynos 5250</td>
<td>2GB</td>
<td>16GB, 32GB, 64GB</td>
<td>Android 4.0</td>
</tr>
</tbody>
</table>

CREDIT TO: WIKIPEDIA
Quality Function Deployment (QFD)

QFD is a design planning tool:
• for translating customer needs into appropriate product development requirements
• that identifies the significant item(s) on which to focus time, product improvement efforts and other resources

QFD enables:
• the identification of important issues and items
• the identification of trade-offs and synergies
House of Quality (HOQ)

- Design tool for coordinating design efforts towards goods customers WANT
- House of quality (HOQ) is part of QFD
- Focus on quality and customer needs across the design process and across corporate boundaries
- Guide design priorities based on customer needs and competitive benchmarking
- Over 70% of US companies use QFD (Ford, Xerox, Toyota …)
Effect of QFD on Performance

- Changes = Money
- Earlier Changes = Less Money Spent

Customer desires (qualitative)

House of Quality (HOQ)

HOQ Translates Needs to Specifications

Customer Needs

HOQ

Engineering Requirements and Specifications

Product performance (quantitative)

Specification is a:

Metric with Target Value & units

- mass < 0.1 kg
- volume < 250 cm³
House of Quality (HOQ) components

- Customer needs/perceptions
- Engineering metrics/requirements
  - Targets
  - Direction of improvement
- Conflict/synergies
- Relationship matrix
- Correlation matrix
House of Quality (HOQ) components

Customer needs/perceptions:
• These are the ‘whats’
• Assigned numerical importance (e.g., 1 to 10)

Engineering metrics/requirements:
• These are the ‘hows’
• Determine most important ones using Relationships
• Determine synergies/conflicts with Correlations

Relationship matrix (RM):
• Maps relationship between ‘hows’ and ‘whats’
• Quantitative relationship levels (e.g., 1, 3 and 9)

Correlation matrix (CM):
• Maps correlation between engineering requirements
• Strong positive, positive, negative, strong negative
## Relationship Matrix in HOQ

| Direction of Improvement | ▲ | ▼ | ▼ | ▼ | ▼ | ▲ | ▼ | ▼ | ▼ | ▼ | ▼ | ▼ | ▼ | ▼ |
|--------------------------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Engineering Requirements |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Customer Requirements    |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| (Explicit and Implicit)  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| operable by person with disabilities | ○ | ● |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Portable/Mobile           | ○ | ○ |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Signals when performing desired actions | ● | ● | ● |   |   |   |   |   |   |   |   |   |   |   |   |
| lightweight               | ● |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| repairable by staff       |   | ▼ | ● | ● | ○ |   |   |   |   |   |   |   |   |   |   |
| easily replaceable parts  |   |   | ● |   |   |   |   |   |   |   |   |   |   |   |   |
| predictable page turning  |   |   |   |   |   |   |   |   |   |   |   |   |   | ○ | ● |
| low failure rate          |   |   |   |   |   |   |   |   |   |   |   |   | ■ | ● |   |
| safely handles variety of reading materials |   |   |   |   |   |   |   |   |   |   |   |   | ● | ● |   |

### Notes:
- ▲: Increase
- ▼: Decrease
- ○: No change
- ▼: Consider
- ●: Strongly agree
- ▼: Disagree
- ○: Neutral
- ▼: Strongly disagree
- ◇: Very strong agreement

### Improvements:
- **Tolerance of user-initiated motions**
- **Grip force required of operator**
- **Total mass**
- **Carrying dimensions**
- **Auditory volume of visual signals**
- **Match signals with user-generated actions**
- **Intensity of visual signals**
- **Number of assembly and disassembly operations**
- **Error in aligning parts**
- **# Specialty components**
- **# Tools needed to repair**
- **Grainularity of page turning control**
- **Error rate in page turning**
- **Rate of wear of components**
- **Adjustable range of dimensions**
- **Force on the page**

### What:
- What features are being assessed?

### How:
- How are the features improved?

---

**Georgia Tech**

**Creating the Next**
## Correlation Matrix in HOQ

<table>
<thead>
<tr>
<th>Engineering requirements</th>
<th>Column #</th>
</tr>
</thead>
<tbody>
<tr>
<td>tolerance of user-initiated motions</td>
<td>1</td>
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<tr>
<td>grip force required of operator</td>
<td>2</td>
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<tr>
<td>total mass</td>
<td>3</td>
</tr>
<tr>
<td>carrying dimensions</td>
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<tr>
<td>auditory volume of signals</td>
<td>5</td>
</tr>
<tr>
<td>match signals with user generated actions</td>
<td>6</td>
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<tr>
<td>intensity of visual signals</td>
<td>7</td>
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<tr>
<td>number of assembly and disassembly orientations</td>
<td>8</td>
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<tr>
<td>error in aligning parts</td>
<td>9</td>
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<tr>
<td># specialty components</td>
<td>10</td>
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<tr>
<td># tools needed to repair</td>
<td>11</td>
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<tr>
<td>granularity of page turning control</td>
<td>12</td>
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<tr>
<td>error rate in page turning</td>
<td>13</td>
</tr>
<tr>
<td>rate of wear of components</td>
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<tr>
<td>adjustable range of dimensions</td>
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<tr>
<td>force on the page</td>
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### Matrix

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<td>force on the page</td>
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</tbody>
</table>
How do you prefer your coffee???
Determine how specific values for engineering requirements influence satisfaction of customer needs

- Scientific studies
- Survey tests
- Focus groups
- Refer to standards organizations (NIOSH, OSHA, NIST, ASTM, etc)

**Coffee grind example**

*Figure 13.9 Coffee quality chart. (Adapted from American Coffee Brewing Institute and reproduced by courtesy of Van Nostrand Reinhold.)*
HOQ Example (e.g., Coffee)

**What**
- Hot
- Taste/flavor
- Smell
- Stimulating
- Aesthetics
- Color
- Cost
- Grind
- Not toxic

**How**
- Serving temperature (Hot)
- Taste jury (Taste)
- Smell jury (Smell)
- Measure caffeine level (Stimulating)
- Jury (Aesthetics)
- Color standard (Color)
- Price (Cost)
- Filter & weight (Grind)
- Lethal Dose 50% (Median, LD 50)
Matrix Weights

- Strong, $\bigcirc = 9$
- Medium, $\bigcirc = 3$
- Weak, $\Delta = 1$

- The 181 from column 1 comes from:
  \[(8)(9) + (6)(3) + (9)(9) + (10)(1) = 181\]
- The sum of the Absolute Importance row is:
  \[181 + 132 + 54 + 99 + 18 + 108 + 90 = 682\]
- The 0.27 in the first column of the Relative Importance row comes from:
  \[\frac{181}{682} = 0.2654 \approx 0.27\]
Analyzing and Diagnosing the HOQ

Look for:
• Blank rows – unaddressed customer need
• Blank columns – unimportant engineering requirement
• Communication opportunities
• Sales Points – competitors strengths/features
• Resolve or prioritize negative correlations
• Final correct targets
• Determining planned quality
• What design requirements to be deployed to Phase II (Parts Deployment)
Summary – QFD/HOQ

Customer requirements
• Rank based on customer priority

Engineering requirements
• Must be measurable (e.g., engineering units), have improvement direction and a target value
• Rate relationship to customer requirements
• Relate tradeoffs with other engineering reqs.
• Determine most important ones using calculation

Describing this figure in text
• Describe chart’s contents, not what the chart is itself!
• What is important for each set of data?
• Use numerical information from figure

See Ch. 2 in book for detail, templates online