Lecture 10: Prototypes

Prototyping

• Role of prototyping in the design process
• Selecting the correct prototyping strategy
• Linkage with design strategy: early or late concept lock

• Assignment
  – You need to develop the right prototypes
  – Need to justify why you are doing the prototype you are doing
Prototyping as a management tool

• Improve efficiency of the PDP
• Increased learning
  – provides a more certain metric about the quality of the product
  – feedback problems to the functional and product teams
• Communication
  – becomes a common metric or language for all functional groups
• A metric for how well the design process is going

Prototypes as a risk mitigation strategy

• Certain characteristics of the product are high risk items.
• Risk = probability of failure * cost of failure
• Prototypes move the measure of probability from an uncertain value (.50) to a certain value (1 or 0).
• Key question:
  – How much are you willing to pay to reduce the uncertainty around failure
Prototyping as a Real Option

- By the option to avoid a problem later on
- The option may or may not be ultimately valuable

- The greater the uncertainty (the higher the cost), the more valuable the option is

Three Stages of Prototyping

- Concept
  - aesthetics
  - shape
- Function/Engineering
  - performance
- Production
  - producibility

System
Subsystem
Components

Concept -> Eng. -> Production
Customer prototypes
What does the customer think

- Industrial design - “look and feel”
  - Renderings - sketch
  - Sketch models - quick 3-D sketch
  - Foam models - models that have the look and feel but no functionality
  - Functional prototypes - models that have look feel and key functionality

Functional Prototypes
Does it function correctly

- Virtual
  - Crash simulation
  - VSA
- Physical
  - Crash test samples
  - Breadboards

Verification / Conformance testing
does it function

Robustness / representative testing
does it function under
  stress
  process variation
  time

- Piece Part
  - simulate individual part behavior
  - durability tests on intermediate shafts
- System
  - simulate how the whole system works together
  - i.e., road handling
Production Prototypes
Can you produce it efficiently

- Made using production equipment
- Used to highlight risk of expensive assemblies
- Very expensive because tooling is expensive

Supplier problems

- Often suppliers making prototypes are different from those making the final tooling
- Pros
  - turn-around time is shorter for prototypes
  - “quality” of prototypes is better
- Cons
  - no learning by final suppliers
  - no teaching by final suppliers
Two prototype types

• Prototype as master model
  – high quality as possible
  – built to validate the design
  – production tries to mimic quality in prototype
• Prototype as problem detector
  – built with production equipment
  – built to validate the design under production conditions

Prototype Metrics

• Fidelity
  – How accurately does the prototype represent the
    • function
    • look
    • production intent
• Time
  – Drives learning cycles
  – “This is representative of the design 10 weeks ago but so many changes have happened, it is invalid”
• Cost
Prototype fidelity

• Examples
  – Sterolithography - good at look, medium at function, bad at production intent, fast to produce, medium expense
  – soft tooling - good at look, medium at function, medium at production intent, slow to produce, expensive

Prototyping improvements

Better prototyping tools
Best practice characteristics

- Proper level of prototyping picked
  - lowest cost/shortest time prototype that will answer the questions
- Production intent as early as possible
- Timing
  - do not overlap prototype cycles
  - time with design reviews
- Propagate learning through the organization

Who should be involved

- Middle prototypes (functional) are
  - primarily for engineering
  - contain significant information for manufacturing
- Who should build it
  - Outsourced/Vendor
    - good: range of capability
    - bad: learning
  - Model shop
    - good: internal learning
    - bad: manufacturing intent
  - Plant
Future of prototyping

- Rapid prototyping technologies
  - part printing
  - printing tooling
  - problems
    - the material characteristics are different
    - expensive
    - still time consuming
- Rapid cutting technologies
  - high speed machining
  - high speed CNC path generation
  - make parts and tools out of final materials

Periodic Prototyping

Cycle 1

Cycle 2

Cycle 3

Cycle 4

• Shorter more rapid cycles
• Earlier beginning of pilot production verification
### Types of prototypes

<table>
<thead>
<tr>
<th>Types of</th>
<th>Role</th>
<th>Benefits</th>
<th>Problems</th>
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<tbody>
<tr>
<td>prototype</td>
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<tr>
<td>Scale model</td>
<td>Drag/fluid models</td>
<td>inexpensive</td>
<td>• scale up effects</td>
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<td></td>
<td></td>
<td></td>
<td>• see the system</td>
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<td></td>
<td></td>
<td></td>
<td>• time consuming</td>
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<tr>
<td>Engineering</td>
<td>System performance</td>
<td>Focus on performance</td>
<td>• Don’t reflect producibility</td>
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<td></td>
<td></td>
<td></td>
<td>• Requires specialized skills</td>
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<tr>
<td>Conceptual</td>
<td>Look/feel</td>
<td>Show the ID of the product</td>
<td>• No indication of performance</td>
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<tr>
<td>Production</td>
<td>producibility</td>
<td>Shows production problems</td>
<td>• Very expensive</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Unable to change product types</td>
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<tr>
<td>Mechanical</td>
<td>Performance of sub-system</td>
<td></td>
<td>• Doesn’t capture the system</td>
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<td>Elements</td>
<td></td>
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<tr>
<td>Computer based</td>
<td>Performance / rapid iteration</td>
<td>Cheep</td>
<td>• Don’t reflect actual performance</td>
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<td></td>
<td></td>
<td></td>
<td>• accepted after time</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Ghosts</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Not trusted</td>
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### Prototype strategies

<table>
<thead>
<tr>
<th>Strategy</th>
<th>benefits</th>
<th>problems</th>
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<tbody>
<tr>
<td>Big gain vs. continual improvement</td>
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<tr>
<td>Early production prototypes</td>
<td>Detect problems earlier</td>
<td>If there is a change prototypes invalidate designs</td>
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<td></td>
<td>Design in electronics</td>
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<tr>
<td>Postpone production</td>
<td>Lower cost</td>
<td>Unexpected problems</td>
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<tr>
<td></td>
<td>Design in metal</td>
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<tr>
<td>Suppliers make protos</td>
<td>better learning</td>
<td>loose control of the learning</td>
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<tr>
<td>Small changes “seat changes”</td>
<td>Easier to find difference and fine tune</td>
<td>Locking out other possible configurations</td>
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<tr>
<td>Delay second</td>
<td>Don’t commit to design</td>
<td>Don’t have the benefit of learning</td>
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<tr>
<td>Representation</td>
<td>captures production (early detection)</td>
<td>changes to design is hard</td>
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<tr>
<td>Conformace (proto as master)</td>
<td>Captures the design intent/explore design</td>
<td>hard to manufacture</td>
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<tr>
<td>Two different</td>
<td>Explore more concepts</td>
<td>Inability to isolate fine tuning</td>
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Questions

- What strategy would you use in New Zealand
- Are the problems BMW is facing the same as New Zealand
  - what are the similarities
  - what are the differences

Key points

- Prototypes are “investments” that whose return is information and uncertainty reduction. In addition it finds problems that couldn’t be detected
  - tradeoffs/performance can’t be predicted with simple models
    - non-linear, highly constrained, highly coupled problems
    - function is not quantifiable “ride” “fee” “look”
- Change in competitive field changes the design/prototyping strategies
  - time, $, quality goals
  - push into more “non-hardware” work
- Used to validate designs when the cost of getting it wrong is very high
- Prototypes are on the critical path -- shorten prototype time, shorten design time
- Integral to the design process
- Prototypes are used to reduce uncertainty
- Design-test-refine cycle
Lecture 11: Tools and methods

• Newbold, R. C. Project Management in the Fast Lane: Applying the theory of constraints

• What are the difference between critical chain and other scheduling.
• What are the benefits
• What is required to execute the projects in this mode?