Generating and Evaluating Design Alternatives

Senior Design
ME481
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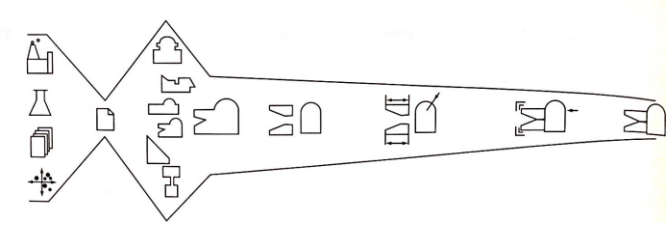
Interplay: Technology & Design Process

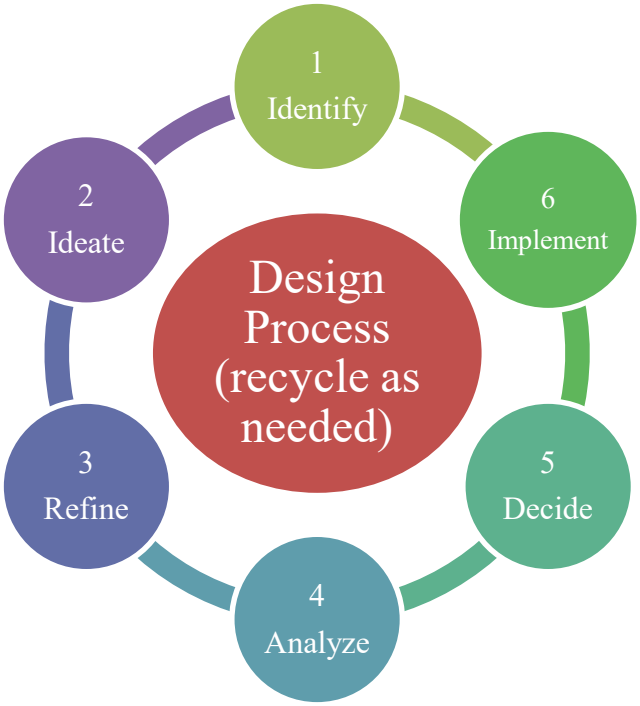
Fitting technological advances to human needs and habits

- Technology influences design
- Big obstacles from a product design standpoint
- Historical parallels to design
  - Cars like carriages, TVs like radios
  - 2nd or 3rd generations of a design will look like new
- Study of human behavior
  - Social groups to adjust to new technologies
    - email and mobile
- Design is a funnel-shaped process



Eppinger, Chapter 2

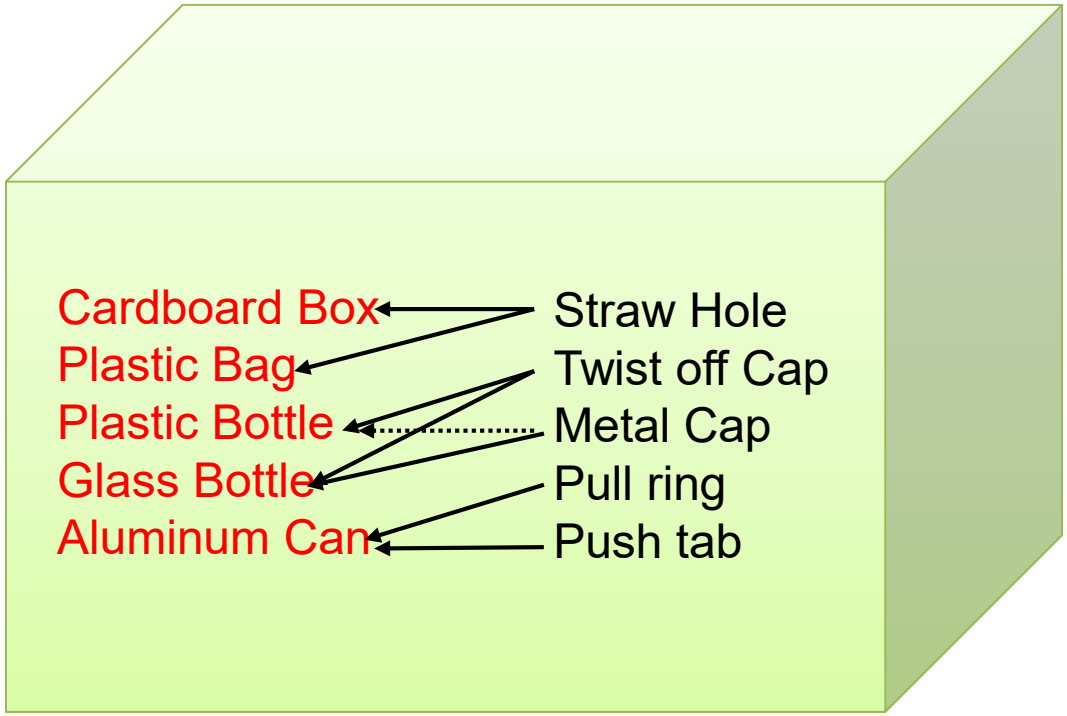
Design Process



Problem Identification	Preliminary Ideas	Refinement	Analyses	Decision	Implementation
• Background • Data • Causes • Effects • Needs • Economics	• List Ideas • Sketches • Ideate • Brainstorm • Notes • New approach	• Angles and lengths • Scale drawings • Physical properties • Shapes and forms • Intersections development • Weights and volumes	• Mathematics • Graphics • Engineering • Experience • Logic • Science	• Accept • Combine • Continue • Stop • Restudy • Reject	• Working drawings • Models • Finding solutions • Marketing • Details • Specification

Design Space

Conceptualization of a space that incorporates all possible designs



Juice Container Design Space

Complex Design Spaces

Problem has a large design space if:

- number of potential designs is large
- number of design variables
- number of values they can assume is large

Artifacts with large design spaces

- Airplanes
- Buildings
- …

By contrast, what has a small design space?

Expanding Design Space: Generating Design Ideas

Investigate available design ideas

- Talk to experts that work on related designs
- Product literature on existing products
- Visionary/research papers and articles
- Patent search

Expand on available design ideas

- Create patents

Group activities for idea generation

- Brainstorm via divergent and convergent thinking

Brainstorming

RULES OF BRAINSTORMING:

a) Criticism is ruled out
b) The wilder the idea, the better the outcome
c) Quantity is needed
d) Participants should seek ways to improve the proposed ideas

ORGANIZATION OF A BRAINSTORMING SESSION:

a) A one-page outline of information about the session should be given to panel members a few days before the session
b) The problem to be brainstormed should be defined
c) A moderator (not a leader) should be selected to be in charge of the session
d) The moderator should not permit long responses that would slow down the flow of ideas
a) Each team member should generate at least three ideas
b) A recorder should produce the list of ideas gathered during the session for distribution among the participants

SELECT BEST IDEAS FROM THE IDEAS GENERATED DURING THE BRAINSTORMING SESSION. USE THE SELECTED IDEAS OR THE MODIFICATION AND/OR COMBINATION OF THE IDEAS

Other Methods to Expand Design Space

Group activities can also be useful in expanding the design space, and a number of techniques have been developed to encourage such divergent thinking, including:

- 6-3-5 method
  - Six team members seated around a table
  - Each of whom writes down three design ideas
  - Circulated past each of the remaining team members in a sequence of five rotations of written (only) comment
- C-sketch method
  - Starts with a team seated around a table, with each member sketching one design idea on a piece of paper, and then proceeds as does the 6–3–5 method
- Gallery method
  - In the gallery method, team members first develop their individual, initial ideas within some allotted time, after which all of the resulting sketches are posted on a corkboard or a conference room whiteboard

How to Evaluate Existing Design Ideas

Find and understand them

- Literature search
- Advertising and product literature
- Design and legal codes
- Standards (often based on performance analysis available in the standards literature)

Leverage existing products

- Benchmark how they perform
- Dissect or reverse-engineer them

Mathematically analyze to determine performance

Morphological Chart: Organizing Functions and Means

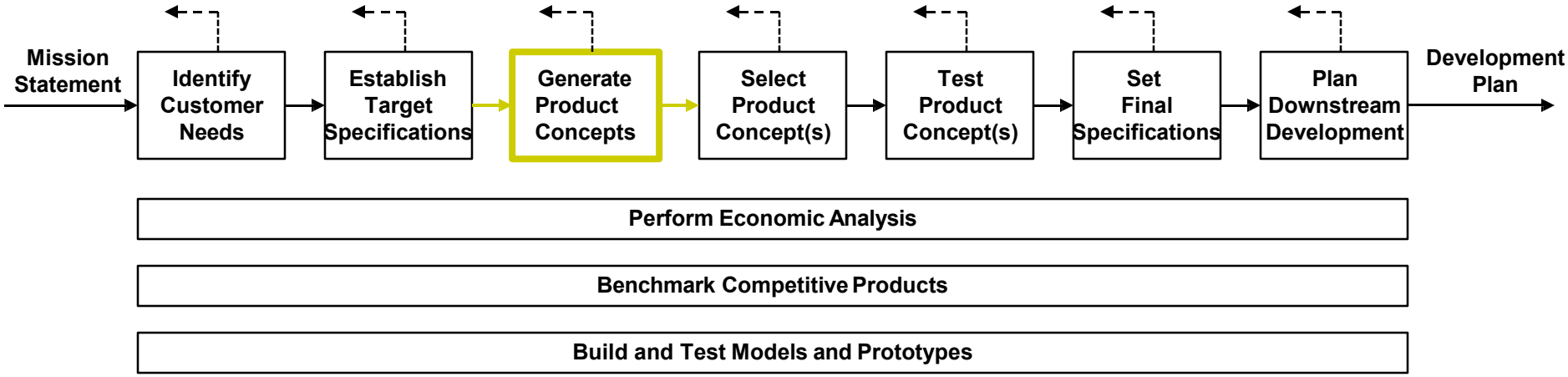
- List of functions or features
- List of different means of each function or feature identified
- Assemble designs in the classic *Chinese Menu* style

Functions listed in the leftmost column.
The means by which each can be implemented are arrayed along a row to each entry's right

MEANS / FUNCTION	1	2	3	4	5	6
Contain Liquid	Can	Bottle	Bag	Box	••••	••••
Fill and Seal Container	Fill and Heat Seal	Sealed Cap	Glue Container Material	Twist Top	Bottle Cap	
Empty Container	Pull Tab	Inserted Straw	Twist Top	Tear Corner	Unfold Container	Zipper
Resist Forces	Thick Walls	Flexible Materials				
Identify Product	Shape of Container	Distinctive Label	Color	••••	••••	••••

Choosing the Best Idea

… the best way to get a good idea is to get a lot of ideas… Linus Pauling



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- Numerical Evaluation Matrix
- Priority Checkmark Method
- Best of Class Chart

Numerical Evaluation Matrix: Juice Container

- Note that only three of the six objectives originally identified for this design are utilized here,
  - Because we think these objectives are more important than the others
  - and because we have metrics (and presumably data) for these objectives

Design Constraints (C) and Objectives (O)	Glass Bottle, with Twist-Off Cap	Aluminum Can, with Pull-Tab	Polyethylene Bottle, with Twist-Off Cap	Mylar Bag, with Straw
C: No sharp edges	×	×		
C: Chemically inert				
O: Environmentally benign			80	40
O: Easy to distribute			40	60
O: Long shelf life			90	100

Priority Checkmark Method: Juice Container

- This chart qualitatively reflects
  - A client's values in terms of the priority
    - Assigned to each objective
    - Ordered in the PCC

Design Constraints and Objectives	Priority (✓)	Glass Bottle, with Twist-Off Cap	Aluminum Can, with Pull-Tab	Polyethylene Bottle, with Twist-Off Cap	Mylar Bag, with Straw
C: No sharp edges		×	×		
C: Chemically inert					
O: Environmentally benign	✓✓✓			1 × ✓✓✓ ✓✓✓	0 × ✓✓✓ ••••
O: Easy to distribute	✓			0 × ✓ ••••	1 × ✓ ✓
O: Long Shelf Life	✓✓			1 × ✓✓ ✓✓	1 × ✓✓ ✓✓

Best of Class Chart: Juice Container

- This chart presents the rank ordering of the metrics results for each acceptable design.
- Notice that in this case, the client and the designer will need to select between the winner for the highest objective, or a design that wins on both of the other ones

Design Constraints (C) and Objectives (O)	Glass Bottle, with Twist-Off Cap	Aluminum Can, with Pull-Tab	Polyethylene Bottle, with Twist-Off Cap	Mylar Bag, with Straw
C: No sharp edges	*	*		
C: Chemically inert				
O: Environmentally benign			1	2
O: Easy to distribute			2	1
O: Long shelf life			2	1

Case Study:

DESIGN OF A STABILIZER FOR MICROLARYNGEAL SURGERY

Initial statements:

- Surgeons who perform vocal cord surgery currently use micro laryngeal instruments, which must be use at a distance of some 12-14in to operate on a surface with a very small structure (1-2 mm).
- The tremor in the surgeon's hand can become quite problematic at this scale.
- A mechanical system to stabilize the surgical instruments is required. The stabilization system must not compromise the visualization of the vocal cords.

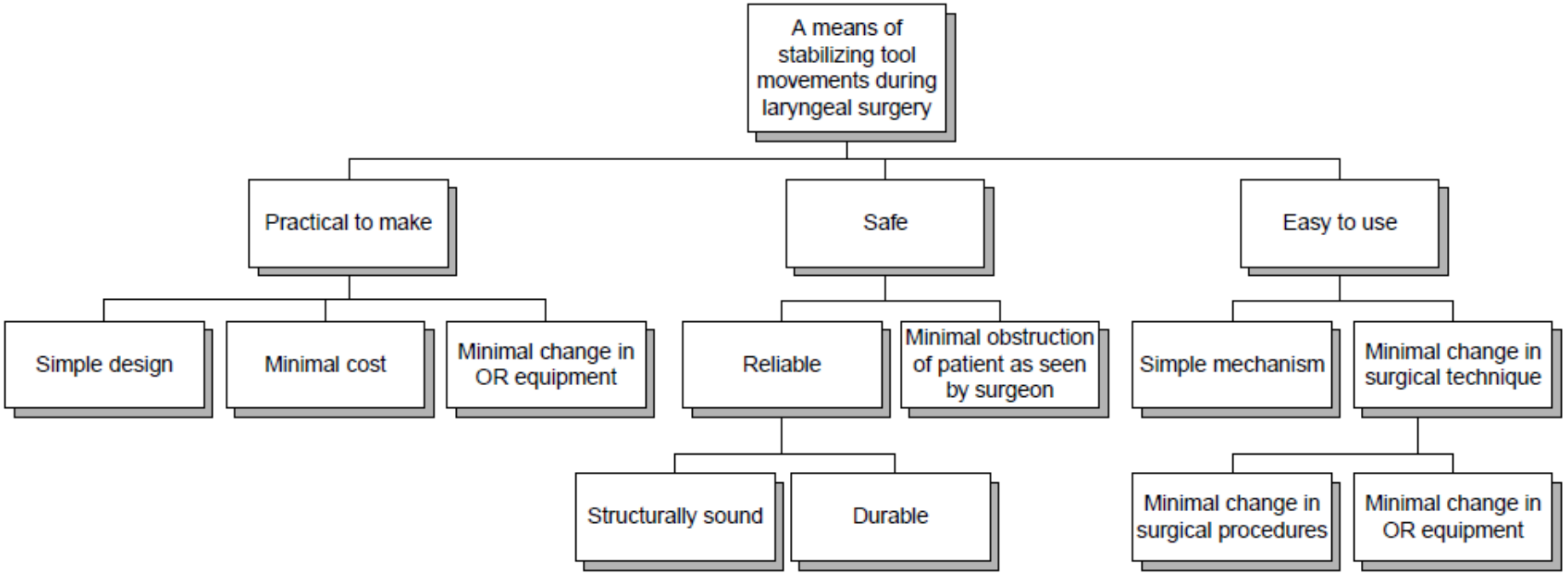
Revised Problem Statement:

- Microlaryngeal surgery seeks to correct abnormalities in the vocal cords. The abnormalities, such as tumors and cysts, are often 1-2mm in size and are typically removed from the vocal cords, which are only 0.15mm in size.

- During the operation, the surgeon must control his or her surgical instruments from a distance of 300-360mm (12-14in) due to the difficulties in accessing the vocal cords. At this small scale, the physiological tremor in the surgeon's hand can be problematic.

- Design a solution that minimizes the effects of hand tremors in order to reduce the unintentional movements at the distal end of the instrument to an amplitude of no more than 1/10 of a millimeter. The solution must not compromise visualization of the vocal cords.

Objective tree:



Constraint list for the device:

- Must be made of nontoxic materials,
- Must be made of materials that do not corrode,
- Must be serializable,
- Cost must not exceed $5,000,
- Must not have sharp edges,
- Must not pinch or gouge the patients,
- Must be unbreakable during normal surgical procedures.

Pairwise Comparison Chart (PCC)

Goals	Reduce Tremor	Sturdy	Safe	Inexpensive	Easily Used	Score
Reduce Tremor	••••	1	1	1	1	4
Sturdy	0	••••	0	1	0	1
Safe	0	1	••••	1	1	3
Inexpensive	0	0	0	••••	0	0
Easily Used	0	1	0	1	••••	2

- An entry "1" indicates the objective in that row is more important than that of the column in which it is entered.
- It shows that the reduction of the surgeon's tremor is the most important objective for this project while cost is the least important.

This ranking helped focus the team's attention, as well as seeming to accord with our intuitions.

Functional analysis

To determining what a successful design will actually do

The micro laryngeal stabilizer must do the following:

- Stabilize the instrument,
- Move the instrument,
- Stabilize the distal end of the instrument,
- Reduce surgeon's muscle tension (shaking tremors) during surgery,
- Stabilize itself.

Morphological Chart

- Functions and the corresponding means
- Implementations for each function
- Possible design solutions are assembled by selecting one means from each row

FUNCTIONS	POSSIBLE MEANS						
Stabilize instrument	Hand	Stand	Clamp	Magnet	Edge of Laryngoscope	Wire	
Move instrument	Hand	Gears	Pneumatics	Ball bearings	Lever	Pulley	
Stabilize distal end of instrument	Magnet	Crosswires	Track System	Spring	Gyroscopes	Ball Bearings	Stand
Reduce muscle tension of surgeon during surgery	Instrument Stand	Hand Platform	Pillow	Elbow Platform	Forearm Rest	Shoulder Sling	
Stabilize itself	Gyroscope	Springs System	Stand	Magnet	Suspension System	Rest against stable surface	Attach to Laryngoscope

- Conceptual design phase of the design process by narrowing the field of possible designs and, eventually, selecting a final design.

Final Design