VM450 & VE450

Concept Generation and Selection

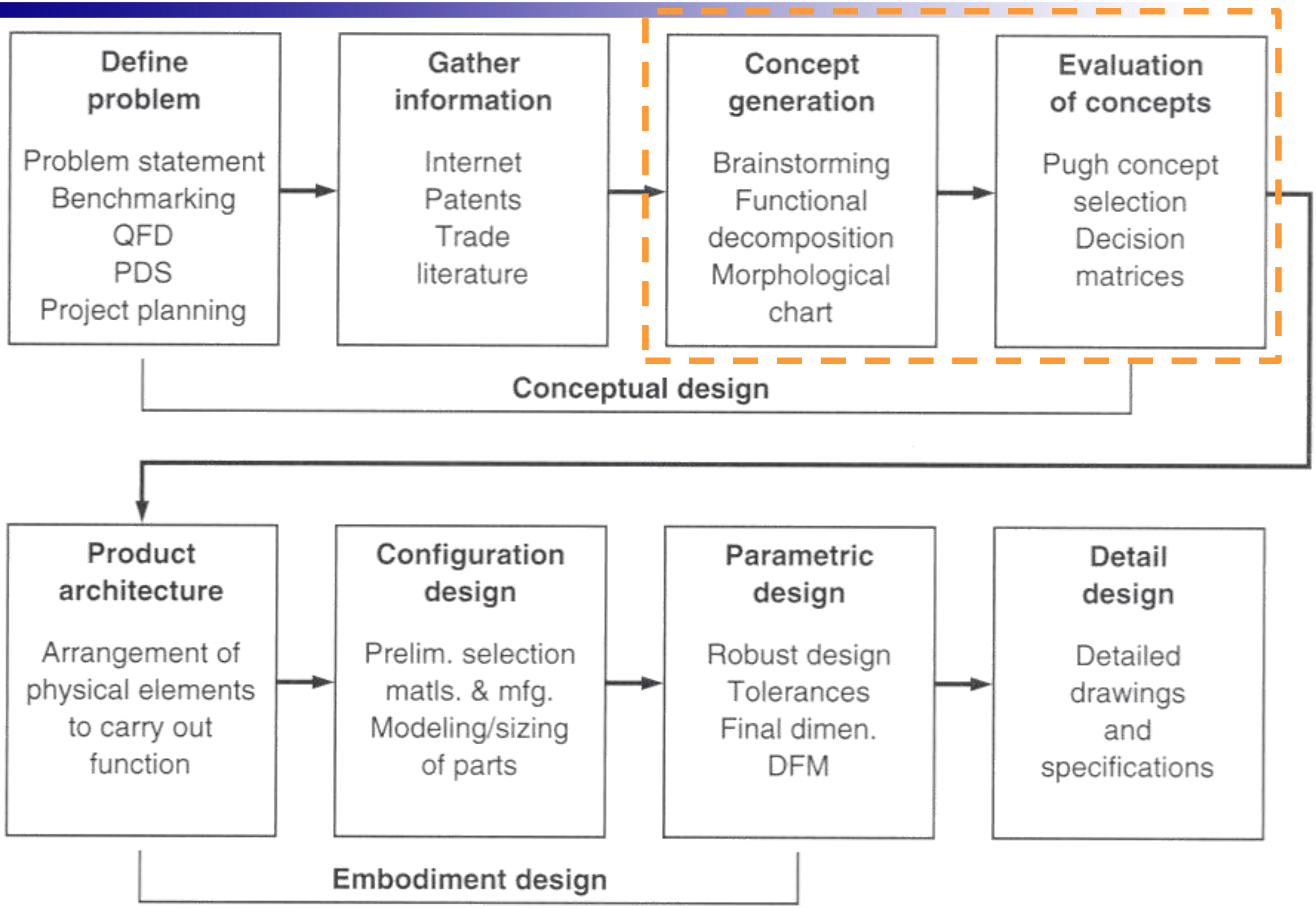
Outline

- Concept generation
  - Brainstorming
  - Morphological analysis
  - Theory of Inventive Problem Solving (TRIZ) (optional)

- Decision making
  - Decision matrices

"Maybe that's why young people make success. They don't know enough. Because when you know enough, it's obvious that every idea that you have is no good."
--Richard Feynman, Nobel Laureate

Product Development Process



Conceptual Design

- Objectives
  - ❈ Create solution concepts
  - ❈ Create a variety of solution concepts
  - ❈ All feasible
- Difficulty: for open-ended problems
  - ❈ Multiple solutions
  - ❈ Value of different solutions depends on end users or/and decision makers
- Constraints
  - ❈ Feasibility
  - ❈ Decision criteria (level of value depends on end users or/and decision makers)

Concept Generation: A Few Methods

- Brainstorming
- Morphological analysis
  - Functional synthesis
  - Reverse engineering
  - Synectics
- Theory of Inventive Problem Solving (TIPS/TRIZ)

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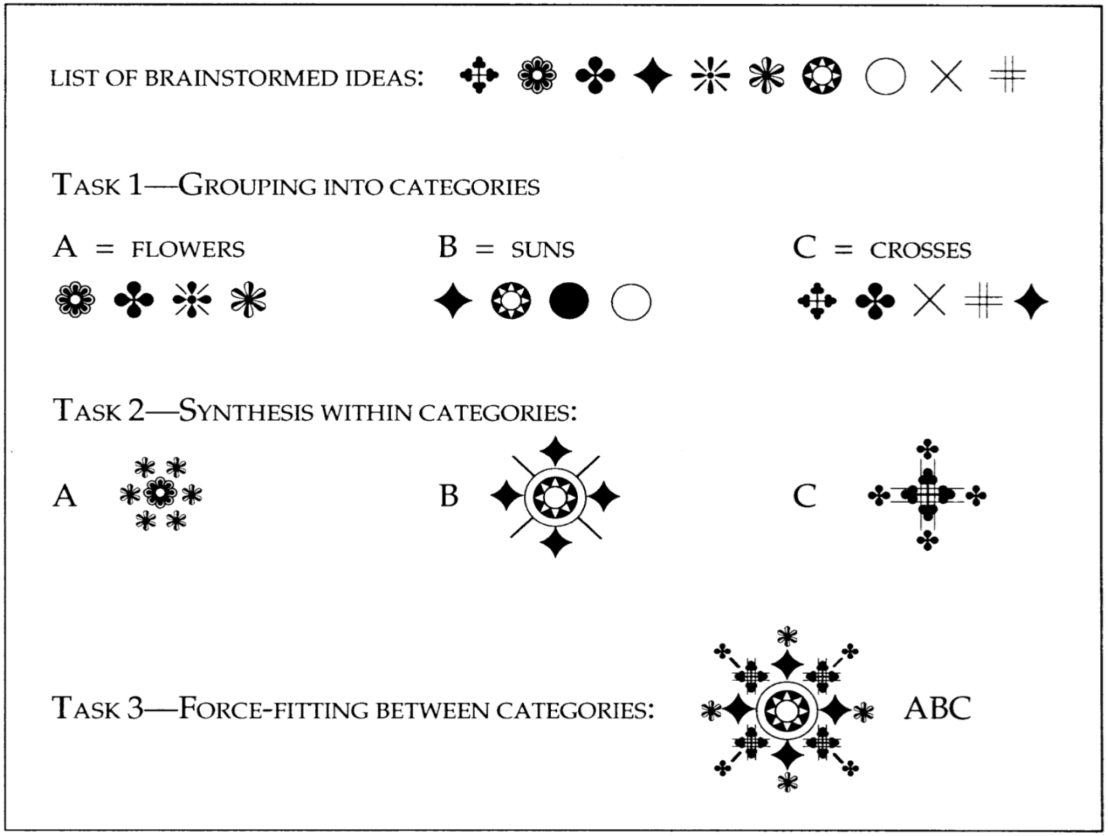
Brainstorming

- Definition
  - A group creativity technique designed to generate a large number of ideas for the solution of a problem.
- Process
  - A facilitator introduces the problem and asks for ideas.
  - If no ideas are forthcoming, the facilitator suggests a lead to encourage creativity.
  - All participants present their ideas. Participants should organize their thoughts so that ideas can be presented in detail and clearly.
  - The idea collector records all the ideas and make sure the record means what is intended by the originator

Brainstorming

- Process (cont'd)
  - The whole list is reviewed to ensure that ideas are understood.
  - Duplicate and obviously infeasible ideas are removed.
  - Ideas are connected and categorized.



- A popular method but the effectiveness hasn't been proven by solid evidences.

Concept Generation: A Few Methods

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Morphological Analysis

- A method for representing and exploring all the relationships in multi-dimensional, non-quantifiable (or non-commensurate) problems.
  - A technique allows people to think more efficiently.
  - Developed by Fritz Zwick
  - It is a non-quantified method for modeling complex problem
- J. W. von Goethe (1749-1832) first used the morphology as an investigative tool in science
  - *Increased computing power has sparked a resurgence of this method*

Morphological Analysis

- In biology, morphology means the form and structure of a plant or living system.

- The morphological chart is a way of creating concepts from the functional structure of the design problem.
  - Start with the function structure
  - Identify the required sub functions to achieve the desired design solution
  - Identify a number of physical solutions for each sub function
  - Combine the physical solutions into design concepts.

A systematic exploration of many possible design solutions

Morphological Analysis

- Example: a nail gun design

Convert electric energy to mechanical energy

- Rotary motor w/ transmission
- Linear motor
- Solenoid

Accumulating energy

- Potential: gravitational and elastic (spring, compressed air, etc.)
- Kinetic

Transfer energy to nails

- One impact
- Multiple impacts
- Push

Morphological Analysis

- Applied to System Design
  - Perform functional decomposition in a structured way
  - Search for solutions for each function (recursion becomes apparent)
  - Consider every variant for feasibility and suitability

- Function Synthesis
  - Generate solutions for the decomposed sub-functions, combined into a finite set of concept variants
  - Morphological matrix shows a breadth of form solutions
  - Concepts are generated directly from the functional specification

Morphological Analysis

- The morphological approach is based on the function analysis.

- Function analysis (or functional decomposition) is a *hierarchical* description of the intended behaviors
  - *Describe the functions and sub-functions* necessary to achieve the overall behavior defined by the PDS
  - Form and solution independent to stimulate creativity
  - *Generate function structure* that is a map of a focused design problem
  - Descriptions based on the specific physical forms of a device should be avoided

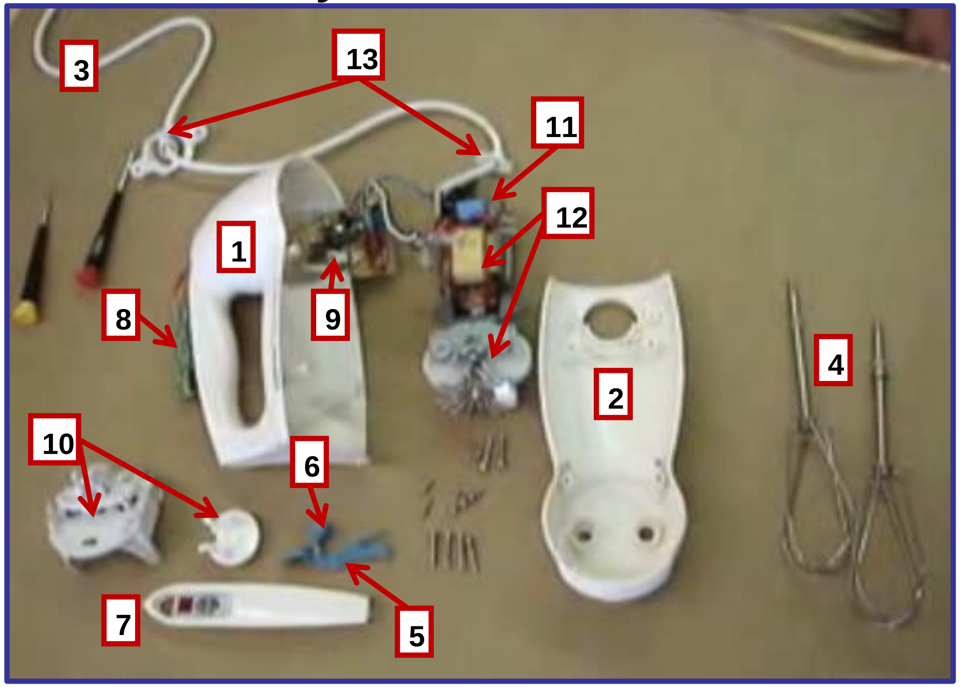
Morphological Analysis

- Process of Functional Decomposition
  - Input
    - Problem formulation and PDS
  - Process
    - Identify essential behaviors
    - Create the function structure
    - Identify solution principals
    - Identify flows of energy, materials, signals, etc.
    - Use the morphological chart to synthesize alternative solutions
  - Output
    - Conceptual designs spanning space defined by problem formulation (all or most the possibilities)

Morphological Analysis

- Physical decomposition (or reverse engineering)
  - A top-down approach to understanding a device
  - Helpful for the functional decomposition
    - Define root diagram of the physical system
    - Identify major subassemblies of the system
    - Identify connections between subassemblies

Toastmaster™
6-speed Hand Mixer

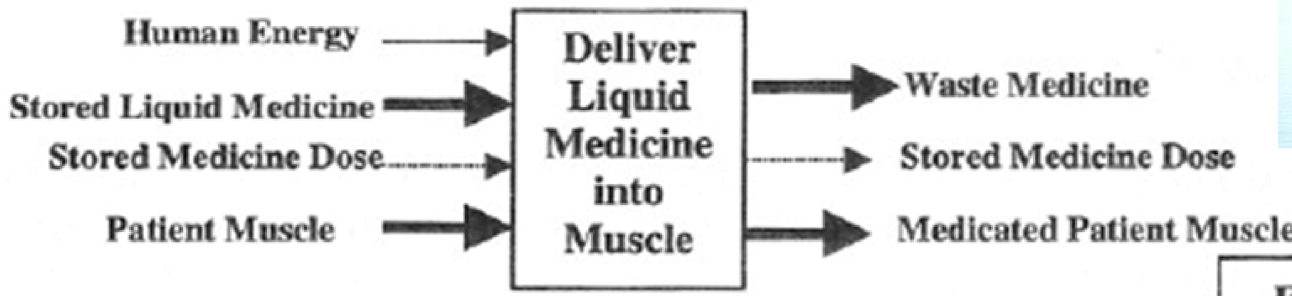


Function Structures

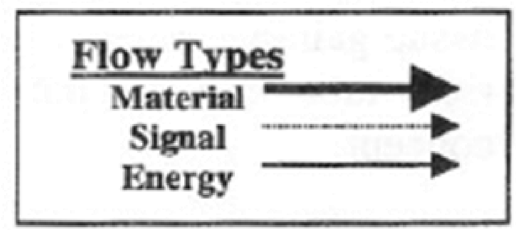
- Start from a black box
- Create function chains for flows of energy, materials and signal
- Arrange the function blocks in a desired order
- Add the energy, material and signal flows between the function blocks
- Examine each block to determine whether additional energy, material or signal flows are necessary
- Configure function chains into a complete functional model

Morphological Analysis

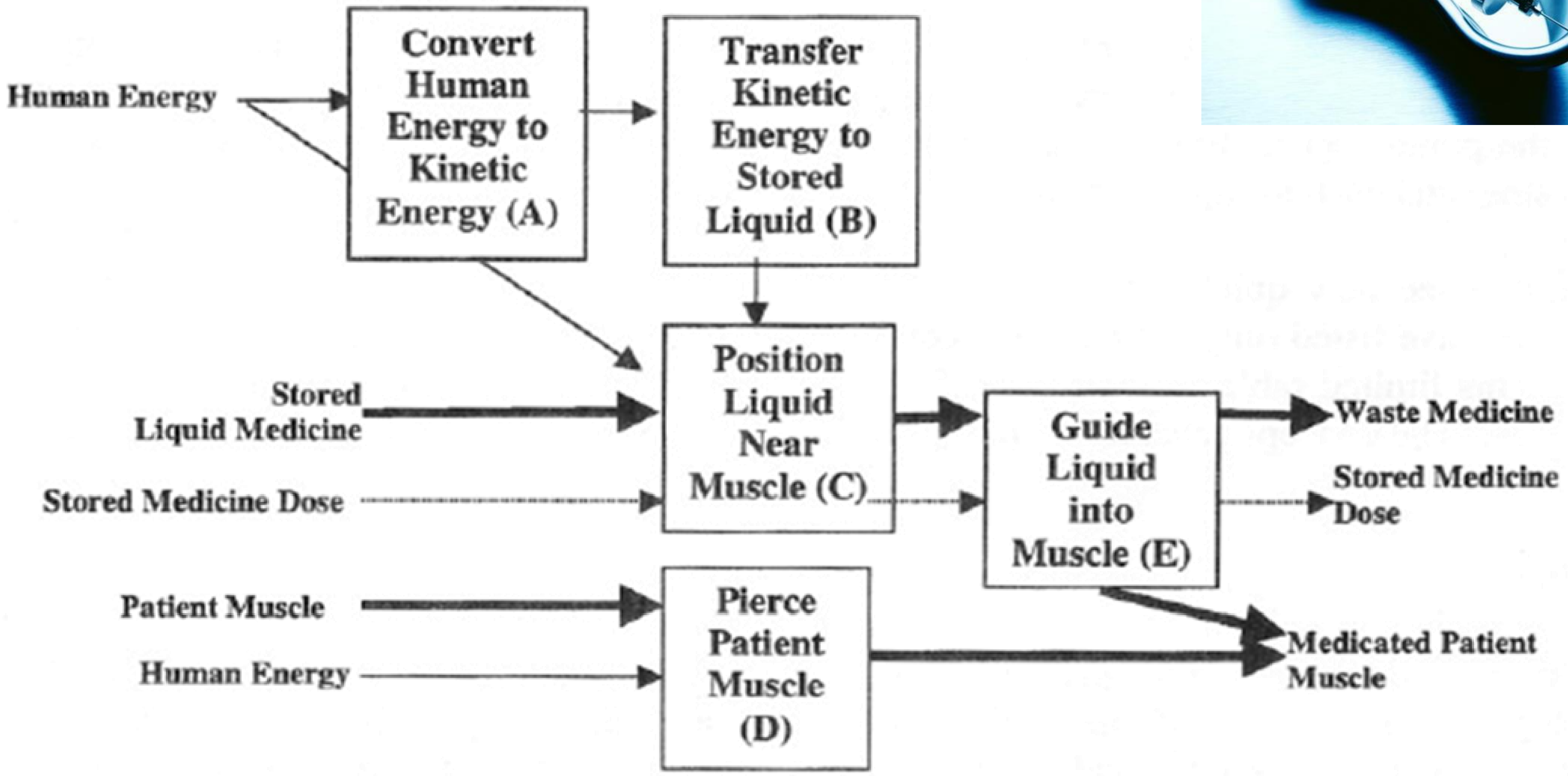
- Example: a portable syringe design



(a) General Function Structure



- Example: a portable syringe design



(b) Detailed Function Structure Showing Decomposition

Morphological Analysis

- Example: a portable syringe design
  - 2000 possible combinations
  - Select only feasible alternatives
  - One can easily create 8 to 12 distinct concepts.

Concept Number	Sub-Problem Solution Concepts				
	Convert human energy to kinetic energy	**Transfer kinetic energy to stored liquid**	**Position liquid near muscle**	**Pierce patient muscle**	**Guide liquid into muscle**
1	Hand pump	Heating liquid	Manual method	Sharp pointed tool	Rigid tube
2	Piston and cylinder	Physically displacing liquid	Suction device	Shearing tool	Flexible tube
3	Crank	Pressure differential	Adhesive	Hole punch	Misting sprayer
4	Fan	Mechanical stirrer	Physical connecter attached to skin	Multiple puncture sites	Osmosis
5		Radiation	Strap and cuff		Funnel

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TRIZ

- Theory of Inventive Problem Solving (TIPS/TRIZ)
  - This acronym is pronounced like “ta-rrees”
- Genrich Altshuler founded TRIZ (or TIPS in English)
  - Altshuler determined patterns of design evolution that engineering systems change or develop consistently with laws (analogous to evolutions of natural systems due to laws of nature)
  - Typical keys principles are repeated in solutions

- TRIZ is a process of reframing a designing task so that the key contradictions are identified and inventive principles are applied.

TRIZ

- Contradiction approach: model task as physical contradiction and use separation principles
  - Physical characteristic: some aspect of product or service must exist in an opposing state (creating the contradiction) to perform intended behavior
  - Four separation principles can be applied to the task
    - Separation in space
    - Separation in time
    - Separation within a whole and it's parts
    - Separation upon conditions

TRIZ

- 40 inventive principles
  - #9 Prior Counteraction
    - If it is necessary to carry out some action, consider a counteraction in advance
    - If an object must be in tension, provide anti-tension in advance.
  - #36 Phase Transition
    - Implement an effect developed during the phase transition of a substance; e.g., to control the expansion of ribbed pipes, they are filled with water and cooled to freezing."
  - …

TRIZ Process

- Identifying the problem
  - Consider useful function, harmful effects, and ideal results
- Formulate the problem
  - Restate the problem in terms of physical contradictions, and identify problems that could occur
- Search for previously well-solved problems
  - Find the principle that needs to be changed, and the principle that is an undesirable secondary effect from the 39 engineering parameters.
- Look for analogous solutions
  - Using the contradiction table and find the solution number among the 40 inventive principles

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Evaluation Method

- Design requires a succession of decisions about things like what concept to pursue or what material to use
- Evaluation is the first part of a “selection” type of decision making in which alternatives are first compared before making a decision on which is best.
- ALWAYS START WITH ANALYTICAL DATA TO EVALUATE PERFORMANCE WHEN AVAILABLE

Comparison Based on Absolute Criteria

- The emphasis is NOT on detailed examination but on eliminating any concepts that are not able to meet an important customer requirement.

- Evaluation based on judgment of feasibility
- Evaluation based on assessment of technology readiness
- Evaluation based on “go” or “no go”, while screening Customer Requirements

Comparison Based on Relative Criteria

- Identify a way to model performance of designs, then
  - Select an evaluation tool based on the type of performance measures and type of selection task
  - Apply a performance measure to all the alternatives

- When compare alternatives on more than one performance measure
  - Select an evaluation tool based on the type of performance measures and type of selection task
  - Determine weighting factors for each criterion
  - Determine a relative rating

Weighted Decision Matrix

Design criterion	Weight factor	Unit	Welded plates			Riveted plates			Cast steel plates		
			Value	Score	Rating	Value	Score	Rating	Value	Score	Rating
Material cost	0.18	$/lb	60	8	1.44	60	8	1.44	50	9	1.62
Manufacture cost	0.30	$	2500	7	2.10	2200	9	2.70	3000	4	1.20
Repair cost	0.12	Exp	Good	7	0.84	Excel	9	1.08	Fair	5	0.60
Durability	0.24	Exp	High	8	1.92	High	8	1.92	Good	6	1.44
Reliability	0.12	Exp	Good	7	0.84	Excel	9	1.08	Fair	5	0.60
Production time	0.04	Hour	40	7	0.28	25	9	0.36	60	5	0.20
					7.42			8.58			5.66

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					7.42			8.58			5.66

First, apply the best appropriate score.
Second, multiply this score by the weighting factor.

Weighted Decision Matrix

- How to determine weighting factors
  - Direct assignment – designer distributes 100 percents between different criteria according to importance.
    - Requires experience with product line.
  - Hierarchical objective tree – compares apples with apples.

Crane hook (1.0)

- Cost (0.6)
  - Materials (0.18)
  - Manufacture (0.30)
  - Repair (0.12)
- Quality (0.4)
  - Durability (0.24)
  - Reliability (0.12)
  - Production time (0.04)

Weighted Decision Matrix

- How to determine weighting factors
  - Direct assignment – designer distributes 100 percents between different criteria according to importance.
    - Requires experience with product line.
  - Hierarchical objective tree – compares apples with apples.
  - Pairwise comparison – an analytic hierarchical process

Criteria	A	B	C	D	Row Total	Weighting Factor
A	-	1	0	0	1	0.17
B	0	-	1	1	2	0.33
C	1	0	-	0	1	0.17
D	1	0	1	-	2	0.33
					6	1.00

"1" is assigned to the more important criterion

Weighted Decision Matrix

- Evaluation of design parameters and values

11-point scale	Description	5-point scale	Description
0	Totally useless solution	0	Inadequate
1	Very inadequate solution		
2	Weak solution	1	Weak
3	Poor solution		
4	Tolerable solution	2	Satisfactory
5	Satisfactory solution		
6	Good solution with a few drawbacks		
7	Good solution	3	Good
8	Very good solution		
9	Excellent solution exceeding the requirement	4	Excellent
10	Ideal solution		

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Summary

- Concept generation methods
- Make a selection decision

Acknowledgement
Some slides in this presentation are adapted from those provided by Prof. Linda Schmidt, M.E., University of Maryland