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ME 1110 – Engineering Practice 1

Engineering Drawing and Design - Lecture 12

Engineering Design Process – Part 2
Concepts, Decisions and Final design

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Objectives for today

- Learn remaining 5 phases in the Engineering Design Process
- Coursework DE2 – Satellite hinge





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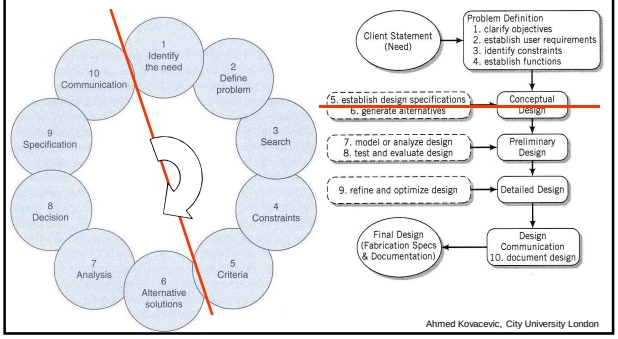
Engineering Design Process



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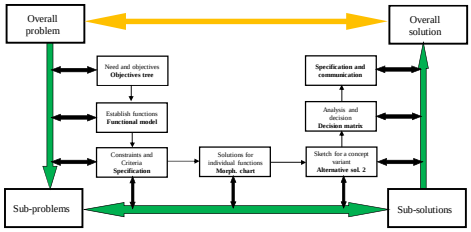
How to obtain an optimal solution



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6. Alternative Solutions

- **Derive alternative solutions for a problem**
- In order to solve the problem group has to propose a list of possible solutions. More innovative solution – better product.
- The nature of Invention

  "Me an inventor ??!" ⇒ "Why not?"

  Are you afraid of that??

- Building the List of possible solutions:

  a) Chekoff list or b)Brainstorming

  » Checkoff list – designed to direct thinking
  - It suggests possible ways how to change and use existing solution
  - Make a **list of the features** for the first solution: *shape, size, material, manufacturing method, colour, arrangement, …*
  - Try to conceive how the current **solution changes** if you change features **according to the words in your list**. Ask yourself:
    Why is the solution like it is?
    Will change be better or worse?
    What was the reason for the original solution to be made that way? …
  - Use check list words: "**MODIFY**" and "**REARANGE**" to guide or focus your efforts

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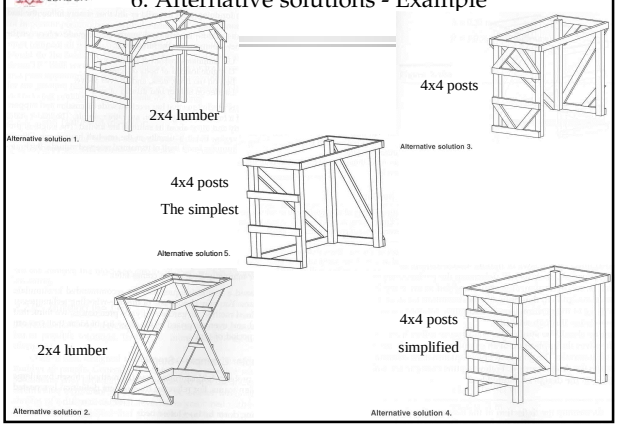
6. Alternative Solutions - Brainstorming

Brainstorming – short and effective group session for obtaining solutions

- Widely accepted method
- The **Leader states the problem** and **ideas** for solutions are **invited**
- The session lasts for approximately **one half of an hour**
- Important rules in brainstorming process
  - Groups of **4-8 members** are the most successful,
  - **Free expression** is essential. Evaluation of ideas must be avoided. Nothing should be said to discourage a group member from speaking,
  - **The leader is key figure**. The leader sets the tone, tempo, encourages members to speak, and give a stimulus when things begin to drag
  - **The members** of the group **are equal**. No one should try to impress, support or discourage other member of the group.
  - **Recording is necessary**. Everything that is said must be recorded, either mechanically or manually.
- Often, group needs few minutes to rid out of the natural reserved attitude.
- Mostly, brainstorming is fun
- Always, brainstorming gives surprisingly high number of ideas.

6. Alternative solutions - Example



Brainstorming Exercise

- As a team use brainstorming session to generate as many ideas for each of four functions in a mousetrap design:

Attract mouse
Stop mouse
Store mouse
Export mouse

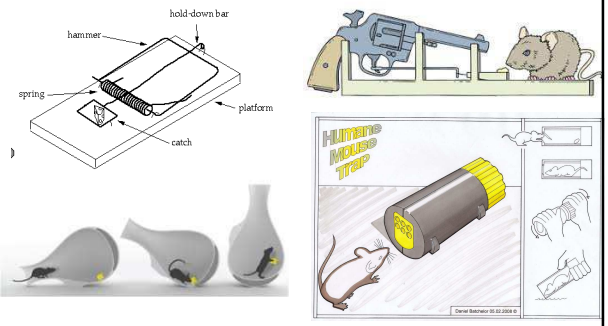
- Spend 3 minutes for each sub-function to generate and sketch as many ideas as possible. List these next to sub-functions.

Example:

Morph Chart for Mousetrap Design

SUBFUNCTION	SOLUTION IDEA		
Attract mouse	Cheese tunne...	squeaks	robot
Stop mouse	spring/kill	block exit	anesthesia
Store mouse	box	cage	ziplock
Export mouse	release outdoors	recycle	catapult

Example: Mousetrap alternative solutions



Propose 3 alternative solutions

7. Analysis

- **The purpose of design process is to find the optimal solution.**
- The analysis is a pivotal point in the design process
- The **purpose of analysis** is to **determine performance** capability of each alternative solution.
- By this means, solutions which are not proved during this phase may be discarded or modified – possible repetition of some previous steps.
- Analysis involves the use of **mathematics and engineering principles** to determine the performance of a solution.
- Engineer must select appropriate method of analysis.
- Mostly, analysis performed by engineers is based on **laws of nature, laws of economics and common sense**.

7. Analysis – cont. (1)

- **The Laws of Nature**
  - » Many laws you already know – many more jet to learn
  - » **Conservation principles** – mass, energy, momentum …
  - » Laws: Hooke's : load – deformation
    Newton's: forces – resulting reactions and motions
    Laws of thermodynamics: work – energy
  - » **Analysis should validate an idea against the laws of nature**.
  - » The most common means of validation is by **mathematical modelling** of the system.
  - » Results can be presented in graphs or tables.
  - » Sometimes, scale models are necessary to evaluate proposed design.

7. Analysis – cont. (2)

- **The Laws of Economics**
  - » Economics and money are part of engineering design and decision making.
  - » Many ingenious project or desired parts did not reach market because these are deemed to be economically infeasible.
  - » Question: How does somebody know if a product (component) is going to be economically successful and confirmed? There is a mathematical apparatus called **Statistics!**
  - » This gives an idea of the potential market, cost of manufacturing, potential price of the product, potential profit or loss; all is based on sampling of a small representative group.

7. Analysis – cont. (3)

- **Common Sense**
  - » Engineer must believe in engineering calculations and statistics, but must always check the validity of all these calculations.

Prove: 2=1

$a = b \quad | \ *a$

$a^2 = ab \quad | \ +(a^2 - 2ab)$

$a^2 + (a^2 - 2ab) = ab + (a^2 - 2ab)$

$2(a^2 - ab) = a^2 - ab \quad | \ /(a^2 - 2ab)$

$2 = 1$

Prove: 2=0

$x = 1 \quad | \ ^2$

$x^2 = 1 \quad | \ ^{-1}$

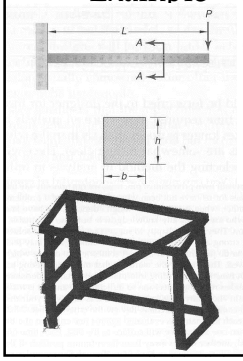
$x^2 - 1 = 0$

$(x + 1)(x - 1) = 0 \quad | \ /(x-1)$

$x + 1 = 0$

$1 + 1 = 0$

7. Analysis - Example



Solution The deflection of the end of a cantilever beam for the configuration shown is given by

$$d = \frac{PL^3}{3EI} \quad \text{(constraint equation)}$$

where d = deflection, m

E = modulus of elasticity, a material constant, Pa

$= 2.07(10^{11})$ Pa for structural steel

I = moment of inertia, m^4

For a rectangular cross section

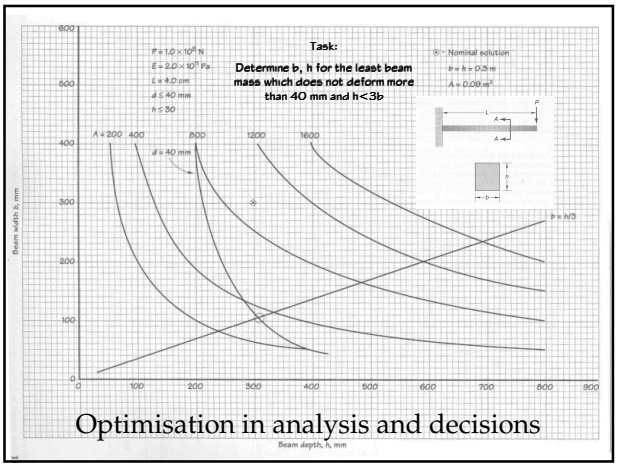
$$I = \frac{bh^3}{12} = \frac{(0.2)(0.4)^3}{12} = 1.067(10^{-3})\ m^4$$

Therefore

$$d = \frac{(10^5)(4)^3}{3(2.07)(10^{11})(1.067)(10^{-3})} = 9.66\ (10^{-3})\ m = 9.7\ mm$$

P, N	L, m	h,m	b,m	E, Pa	I, m^4	d,m
1.00E+05	4	0.1	0.2	2.07E+11	1.67E-05	0.618357
1.00E+05	4	0.2	0.2	2.07E+11	0.000133	0.077295
1.00E+05	4	0.3	0.2	2.07E+11	0.00045	0.022902
1.00E+05	4	0.4	0.2	2.07E+11	0.001067	0.009662
1.00E+05	4	0.5	0.2	2.07E+11	0.002083	0.004947
1.00E+05	4	0.6	0.2	2.07E+11	0.0036	0.002863

CANTILEVER BEAM DEFLECTION FOR RECTANGULAR SECTION



Optimisation in analysis and decisions

8. Decision

- **The "toughest" part** of the design process is to decide which solution is "the best". Why is it so?

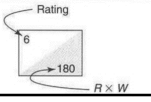
  The answer is **"Trade off!"** – The best solution is newer "the best" against each single criteria. Compromise!
- Organisation for Decision
  - » As much information about each solution as possible
  - » Available information should fairly and accurately represent the alternatives.
- Criteria in Decision
  - » The objective of design: to find the best solution within the available time.
  - » Thorough search, alternative solutions and analysis give a chance for fair decision. **Decision making – art and <u>science</u>**

8. Decision matrix

Criteria	Weight, W%	Alternative Solutions 1	2	3	4	5	6	7
Ease of assembly	35	4 / 140	5 / 175	6 / 210	8 / 280	8 / 280		
Functionality	25	5 / 125	8 / 200	8 / 200	8 / 200	8 / 200		
Cost	25	6 / 150	6 / 150	5 / 125	7 / 175	7 / 175		
Stability	15	7 / 105	3 / 45	9 / 135	9 / 135	10 / 150		
Total	100	520	570	670	790	805		

Rating scale R

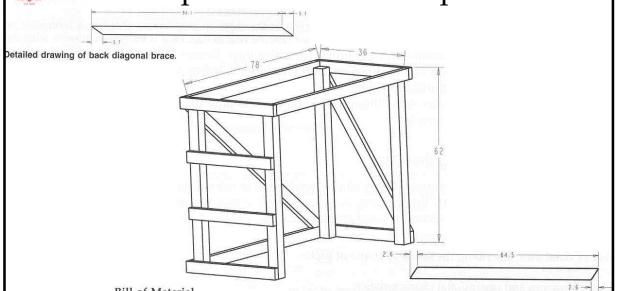
Excellent	9–10
Good	7–8
Fair	5–6
Poor	3–4
Unsatisfactory	0–2



9. Specification

- Graphical and technical specification:
  - » **Detailed drawings** that describe the size and shape of each part.
  - » **Layouts** which define clearances and operational characteristics
  - » **Assembly drawings** to clarify relationship of parts.
  - » **Written notes**, standards, specification concerning quality and tolerances.
  - » A complete **bill of materials**

9. Specification - Example



Detailed drawing of back diagonal brace.

Detailed drawing of end diagonal brace.

Bill of Material

Item	Amount Required	Cost*, $
2" × 4" × 16'	3	18.00
2" × 4" × 8'	1	2.89
4" × 4" × 8'	4	32.00
3" deck screws	1 lb.	2.50
		55.39

10. Communication

- Selling the Design
  - » It takes place all the way through the design process.
  - » Engineer must convince customers, management, sales etc. on the advantages of the product.
  - » There are many ways of communication. The most used are:
- The Written Report
  - » Appropriate cover page
  - » Abstract
  - » Table of contents
  - » Body
  - » Conclusion and recommendation
  - » Appendices
- The Oral Presentation
  - » To be prepared: be familiar with subject and to have presentation prepared and checked carefully with only important data
  - » To be convincing, speak clearly and loudly enough, look to the audience

Instead of Conclusion

Engineering design
Design process
Bloom's Taxonomy on learning
Customer satisfaction
Constraint
Criteria
Reverse engineering
Alternative solutions
Check off lists

Brainstorming
Solution space
Analysis
Synthesis
Payoff function
Decision matrix
Specification
Communication

DE2 – Satellite hinge

Conduct the engineering design process to select an optimal hinge for a small satellite panel deployment

1) *Define the problem* in one sentence
2) *Define objectives for design* - half page
3) Define design *constraints*.
4) *Make graphs angle-time*, velocity-time, acceleration-time, torque-time for both hinges (A) & (B) (Fig.2)
5) *Specify 4 design criteria* which will later be used to make decision.
6) Propose three alternative solutions for hinge
7) Make an *analysis* of all three solutions: weight, size, approximate cost of material.
8) Make the *decision matrix* and select the best satellite hinge.