EP145 Introduction to Engineering

Topic 5

Engineering Design

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http://www1.gantep.edu.tr/~bingul/ep145

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Introduction

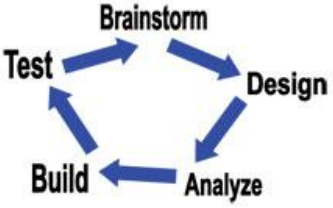
We said:
*Engineers uses the principles of physics and mathematics to **design** millions of products and services that we use in our everyday lives*.

In this chapter we will consider the constitutes of the ***design process***.

Engineering Design Process

The engineering design process involves a series of steps that lead to the development of a new product or system [1, 2]:

1. Recognize the need for a product or a service
2. Define and understand the problem
3. Do preliminary research and preparation
4. Conceptualize ideas for possible solutions
5. Synthesize the findings
6. Optimize solutions
7. Produce and improve your design
8. Present the final solution



1. Recognizing the need

People should state the challenge problem in their own words, and try to answer the following questions:

- What is the problem?
- What is our goal?
- What do we want to accomplish?
- How can I design a _____ that will _____?

2. Problem Definition and Understanding

- This is the most important step in any design process.
- The best way to fully understand a problem is by asking many questions:
  - What are the project requirements?
  - What are the constraints (limitations)?
  - Are there restrictions on the size or the type of materials that can be used?
  - How much money are you willing to spend on this project?

3. Resarch & Preparation

A significant amount of time is spent on research.

- Investigate existing technologies and methods to use
- Explore many possible solutions
- Determine the materials and tools

4. Conceptualization

- Brainstorm different designs
- Build upon the wild and crazy ideas of others
- Draw a diagram of your idea
- Take into account environmental and cultural considerations
- Consider
  what analyses you must do and
  how you will test it to make sure it works

5. Synthesis

Good engineers are analytical, detailed oriented, and productive.

During this stage consider details:

- perform calculations
- run computer models
- narrow down the type of materials to be used
- answer how the product is going to be fabricated

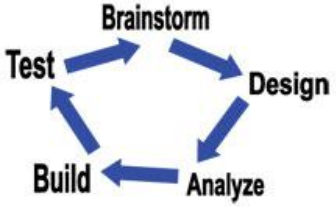
6. Optimisation

Optimization means minimization or maximization.

Based on the needs identified, select the most promising idea.

7. Produce and Refine the Design

- Assign team tasks
- Build a Model or Prototype
- Test it against your design objectives
- Discuss how you could improve your product



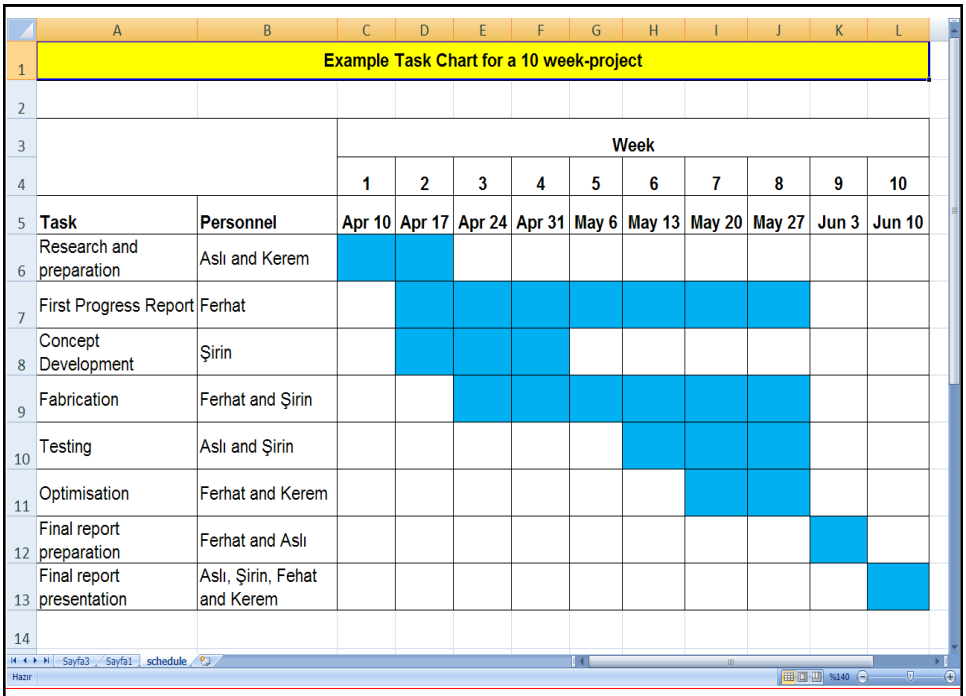
8. Presentation

Now, you have a final solution.

- Prepare not only an oral presentation but also a written report.
- Communicate your solution to the client, who may be
  - your boss,
  - another group within your company, or
  - an outside customer.

Project Scheduling and Task Chart

- Project scheduling is a process that engineering managers use to ensure that a project is completed on time and within the allocated budget.
- The project schedule is used to estimate what resources are needed at what time and for how long.
- In project management, a schedule consists of a list of a project's terminal elements with intended start and finish dates.



Example Task Chart for a 10 week-project

Task	Personnel	Week 1 (Apr 10)	2 (Apr 17)	3 (Apr 24)	4 (Apr 31)	5 (May 6)	6 (May 13)	7 (May 20)	8 (May 27)	9 (Jun 3)	10 (Jun 10)
Research and preparation	Aslı and Kerem	■	■								
First Progress Report	Ferhat		■	■	■	■	■	■	■		
Concept Development	Şirin		■	■	■						
Fabrication	Ferhat and Şirin			■	■	■	■	■	■		
Testing	Aslı and Şirin						■	■	■		
Optimisation	Ferhat and Kerem							■	■		
Final report preparation	Ferhat and Aslı									■	
Final report presentation	Aslı, Şirin, Fehat and Kerem										■

Decision Matrix

A **decision matrix** is a list of values in rows and columns that allows an analyser to systematically

- identify
- analyze
- rate

the performance of relationships between sets of values and information.

A Case Study: Can Crusher

Empty Aluminum soda, cola and etc. cans can be recycled.

You are asked to design a simple device to crush aluminum cans.

There are five criteria whose assigned weights are:

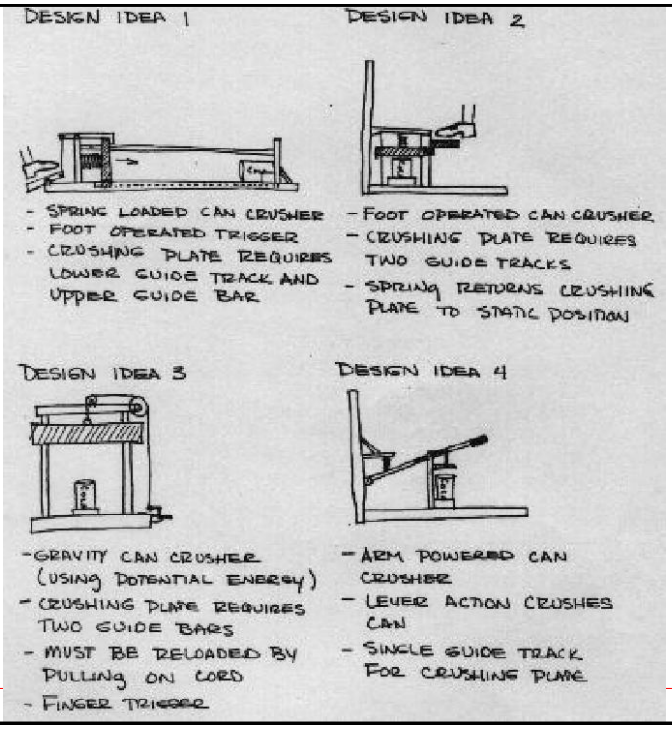
- Safety 30 percent (30 points)
- Ease of use 20 percent (20 points)
- Portability 20 percent (20 points)
- Durability and strength 20 percent (10 points)
- Cost 10 percent (10 points)

A Case Study: Can Crusher

Four alternative solutions to this problem are as follows (see next page):

1. A spring-loaded crusher (D1)
2. A foot-operated device (D2)
3. A gravity-powered dead weight crusher (D3)
4. An arm-powered lever arm crusher (D4)
5. Any other solution designed by you*!*

http://www.iisme.org/etp/HS%20Engineering-%20Engineering.pdf



Each solution against the five criteria are compared by using a **decision matrix**. Obviously, D4 is the best design.

Example decision matrix for evaluating alternative can crusher designs (D1, D2, D3, D4)

		Rate (R)				R x W			
Criteria	**Weight (W)**	**D1**	**D2**	**D3**	**D4**	**D1**	**D2**	**D3**	**D4**
Safety	30	2	9	2	9	60	270	60	270
Easy of use	20	8	9	6	9	160	180	120	180
Portability	20	5	3	2	8	100	60	40	160
Durability	20	8	8	6	8	160	160	120	160
Cost	10	6	5	7	8	60	50	70	80
Total						**540**	**720**	**410**	**850**

Rating:	
Excellent	*9-10*
Good	*7-8*
Fair	*5-6*
Poor	*3-4*
Unsatisfactory	*0-2*

Best

Linear Programming

A linear programming problem may be defined as the problem of optimizing a linear function subjected to linear constraints. The constraints may be equalities or in equalities.
Here is a simple example:

$$x_1 + 2x_2 \le 4$$
$$4x_1 + 2x_2 \le 12$$
$$-x_1 + x_2 \le 1$$
$$x_1 \ge 0$$
$$x_2 \ge 0$$

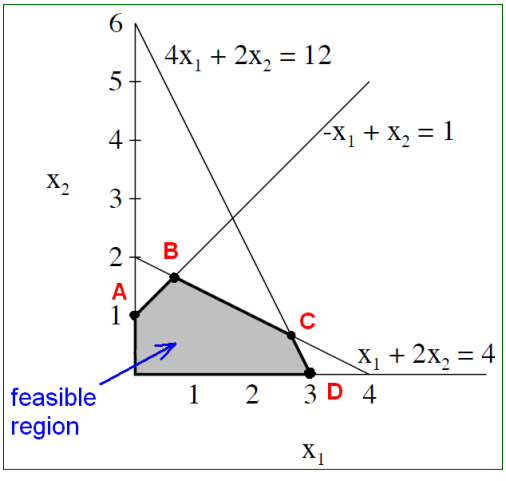
$$Z_{max} = x_1 + x_2$$

In this problem,
there are two unknowns (x_1 and x_2) and five constraints.

*The function to be maximized is called the **objective function**.*

Since we have two unknowns, we can use a graphical method.
We search the point (x_1, x_2) in the plane, that achives the maximum of $x_1 + x_2$.

In general maximum occurs at corner points of the polygon obtained by the intersection points of the lines:



The solution is

Point	Z = (x_1+x_2)
A(1, 0)	1.000
B(5/3, 8/3)	4.333
C(8/3,10/3)	6.000
D(3, 0)	3.000

Maximum is the solution.

EXAMPLE 1

Assume that you have been asked to look into purchasing some storage tanks for your company, and for the purchase of these tanks, you are given a budget of ₺1680. After some research, you find two tank manufacturers that meet your requirements. From Manufacturer *A*, you can purchase 16 m^3 capacity tanks that cost ₺120 each. Moreover, the type of tank requires a floor space of 7.5 m^2. Manufacturer *B* makes 24 m^3 capacity tanks that cost ₺240 each and that require a floor space of 10 m^2. The tanks will be placed in a section of a lab that has 90 m^2 of floor space available for storage.

You are looking for the greatest storage capacity within the budgetary and floor-space limitations. How many of each tank must you purchase?

Solution will be given in the lecture.

EXAMPLE 2

An elementary school wants to send children on a field trip to a museum. The museum staff has informed the school that tours can be scheduled for no more than 50 total people and the school must provide at least one adult chaperone for every 9 students.

a) Make a list of constraints
b) Graph the feasible region
c) Calculate and label the vertices

Solution will be given in the lecture.

EXAMPLE 3

Aslan's Chocolates produces semisweet chocolate chips and milk chocolate chips at its plants in Florya and Arena. The Florya plant produces 3000 kg of semisweet chips and 2000 kg of milk chocolate chips each day at a cost of 1000 TL, while the Arena plant produces 1000 kg of semisweet chips and 6000 kg of milk chocolate chips each day at a cost of 1500 TL. Aslan has an order from Fenerium Supermarkets for at least 30,000 kg of semisweet chips and 60,000 kg of milk chocolate chips.

How should Aslan schedule its production so that it can fill the order at minimum cost? What is the minimum cost?

Solution will be given in the lecture.

Questions

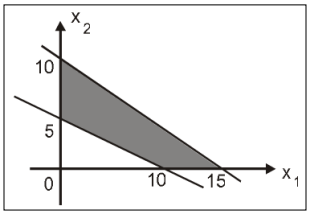
1. List five sports-related products that you think should be designed to make playing sports more fun [2].
2. List five internet-based services that are not currently available, but that you think will eventually become important [2].
3. Investigate the design of at least two different pens and mechanical pencils. Write down
   a) your important design parameters
   b) the advantage and disadvantage associated with each design [2].
4. In the near future, NASA is planning to send a spaceship with humans to Mars. Write down important concerns and issues that must be planned on this trip such as:
   a) How long it would take to go to Mars?
   b) What type and how much food reserves are needed for this trip?
   c) What type of exercise equipment should be on board so muscles won't atrophy on this long trip?
   d) What should be done with the waste?
   e) What is the energy requirement for such a trip [2]?
5. What is the Project Scheduling?
6. What is the Decision Matrix?

7. A decision matrix to evaluate the two alternative designs (D1 and D2) is given below. Fill the table and indicate the best design.

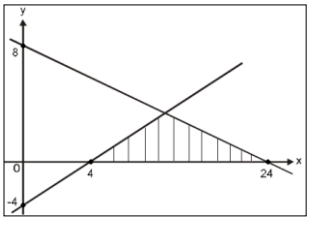
		Rate (R)		R x W	
Criteria	**Weight (W)**	**D1**	**D2**	**D1**	**D2**
Safety	30	4	4		
Easy of use	20	3	4		
Portability	15	4	4		
Durability	25	4	3		
Cost	10	3	2		
Total					

Rating:	
Excellent	*5*
Good	*4*
Fair	*3*
Poor	*2*
Unsatisfactory	*1*

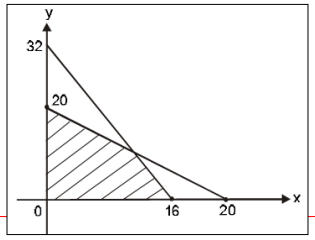
8. The objective function for the feasible region given right is $Z_{max} = 2x_1 + 4x_2$. Find Z_{max}.



9. The objective function for the feasible region given right is $Z_{max} = 4x_1 + 4x_2$. Find Z_{max}.



10. Write down the equations of the feasible region given right.



11. Find Z_{min} for the constraints and objective function given right.

$$2x_1 + x_2 \geq 100$$
$$x_1 + x_2 \leq 80$$
$$x_1, x_2 \geq 0$$
$$Z_{min} = 3x_1 + 2x_2$$

12. Find Z_{max} for the constraints and objective function given right.

$$2x_1 + 4x_2 \leq 1600$$
$$6x_1 + 2x_2 \leq 1800$$
$$x_1 + x_2 \geq 300$$
$$x_1 \geq 50$$
$$0 \leq x_2 \leq 350$$
$$Z_{max} = 2x_1 + 6x_2$$

13. A painter has exactly 32 units of yellow dye and 54 units of green dye. He plans to mix as many gallons as possible of color A and color B. Each gallon of color A requires 4 units of yellow dye and 1 unit of green dye. Each gallon of color B requires 1 unit of yellow dye and 6 units of green dye.
    a) Make a list of constraints,
    b) Graph the feasible region *by using the GNUplot*
    c) Calculate and label the vertices
    d) Find the maximum number of gallons he can mix.

14. In a company, two products P1 and P2 are produced in the three different machines M1, M2 and M3. P1 is produced with M1 in 11 min, with M2 in 7 min and with M3 in 6 minutes; while, P2 is produced with M1 in 9 min, with M2 in 12 min and with M3 in 16 minutes. The maximum working capacity of the machines M1, M2 and M3 are 165 h, 140 h and 160 hours respectively. The profit of P1 is 900 TL and of P2 is 1000 TL. What is the maximum profit of the company?

References

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