GE105: Introduction to Engineering Design

Problem Formulation

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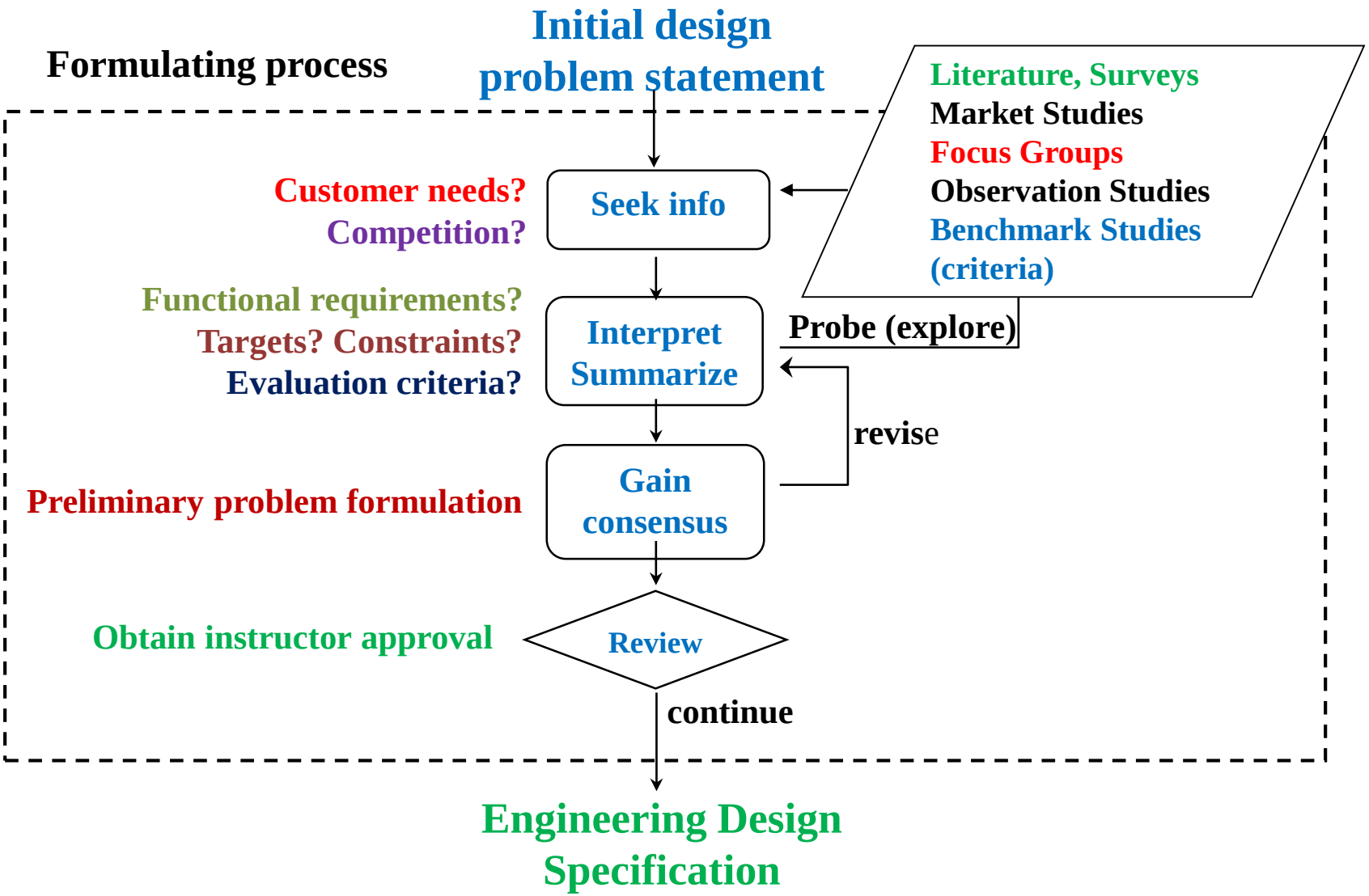
The Nature of Design

Design problems have:

- An objective (a *goal)* to be achieved
- Some *constraints* within which the objective/goal must be achieved
- Some *criteria* by which a good solution is recognized

- *Constraints* set specific (usually quantitative) targets or limits
- *Criteria* are more flexible and might be used for judging between different design proposals, each of which meets the specific constraint targets.

Decisions and information flow during problem formulation



Need Analysis

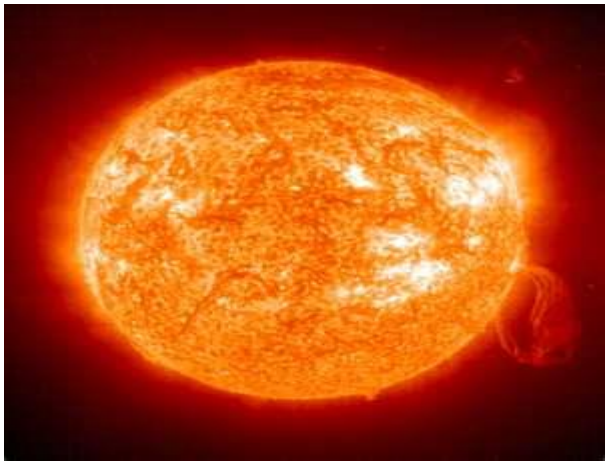
The purpose is to make a case and will help in defining objectives, constraints, and criteria.

- Quality needed
- Efficiency.
- Reliability
- Safety
- Economic
- Social and ethical issues.
- Aesthetics (nature of art, beauty, and taste)
- Maintainability
- Flexibility
- Durability
- Environmental impact

Design Objectives

The complete statement of the design objectives is an essential part of the problem formulation.

Unless the designer is aware of the totality of the problem he is obviously not able to produce the best solution.

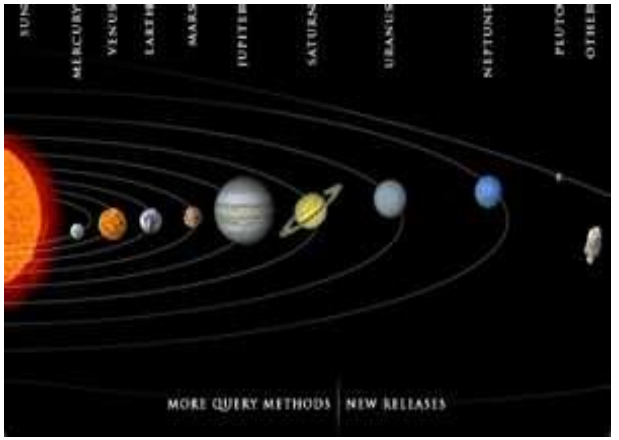


Primary Object (in Solar System): The Sun

It is convenient to consider two components of the design objectives:-

(i)Primary Objective(s) ⇒ (MUST).

(ii)Secondary Objective(s) ⇒ (WANTS).



Secondary Objects (in Solar System): The Planets

Design Objectives

The Primary Objective may be defined as that aspect of the problem formulation which is specified by the customer.

For example a customer presents a problem to design a machine for packaging a powdered foodstuff. This is the primary objective of the design.

If the machine fails to achieve these requirements it is a total failure. Whenever questions of relative importance are considered the primary objective is obviously the most important.

Main Objective is Customer Defined

Helicopter Crash due to Engine Failure

Design Objectives

The Secondary (Less important) **Objectives** may be described as those which are not necessarily specified but are nevertheless essential for the satisfactory achievement of the primary objective.

Examples of secondary objectives include:

(a) Low initial and operating costs.

(b) Freedom from contamination (the presence of a minor constituent in another chemical or mixture).

(c) Safety of operation.

(d) Ability to cope with variable foodstuff properties.

(e) Ease of operation, maintenance and repair

(f) Ability to be installed in the factory.

Secondary Objective here is Safety

Design Constraints

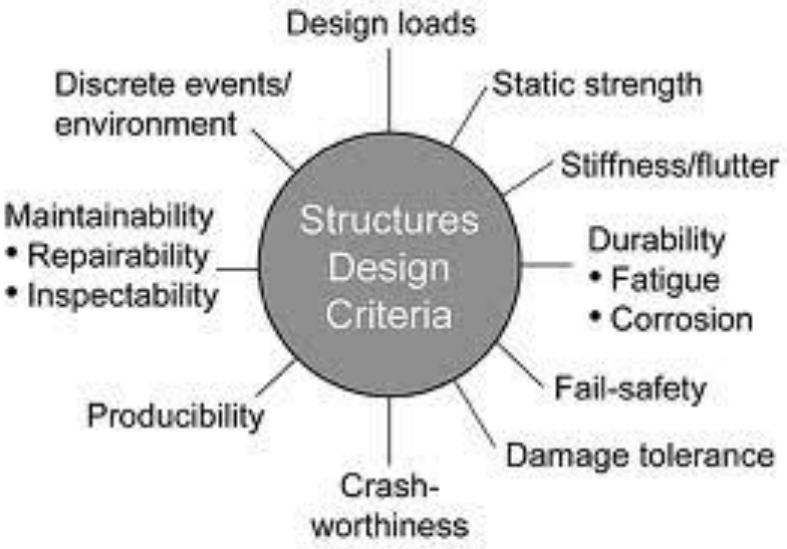
- Constraints are factors that limit the engineer's flexibility.
- They form the design envelope (feasible design space)

Design Constraints

- **Cost:** Cost to design, produce, maintain, support, guarantee, be competitive
- **Time:** Complex project schedules, delivery dates, down-stream process, time to market
- **Knowledge**
- **Legal, ethical:** Patents, intellectual property, product liability, safety requirements.
- **Physical:** size, weight, power, durability
- **Natural factors:** topography, climate, resources
- **Company practices:** Common parts, manufacturing processes
- **Human Factors/Ergonomics**
- **Sustainability (durability)**

Evaluation Criteria

- Design criteria are requirements you specify that will be used to make decisions about how to build and evaluate the product.
- Criteria are derived from needs expressed by customers.
- Criteria define the product physical and functional characteristics.



General Evaluation Criteria

- Safety
- Environmental Protection
- Public Acceptance
- Reliability
- Performance
- Ease of Operation (Usability)
- Durability
- Use of Standard parts
- Minimum Cost
- Minimum Maintenance and Ease of Maintenance
- Ease of Manufacturing
- Aesthetic design (Appearance)
- Geometry
- Physical Features
- Inputs-Outputs
- Use Environment

Example 1

You are asked to design a simple washing machine for clothes.

- Establish need.
- Define the problem.
- Specify the needed information to be gathered.
- Set up criteria for successful design.

Solution of Example 1

Needs

- Device to wash clothes
- Can be easily operated
- Can be started by operating the timer manually
- Variation of rotating speed for different types of clothes
- Dry clothes by spinning
- Capacity up to 5 kg
- Can use voltage 110V/220V
- Low power consumption/wattage less than 100 Watts
- Portable washing machine
- Noise level must not exceed 50dB
- Must be safe
- Filter for the water
- Water inlet and outlet
- Cost must not exceed SR300
- Weight must be less than 10kg

Solution of Example 1

Constraints

- Capacity Up to 5kg
- Noise level less than 50 dB
- Size : 1mx 0.9mx0.5m
- Weight not more than 10kg
- Cost less than SR300

Criteria

- Effectiveness of cleaning the clothes
- After drying no water drop from the clothes
- Can be used up to 5 years without any problem
- Portable
- Easy to use

Solution of Example 1

Problem definition

Design a simple washing machine that can wash different types of clothes and dry them by various spinning speeds. The machine should be 5 kg capacity and easily manipulated. Its size should be limited to 1m/0.9m/0.5m and its weight is not to exceed 100 N. The washing machine must be portable and able to function using 110V or 220V voltage. The machine consumption and cost should be respectively limited to 100 watts and to 300SR. The minimum life duration of the machine should be 5 years.

Solution of Example 1

Needed Information to be gathered:

1. Motor power to be used
2. Speed for various types of clothes
3. Timing needed to clean common types of clothes and dry them
4. Spinning speed needed to dry clothes without damage

Solution of Example 1

Safety

1. If overloaded, the machine shouldn't start
2. Maximum water level to prevent water waist and dangerous current short-cuts.
3. Electrical grounding
4. Stop spinner if the door is opened
5. Kids protection by motor isolation
6. Noise reduction by motor insulation

Example 2

- It is required to design a simple crushing device for cans.
  - Establish need.
  - Define the problem.
  - Specify the needed information to be gathered.
  - Set up criteria for successful design.

Solution of Example 2

Need analysis:

- Design a simple device to crush cans (soft drinks)
- The final product is recycling (green design)
- Does not occupy large space
- High strength material
- Cost 80 – 100 S.R.
- Safe
- Designed for kids
- Light weight (portable) .
- Easy to use
- Easy to maintain
- Heavy and large base (does not tip over).
- Will be used by human power (foot, hands or both) .
- Using available materials/components

Solution of Example 2

- **Primary objective:**
  - Its required to design a simple ,easy to use device to crush cans .
- **Secondary objective:**
  - The device should be easy to construct, easy to maintain, marketable and portable.
- **Constraints:**
  - The cost should not exceed 100 S.R.
  - The weight should not exceed 5 kg.
  - Applied Force should be less than 30 N
  - Safe
  - Does not tip over

Solution of Example 2

- **Criteria for selection:**
  - Lower cost
  - Light weight
  - Lower force
  - Simple manufacturing
  - Simplicity

- **Needed Information:**
  - Type of materials used
  - Typical existing device in the market
  - Average force applied by kid's hand
  - Mechanism for applying force

Example 3 (Next Class)

Design a device for securing a coffee cup near the driver's seat of an automobile. The device should prevent the cup from spilling and should not interfere with the proper operation of the car. It should be universally adaptable to a wide variety of vehicles.

1. Establish need.
2. Design objectives.
3. Set constraints.
4. Set evaluation criteria.
5. Define the problem.
6. Specify the needed information to be gathered.