College of Engineering

GE106:Introduction to Engineering Design

Problem Formulation and Case Studies

By

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Outline

- The Nature of Design
- Design Objectives
- Design Constraints
- Design Criteria
- Case Study 1: Washing Machine
- Case Study 2: Can Crushing Device
- Case Study 3: Car Coffee Cup Holder
- Summary

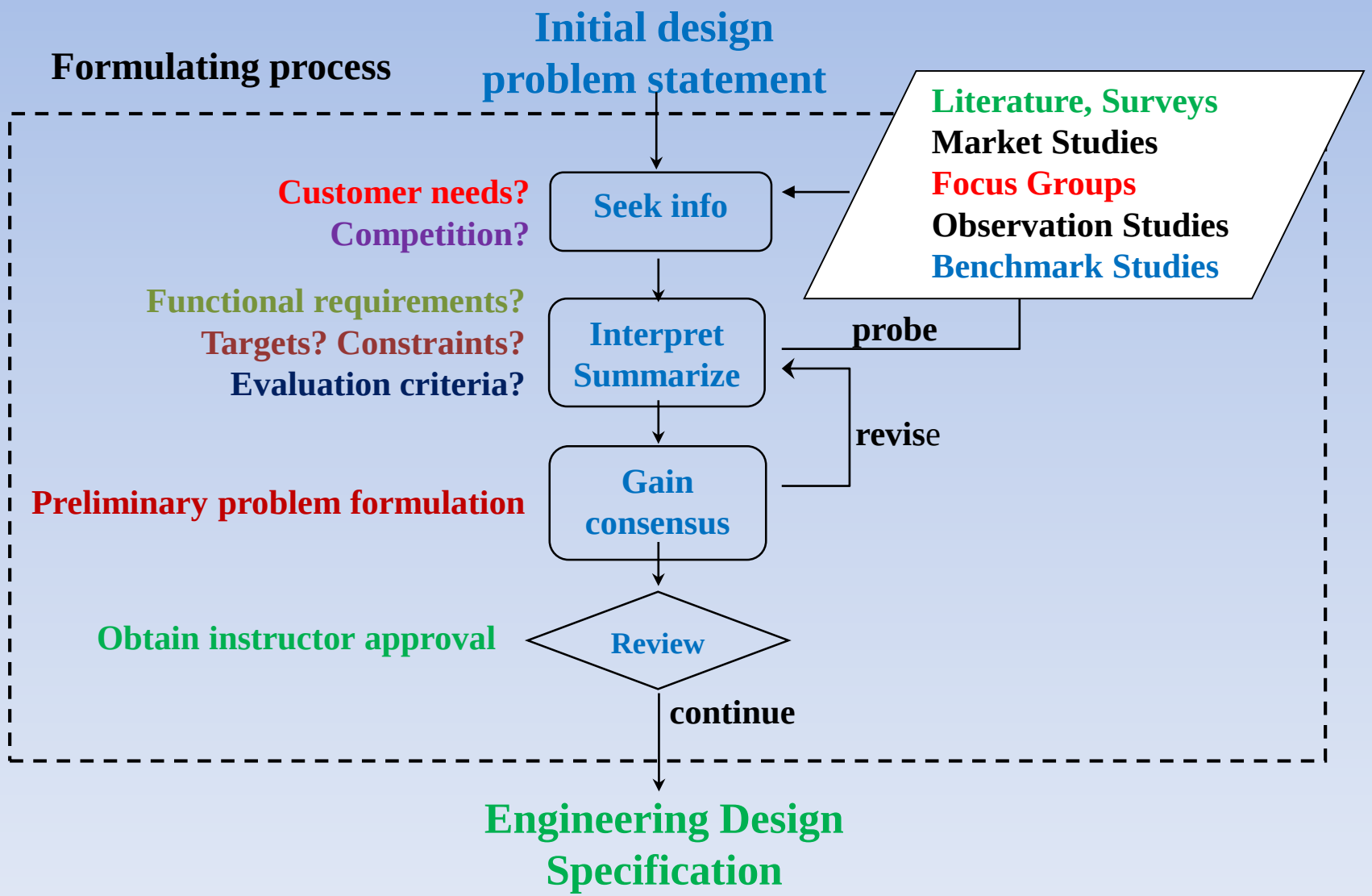
The Nature of Design

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 that will help in defining objectives, constraints, and criteria.

- Quality needed
- Efficiency.
- Reliability
- Safety
- Economic
- Social and ethical issues.
- Aesthetics

- Maintainability
- Flexibility
- Durability
- Environmental impact

Design Objectives

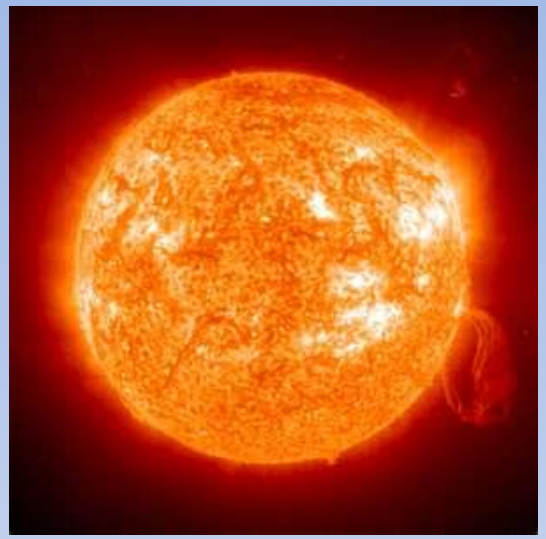
The complete statement of the design objectives is an essential part of the problem formulation.

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

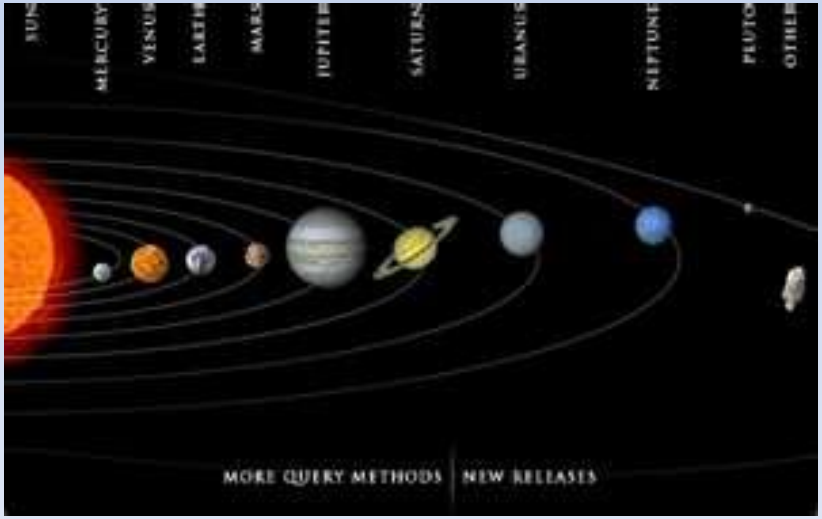
It is convenient to consider two components of the design objectives:-

*Primary Objective(s) ⇒ (MUST)

*Secondary Objective(s) ⇒ (WANTS)



Primary Object (in Solar System): The Sun



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 for:

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 attainment 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.

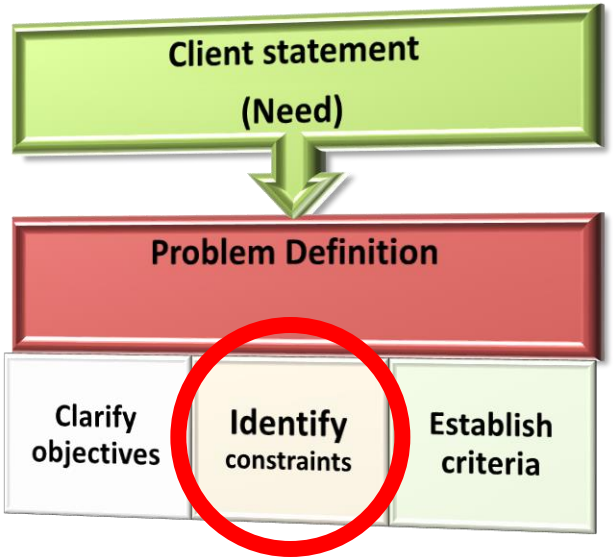
Secondary Objective here is Safety

Design Constraints

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

Constraints

- Constraints are ***boundaries*** that limit the engineer's flexibility; they form the design envelope (feasible design space).
- They help to identify acceptable designs
- Should be measurable
- Should be answered with: True/False; Yes/No
  - Example: Cost <1000 SAR?
    Weight <500 N?
    Flexible system (yes/no)?

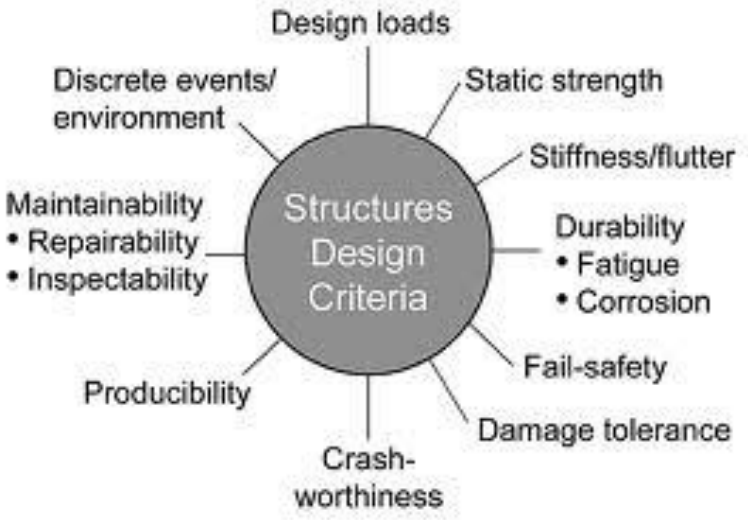


Sources of Design Constraints

- **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**
- **Environment**: bio-degradable materials, recycled materials, green energy

Evaluation Criteria

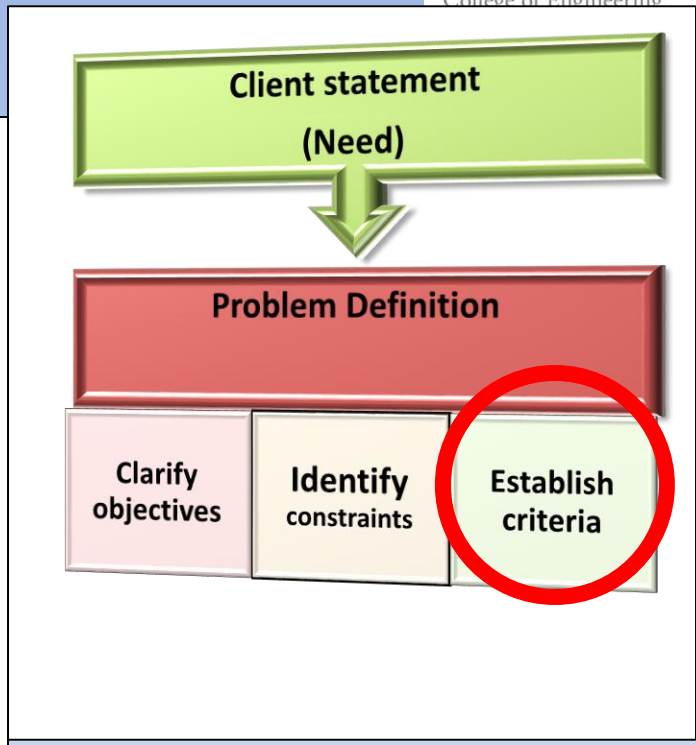
- Design criteria are requirements you specify that will be used to make decisions about how to build and evaluate the product.

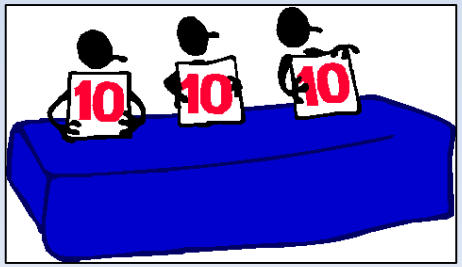


- Criteria are derived from needs expressed by customers.
- Criteria define the product's physical and functional characteristics.

Design Criteria

- Criteria are indicators defining the success of achieving the objectives.
- Criteria define the product physical and functional characteristics.
- They represent descriptive adjectives that can be qualified on a *given scale*: examples: beautiful, low cost, low noise, smart, low weight.
- Might be used for judging between different designs.





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
- Environment of Use

Examples of Criteria

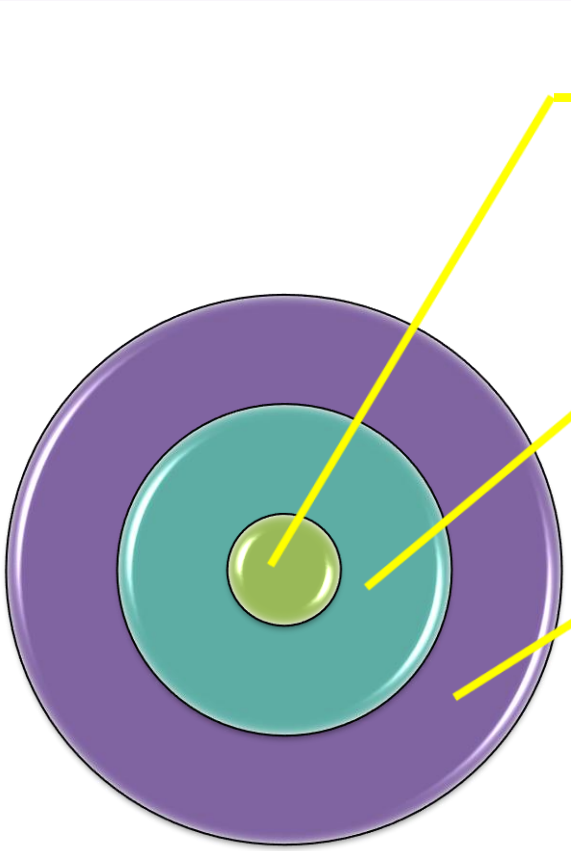
- High safety
- Environment friendliness
- Public Acceptance
- Performance
- Ease of operation
- Durability
- Cost

- Ease of Maintenance
- Ease of Manufacturing
- Aesthetic design (Appearance)
- Geometry
- Physical Features
- Reliability
- Use Environment

These criteria (or whatever criteria you have) are to be qualified (ranked) say *on a scale 1 to 10, where* 1 (worst) and 10 (best) *

Remember!

Before solving a problem, answer:

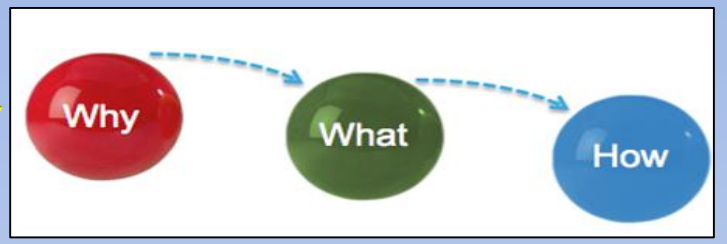


Why
(very few know this)

How
(some know this)

What
(everyone knows this)

Problem Definition & Formulation



Need Analysis

- *List of Specifications*

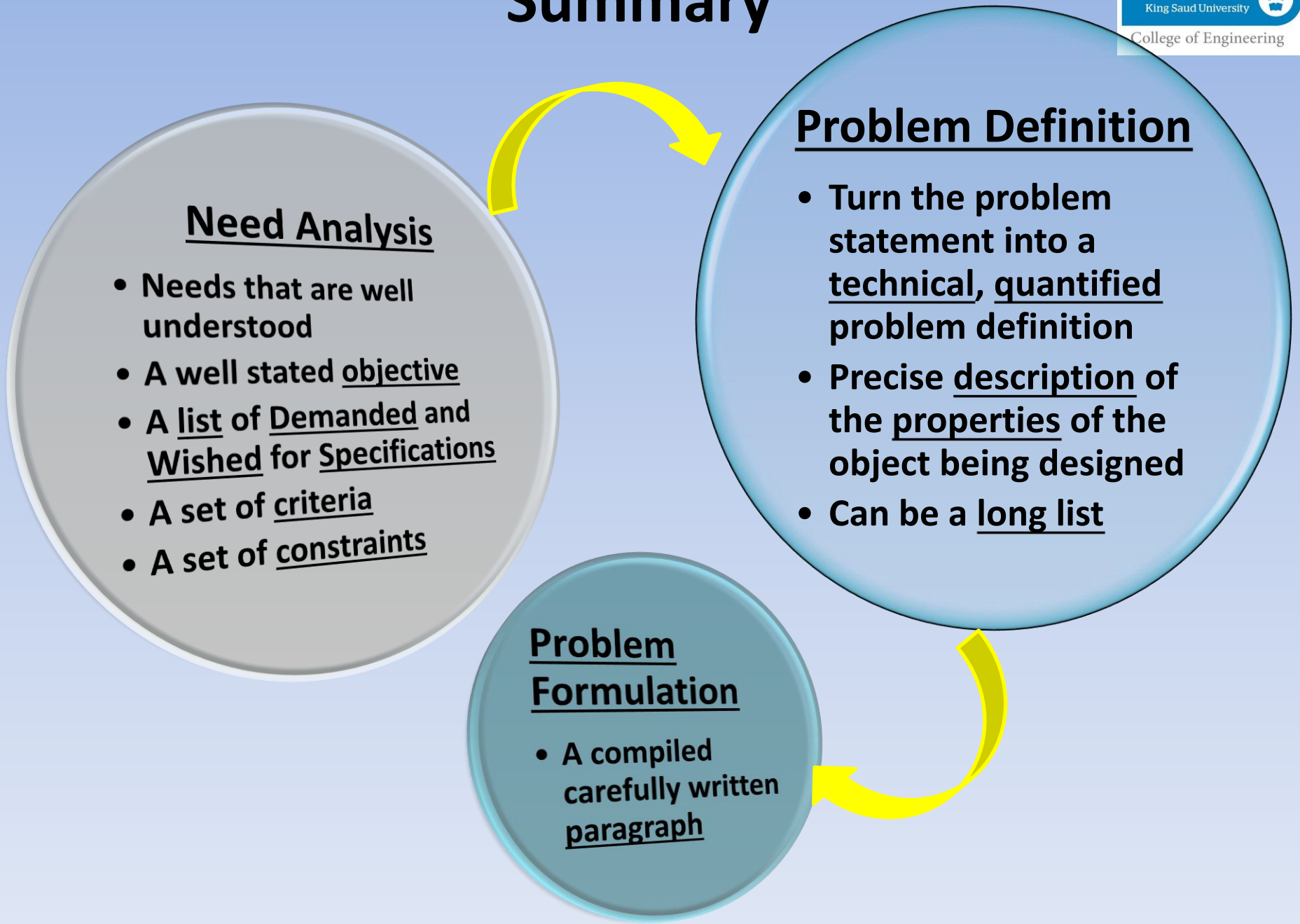
Problem Definition

- *Objectives*
- *Constraints*
- *Criteria*

Problem Formulation

- *A paragraph compiling the above points*

Summary

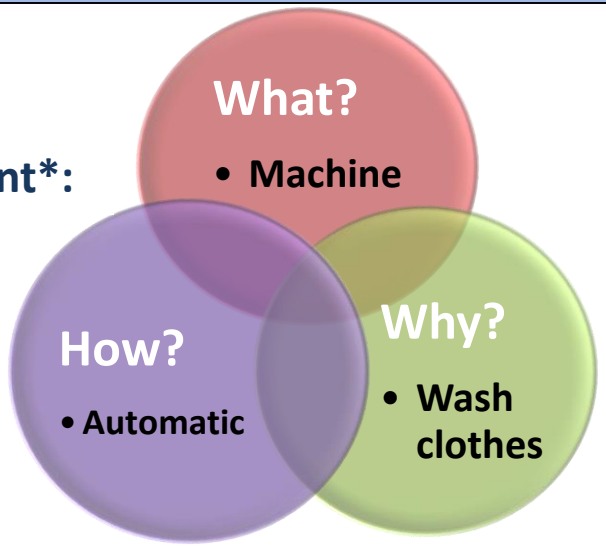

Need Analysis
• Needs that are well understood
• A well stated objective
• A list of Demanded and Wished for Specifications
• A set of criteria
• A set of constraints
Problem Definition
• Turn the problem statement into a technical, quantified problem definition
• Precise description of the properties of the object being designed
• Can be a long list
Problem Formulation
• A compiled carefully written paragraph

Example 1

You were 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 a successful design.

Statement*:



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
- Capacity up to 5 kg
- Can use voltage 110 V / 220 V
- Low power consumption/wattage less than 100 Watts
- Portable washing machine
- Noise level must not exceed 65 dB
- Must be safe
- Filter for the water
- Water inlet and outlet
- Cost must not exceed 500 SR
- Weight must be less than 100 N

Constraints

- Capacity: up to 5 kg
- Noise level less than 65 dB
- Size: 1 m x 0.9 m x 0.5 m
- Weight not more than 100 N (10 kg mass)
- Cost less than 500 SR
- After drying no water drop from the clothes
- 110 / 220 volts
- Portable
- Life more than 5 Years
- Electric consumption less than 100 W.h (Watt-hours)

Criteria

- High effectiveness of cleaning the clothes
- High durability
- Easy to use (simple)
- High number of cloth types

Safety Specifications

- If overloaded, the machine shouldn't start.
- Maximum water level to prevent water waste and dangerous current short-cuts.
- Electrical grounding
- Stop spinner if the door is opened.
- Kids protection by motor isolation.

Problem Formulation [paragraph(s)]

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 1 m / 0.9 m / 0.5m and its weight is not to exceed 100 N. The washing machine must be portable and able to function using 110 V or 220 V voltage. The machine consumption and cost should be respectively limited to 100 watt-hours and to 500 SR. The minimum life duration of the machine should be 5 years.

The machine should have a water level to prevent water wastage and be grounded to avoid electrical shortcuts. Besides, it shouldn't start If overloaded and must stop spinning if its door is open. A motor isolation for kids protection is also a must.

Examples of Needed Information to be Gathered

- Motor power to be used.
- Speed for various types of clothes.
- Timing needed to clean common types of clothes and dry them.
- Common types of clothes to be washed.
- Characteristics of each type of clothes (spinning speed, adequate washing temperature, etc.)

Example 2

Problem Statement: It is required to design a simple crushing device for cans.

Needs Analysis:

- Design a simple device to crash cans (soft drinks)
- The final product is recyclable (green design)
- Does not occupy large space
- High strength material
- It costs 80 – 100 SR
- High safety
- Design for kids
- Light weight (portable)
- Easy to use
- Easy to maintain
- Heavy and large base (does not tip over)
- Will be operated by human power* (foot, hands, or both)
- Using available materials/components

Primary objective:

- 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 SR
- The weight should not exceed 5 kg
- Applied force should be less than 30 N*
- Does not tip over
- Safe

Criteria*:

- Low cost
- Light weight
- Low force
- High safety
- Simple to manufacture
- Simple Design

Needed Information* *:

- Type of materials to be used
- Typical existing devices in the market
- Average force applied by kid's hand
- Different can sizes
- Mechanism for applying force

Example # 3

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.

Tasks:

- Establish need.
- Define the problem.
- Specify the needed information to be gathered.

Statement: Need a device for securing a coffee cup near the driver's seat of an automobile

Needs Analysis:

- Coffee cup holder for car (near the driver seat)
- Locking system to prevent the cup from spilling
- It does not interfere with the proper operation of the car
- Adaptable to a wide variety of vehicles
- Detachable (designed to be unfastened or disconnected without damage)
- Easy to use
- Durable material for various temperatures
- No need to modify car interior
- Cost not exceed 50 SR
- Flexibility of coffee cup size

Primary Objectives:

- Design a device for securing a coffee cup near the driver's seat of an automobile that preventing the cup from spilling, not interfering with the proper operation of the car and adaptable to a wide variety of vehicle.

Secondary Objectives:

- The device should be detachable.
- No modification of car interior is needed.

Constraints

- Spilling free
- Does not interfere with the driver
- Size max: 200 x 150 x 150 mm (H x W x L)
- Weight not to exceed 0.5 kg
- Cost less than SR 50
- 2 years lifetime

Criteria

- Simple
- Easy to install and dispatch
- Durable
- Strong attachment to the car
- High adaptability to car types
- High adaptability to cup sizes

Problem Formulation

Design a **simple device** for **securing a coffee cup** near the driver's seat of an automobile that **prevents** the **cup from spilling**. The device should not interfere with the proper operation of the driver and should be adaptable to a wide variety of vehicles and coffee cup size. The device should be easy to install and detach and no interior modification of the car should be needed. The maximum size and weight of the device are respectively 200 x 150 x 150 mm^3 and 2 kg. It should also be durable, offering a minimum of two years lifetime and a cost of less than 50 SR.

Needed Information*

- Average amount of coffee in cup
- Average coffee cup size and weight
- Coffee cup material
- General car interior layout/design
- Temperature inside the car (max/min)
- Available relevant holder designs in the market

Lesson Summary

Design Objectives, Constraints and Design Evaluation Criteria have been presented and reiterated.

Three case studies were presented on how to:

- Conduct need analysis for a stated problem.
- Formulate a problem statement from a customer need statement, based on the objectives, constraints and criteria.
- How to come up with (determine) the needed information for solving a design problem.

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