UAEU College of Engineering

# GENG 215: Engineering Ethics

**Fall 2018 – Version 6 (2011-2018)**

## Engineering Design – Week 1 – 2 – 3 – 4

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### KEY CONCEPTS

1- What is the engineering design?
2- What is the different between design and analysis?
3- What is creativity in engineering design?
4- Summary of engineering design process:

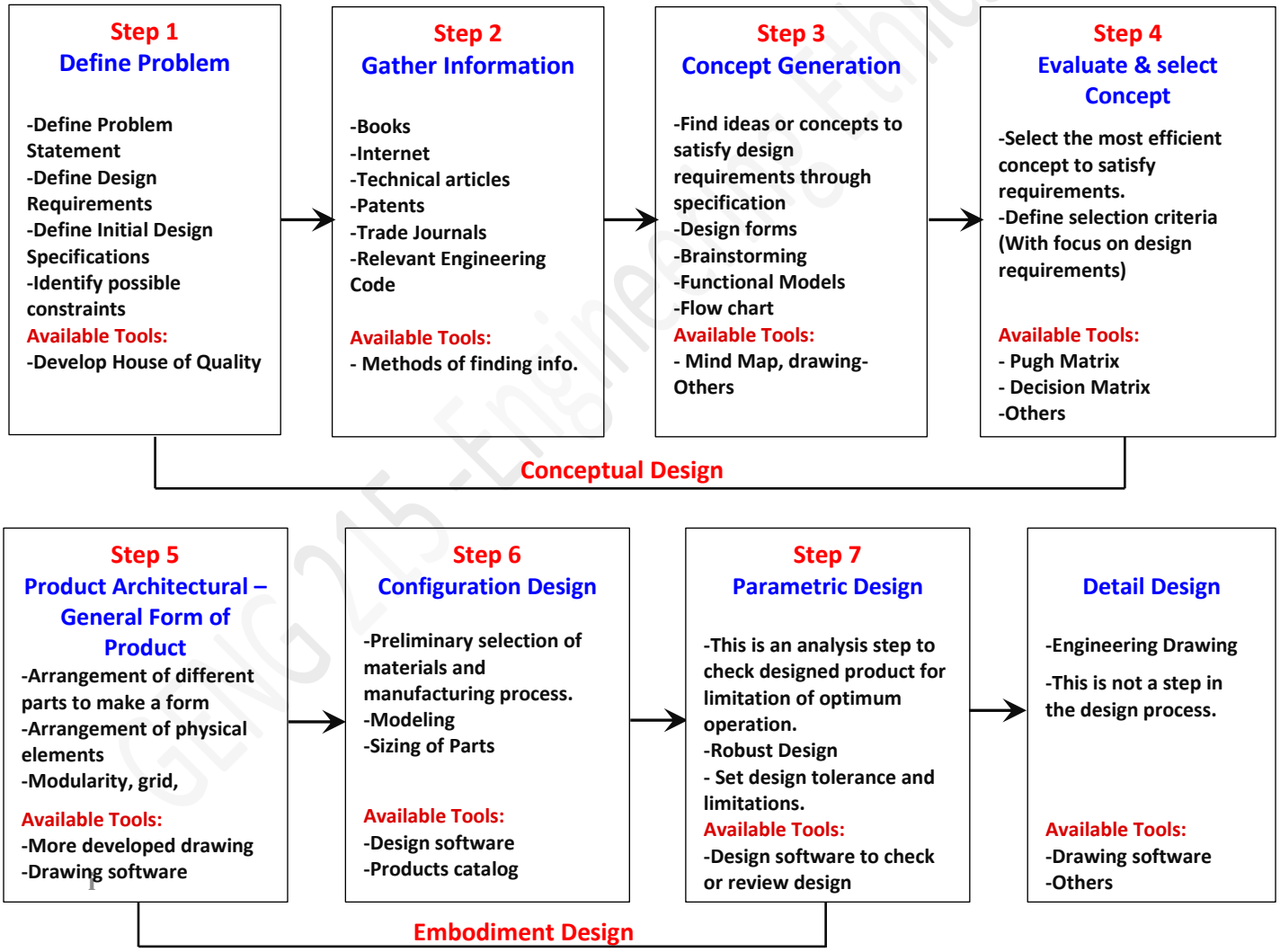



**Figure 1**: Engineering Design Process – Phases and steps

**5- Design Process Steps:**

## A- Conceptual Design Phase (C.D.P)

A-1- The most difficult design phase because of the focus on generating new ideas. Initiating a new idea is not an easy task.

A-2- CDP can be broadly define as the phase where design specifications are defined based on customer requirements and based on elementary cost to generate feasible ideas.

What are the design steps included in Conceptual Design Phase?

**1- Define problems:**

a- Define problem statement

b- Design requirements – Design specifications – constraints

c- Benchmarking

d- Product dissection

e- House of Quality (QFD - Quality Function Deployment): What is house of quality?

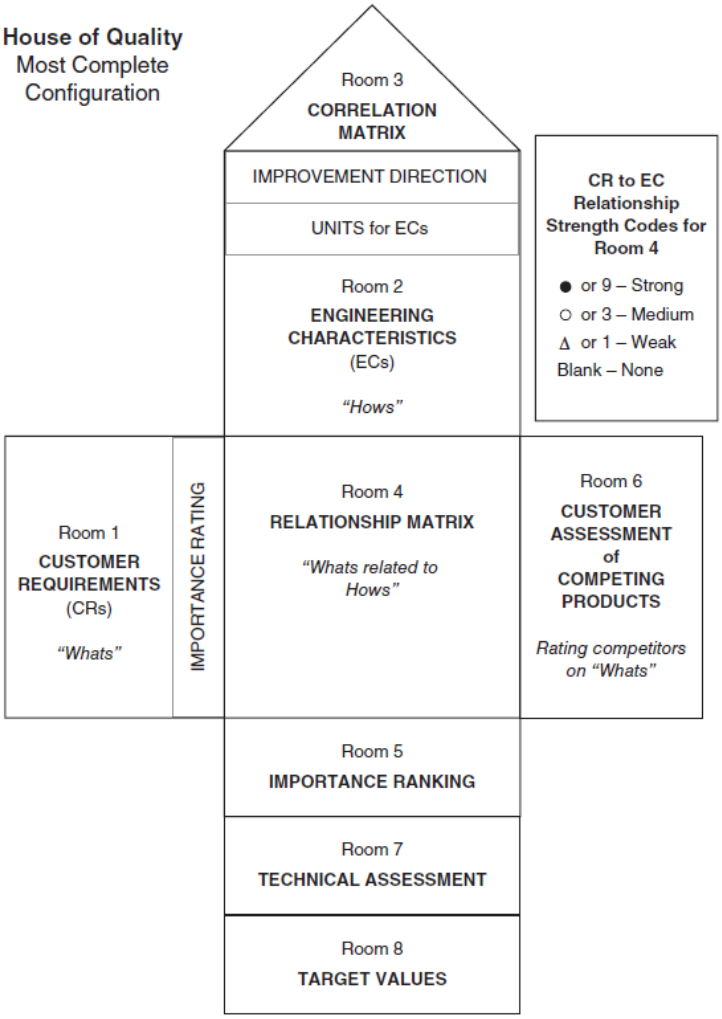



**Figure 2**: Sample House of Quality (or **Quality Function Deployment (QFD)**) tool with major parts marked as Room 1- Room 8

f- Parts of QFD"

**Room 1:** Design requirements

**Room 2:** Design specifications

**Room 3:** Relationship between design specifications

**Room 4:** Design specifications

**Room 5:** For each design specification: I.R. = specification strength (e.g. 1, 3, or 9) X importance rating

Room 6: Comparison to competitor product

- Who are the competitors?
- How do customers perceive the competition's ability to meet the requirements?

**Room 7:** divide each important ranking by the sum of all important ranking

**Room 8:** Classify each design specification with respect to others. High rating indicates most important



| | | Engineering Characteristics | | | | | |
|---|---|---|---|---|---|---|---|
| Improvement Direction | | ↓ | ↓ | n/a | ↑ | n/a | n/a |
| Units | | lbs | in | n/a | ksi√in | n/a | n/a |
| **Customer Requirements** | Importance Weight Factor | Force to open | External dimensions | CD positioning feature in case | Toughness of case material | Hinge design | Shape of case |
| Cost | 5 | | 9 | 3 | 9 | 9 | |
| Crack resistant | 5 | 3 | 3 | 3 | 3 | 1 | 3 |
| Ease of stacking | 5 | 3 | 3 | | | 1 | |
| Ease of removing liner notes | 5 | | 3 | | | | 1 |
| Ease of removing CD | 4 | 3 | 3 | 9 | | 1 | 3 |
| Made of recyclable materials | 4 | | | | 9 | | |
| Ease of opening case | 4 | 9 | 3 | 1 | | 3 | 3 |
| Scratch resistance | 4 | | 1 | | 3 | | |
| Hinge stays together | 4 | 3 | 3 | | | 9 | 3 |
| Waterproof | 4 | 3 | | | 3 | 1 | |
| Raw Score | | 102 | 130 | 70 | 120 | 111 | 56 |
| Relative Weight % | | 17.3 | 22.1 | 11.9 | 20.4 | 18.8 | 9.5 |
| Rank Order | | 4 | 1 | 5 | 2 | 3 | 6 |

**Figure 3: Example of Complete QFD for Design CD Case protective bag or**

**Student should know how to calculate: Row Score, Relative weight, Rank Order.**

**Ethics: What ethical issues might be involved in the Problem definition step?**

1- Engineer might not be qualified to define problem or not proficient in determining specifications.
2- The rating of design specification and requirements (1,3,9) is subjective, and engineer would rate specifications to favor certain design specification related to his specialty or his

company activity. For example, if a company is designing a products with metal, plastic, and wood parts. If the company is specialized in plastic products, then design engineer would rate plastic speciation highly just because his company can produce these parts cheaper. This is unethical.

## How to Build or construct the **House of Quality** or **Quality Function Deployment (QFD) tool?**

**Step 1-List Customer Requirements (WHATs)**
**Step 2-List Technical Descriptors or Specification (HOWs)**
**Step 3- Develop a Relationship Matrix Between WHATs and HOWs**

- ✓ **The L-shape, which is a two-dimensional relationship that shows the intersection of related pairs of items, is constructed by turning the list of technical descriptors perpendicular to the list of customer requirements**
- ✓ **A double circle represents a strong relationship.**
- ✓ **A single circle represents a medium relationship.**
- ✓ **A triangle represents a weak relationship.**
- ✓ **The box is left blank if no relationship exists.**

◎ = 9
○ = 3
△ = 1

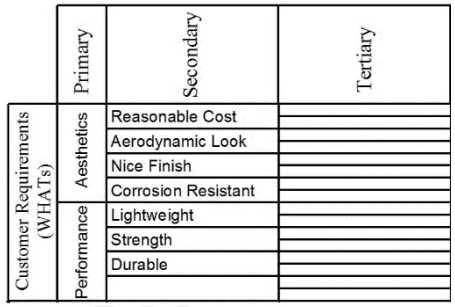



**Figure 3a - Step 1**

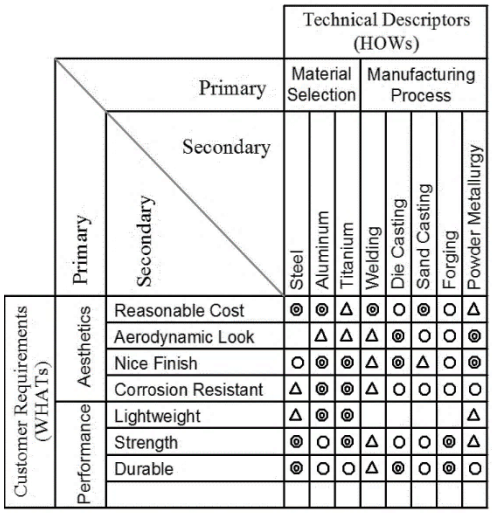
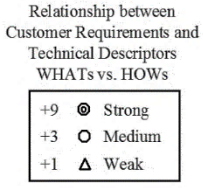



**Figure 3b - Step 3**



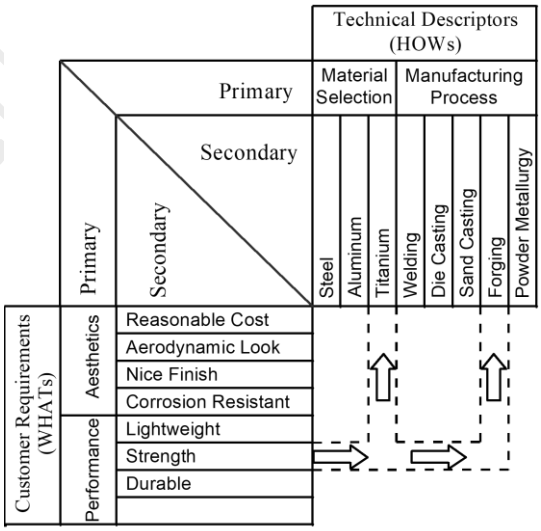




**Figure 3c - Step 2 and Step 3**

## Step 4: Develop an Interrelationship Matrix Between HOWs

- ✓ **The roof of the house of quality, called the correlation matrix, is used to identify any interrelationships between each of the technical descriptors. The correlation matrix is a triangular table attached to the technical descriptors.**

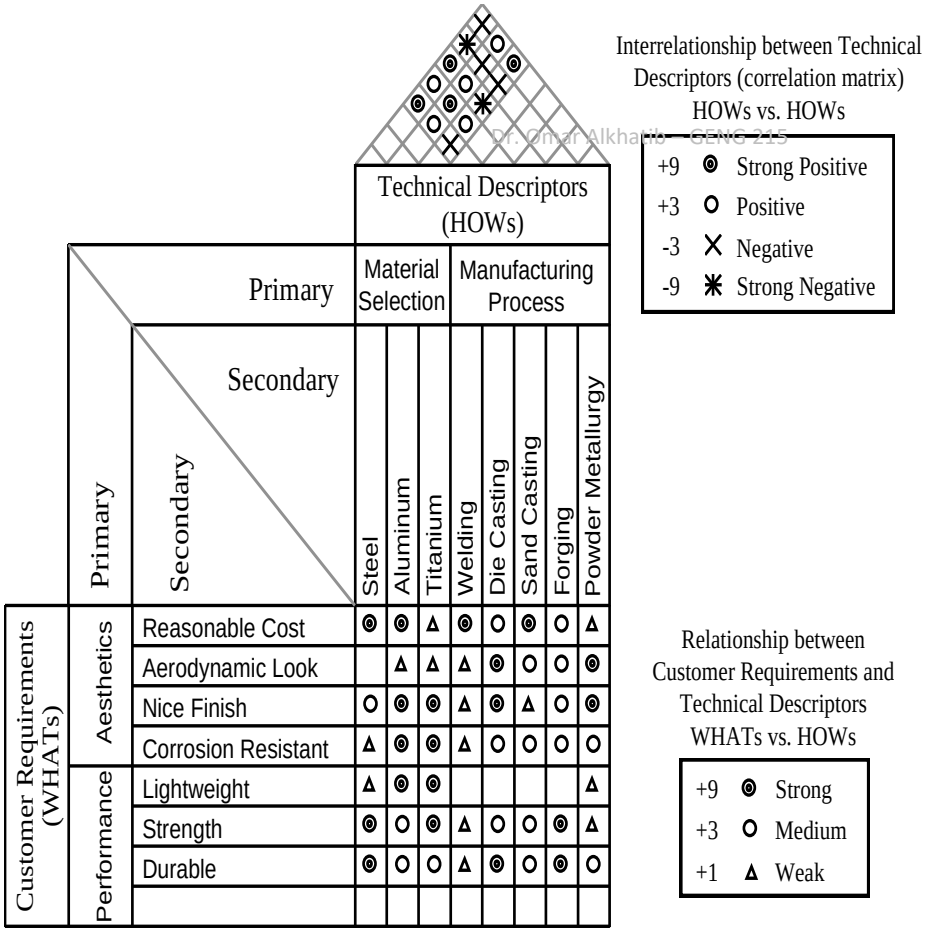



**Figure 1d - Step 4**

## Step 5: Develop Prioritized Customer Requirements (Figure 3e)

- **Absolute Weight = (Importance to Customer) X (Scale-up Factor) X (Sales Point)**
- **The weight can then be used as a guide for the planning phase of the product development.**
  **Example:**
- **For reasonable cost the absolute weight is (8)X(1.3)X(1.5) = 16.**
- **Note that the numbers for absolute weight are rounded off**

## Step 6: Develop Prioritized Technical Descriptors (PTD) (Figure 3e)

- **Absolute Weight and Percent (A.W.P.)**
- **A.W.P. is an easy method for determining the weights is to assign numerical values to symbols in the relationship matrix symbols.**
- **How A.W.P. is Determined:**
  **For example aluminum the absolute weight is (correlation matrix rating X importance factor)**
  **=9x8 + 1x5 + …….**
- **Relative Weight and Percent: use same method as in Figure 3 above.**

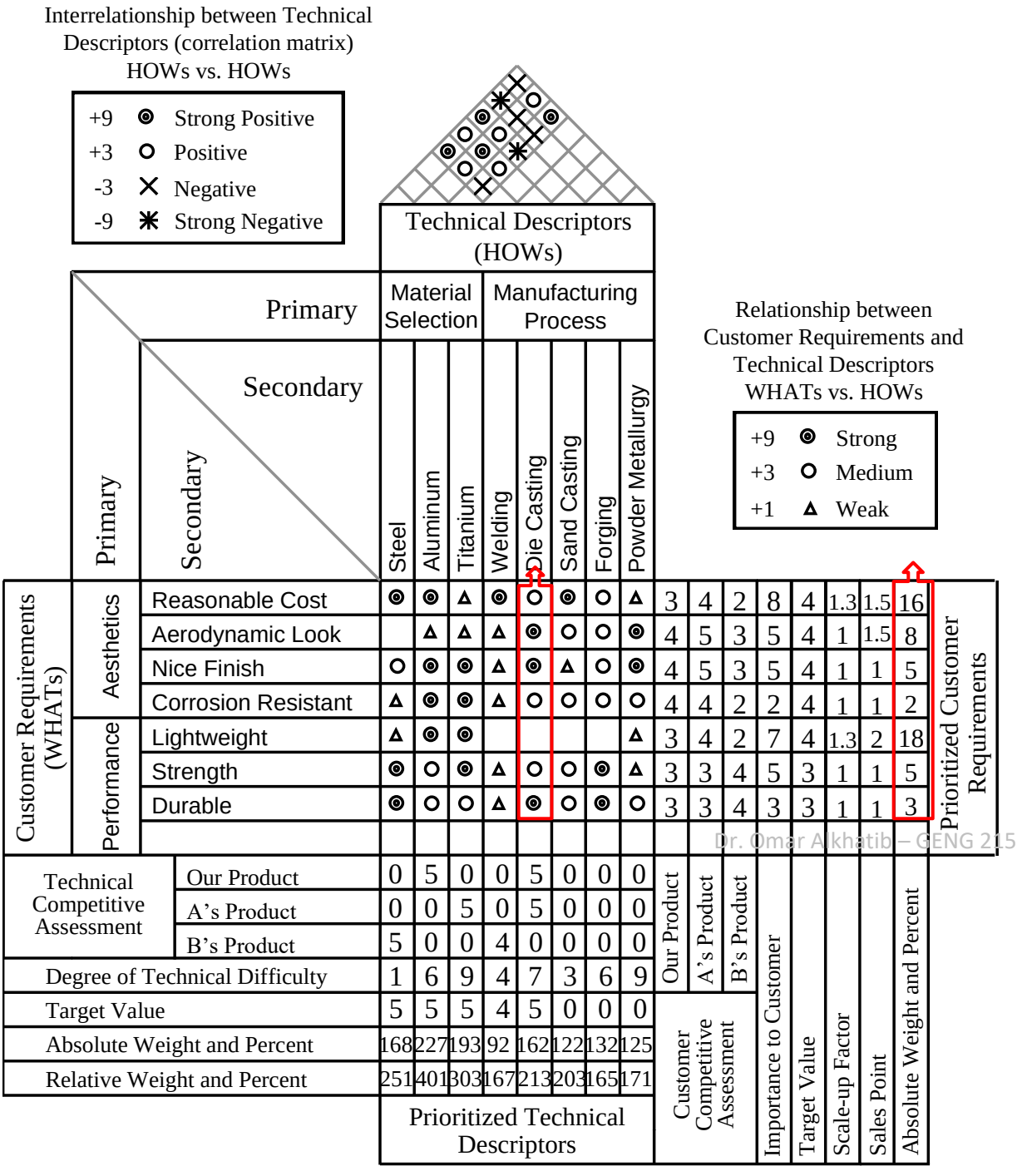



**Figure 3e Complete QFD**

Notes on Figure 3e:

| | | | | | | |
|---|---|---|---|---|---|---|
| Raw Score | 102 | 130 | 70 | 120 | 111 | 56 |
| Relative Weight % | 17.3 | 22.1 | 11.9 | 20.4 | 18.8 | 9.5 |
| Rank Order | 4 | 1 | 5 | 2 | 3 | 6 |

- The "**Relative Weight %**" in Figure 3 is similar to "Absolute Weight & Percent" in Figure 3e, but "**Relative Weight**" and "**Rank order**" in Figure 3 is different than "**Relative Weight & Percent**" in Figure 3e.
- Example: 213 for specification **"Die Casting"** above can be calculated as follows:

**Relative Weight and Percent (RWP):** Higher **RWP** ratings identify and indicate areas where engineering efforts need to be concentrated. For instance, for Die Casting the **RWP** is 3x16 + 9x8 + 9x5 + 3x2 + 0x18 + 3x5 + 9x3 = 213. **(Multiply each specification rating X Absolute Weight and Percent)**

2- **Gather Information** (about design requirements and specifications or design in general):
   a- Internet
   b- Patents
   c- Technical Articles
   d- Trade Journals
   e- Consultants

**Ethics: What ethical issues might be involved in the Gather Information step?**

1- **Honesty in collecting information, honesty when dealing with other engineers' design and intellectual properties, honesty in giving other engineers credit for their ideas and work, honesty in referencing consultant work or review, honesty in including sources of information.**
2- **Engineer should be honest and give credits for other people involved in the design.**
3- **All references used in the design should be all referenced honestly.**

3- **Concepts Generation** (concept is a design idea): the following are some method to help generate design idea or find one.
   a- Creativity methods
   b- Brainstorming
   c- Decomposition
   d- **Systematic Design Methods**: is a method of problem solving techniques using step by step analysis and synthesis

      **Analysis** is the decomposition of a complex system into elements and study the characteristics of each element and its functions and performance.

      **Synthesis (design)** is the incorporation of elements of known characteristics to create a new system.
   e- **Tools: mind-map:** one tool to help generating idea.

**Ethics: What ethical issues might be involved in the Concept Generation Step?**

- Honesty in developing a design idea: was the engineer honest in developing his/her own design idea or did he take it from someone else? Did he give credit for other people who worked with him or referenced sources of this idea? Does this idea satisfy customer needs and design requirements?
- For developed new concept, does this concept really work and feasible for customer requirements? Or just proposed to for financial or economic reasons.

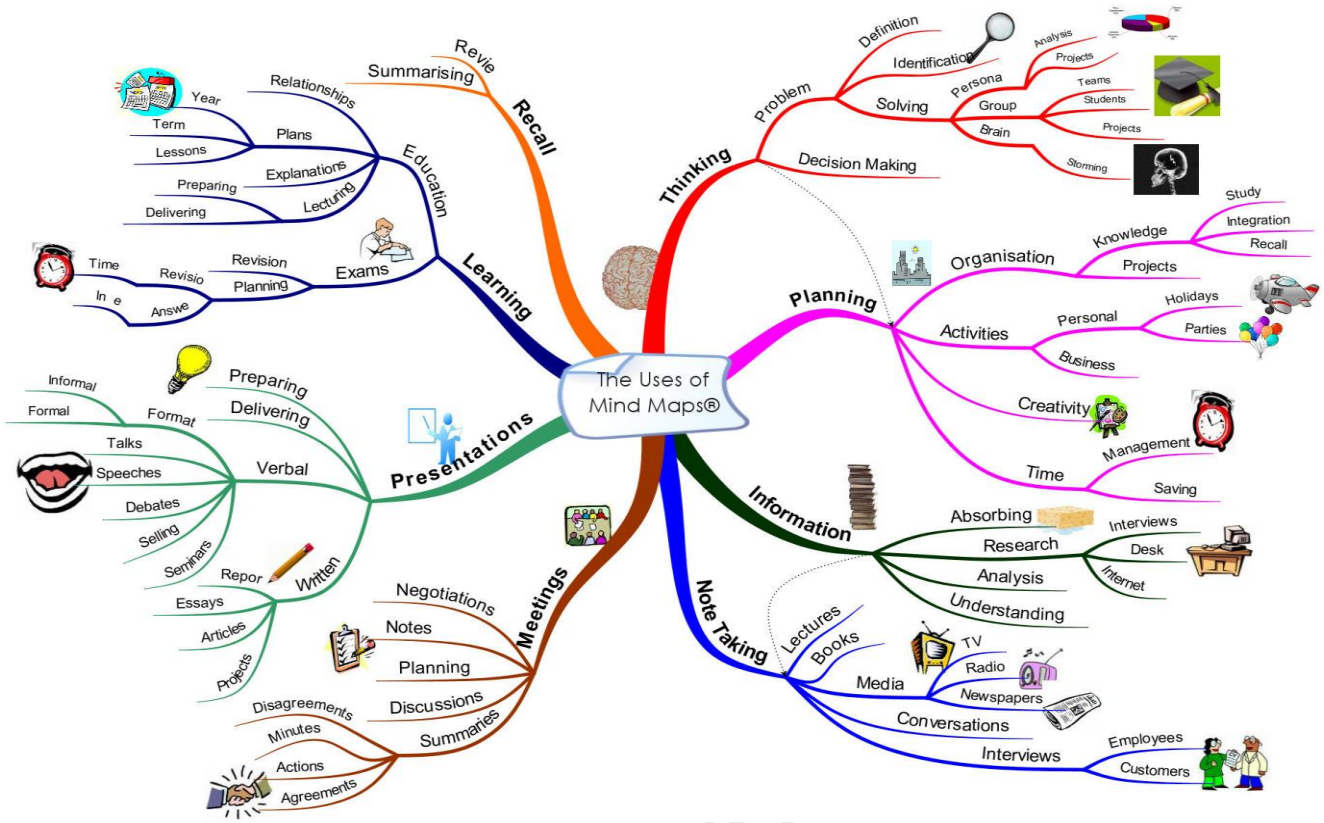



**Figure 4**: Sample of Mind-Map tool (Source: Web) : a tool helps organize, develop, and generate ideas

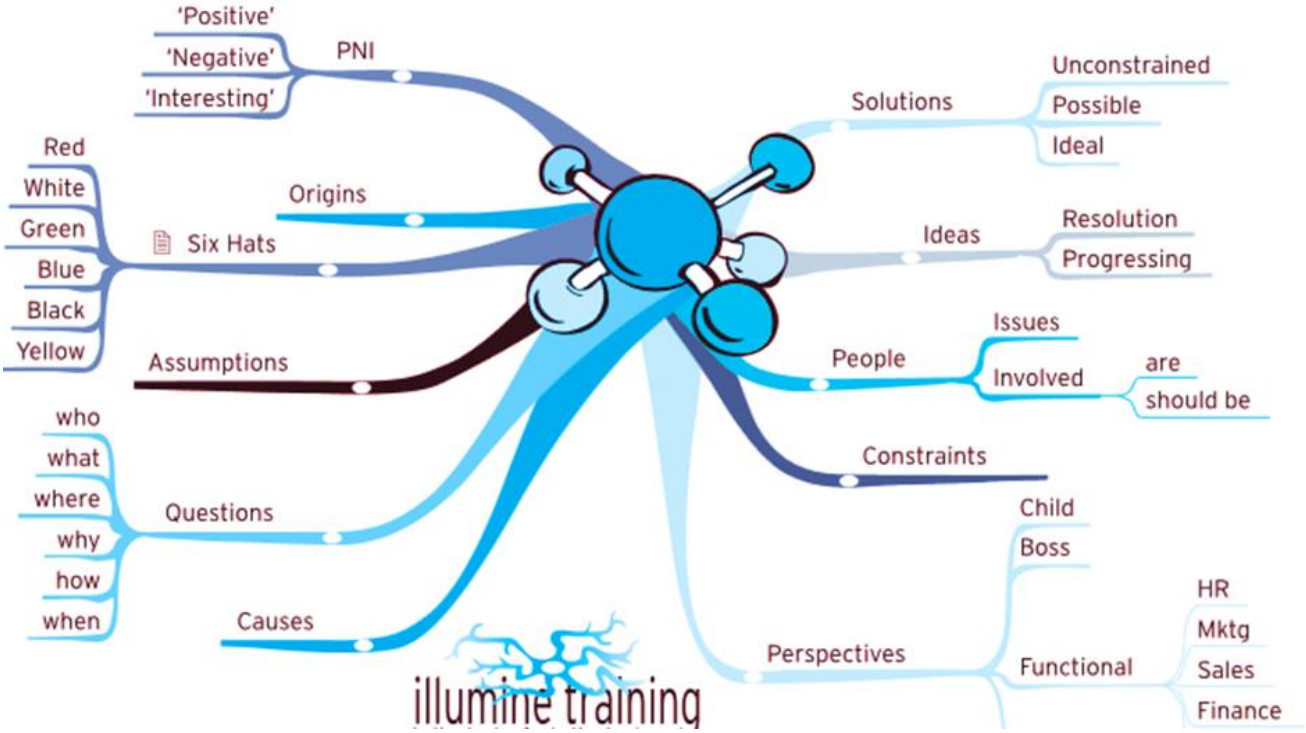



**Figure 4a Mind Map Example**

### 4- Concept Evaluation and Selection

Several design ideas can be generated, and different concepts can be developed, which one should be selected?

- The following are different tools can be used to evaluate a concept and select the most appropriate one:
  - a- **Decision-making**: The process of examining your possibilities options, comparing them, and choosing a course of action or selecting the best design concept.
  - b- **Selection criteria**: Which criteria should be considered to select a design concept?
  - **c- Pugh chart or matrix:**
    a Pugh matrix is used to evaluate various alternatives against a baseline (an existing product or idea). For example, a company has five alternative processes to the one it's using, and it wants to know if any of the five is better or not.
  - d- **Decision matrix:** concept or alternative selection tool similar to **Pugh Matrix**.

**Ethics: What ethical issues might be involved in the Concept Evaluation and Selection Step?**

1- Concept selection tools (decision or Pugh..etc) can be manipulated subjectively to favor certain design concept.
2- Certain design criteria, which would show design disadvantages and weakness, can be removed from concept selection so customer won't be altered to it.

**Sample of Decision Matrix** (can be of different forms, this is the most basic and common form)

| Design Requirements or Specifications or Criteria (Can be any criteria related to design- *what is listed below is just examples criteria*) | **Importance Factor (1-5)** (an approximate number to indicate how important each criteria to customer or in the design) 5→ Most important, or strong relationship, or desired outcome. 1→ Lest important, or weak relationship, or undesired outcome. *(Weight factor sample numbers)* | Concept 1 or Design Alternative 1 *(Sample rating listed below)* | Concept 2 or Design Alternative 2 *(Sample rating listed below)* | Concept 3 or Design Alternative 3 *(Sample rating listed below)* |
|---|---|---|---|---|
| Cost | 5 | 5 | 4 | 1 |
| Weight | 3 | 4 | 2 | 3 |
| Aesthetics | 2 | 5 | 1 | 2 |
| Energy Consumption | 4 | 4 | 5 | 3 |
| Health Issues | 2 | 4 | 4 | 5 |
| Quality | 5 | 5 | 4 | 1 |
| Operation Cost | 3 | 4 | 4 | 2 |
| Environmental Issue | 3 | 5 | 4 | 4 |
| Product accuracy | 4 | 4 | 5 | 1 |
| Maintenance Issue | 3 | 3 | 4 | 4 |
| **Weighted Total** | | 148 | 132 | 79 |
| **Rank Order** | | 1 | 2 | 3 |

***Question 1: How is 148 Weighted Total above can be calculated?***

**Sample Pugh Matrix (Below)** (can be of different forms, this is the most basic and common form)

| **Design Requirements or Specifications or Criteria** (Can be any criteria related to design- *what is listed below is just examples criteria*) | **Importance Factor (1-5)** (an approximate number to indicate how important each criteria to customer or in the design) 5→ Most important, or strong relationship, or desired outcome. 1→ Lest important, or weak relationship, or undesired outcome. *(Weight factor sample numbers)* | Existing Design Concept | Concept 1 or Design Alternative 1 *(Sample rating listed below)* | Concept 2 or Design Alternative 2 *(Sample rating listed below)* | Concept 3 or Design Alternative 3 *(Sample rating listed below)* |
|---|---|---|---|---|---|
| Cost | 5 | 3 | 4 | 5 | 1 |
| Aesthetics | 2 | 2 | 3 | 5 | 2 |
| Energy Consumption | 4 | 2 | 2 | 4 | 3 |
| Health Issues | 2 | 2 | 3 | 4 | 5 |
| Environmental Issue | 3 | 1 | 3 | 5 | 4 |
| Maintenance Issue | 3 | 2 | 1 | 3 | 4 |
| **Weighted Total** | | 40 | 52 | 83 | 55 |
| **Rank Order** | | 4 | 3 | 1 | 2 |

***- Question 2: What is the most important difference between Decision matrix and Pugh Matrix?***

**Sample of Decision Matrix** (Another alternative of decision matrix)

## Engineering Design Decision Matrix

| | | | Options | | | |
|---|---|---|---|---|---|---|
| | | | Option A | Option B | Option C | Option D |
| Selection Criteria/Category | Weight (1-5) | Multiply | Score / Weighted Score | Score / Weighted Score | Score / Weighted Score | Score / Weighted Score |
| | | x | | | | |
| | | x | | | | |
| | | x | | | | |
| | | x | | | | |
| | | x | | | | |
| | | x | | | | |
| | | x | | | | |
| | TOTAL SCORE | = | | | | |

| | | Concept 1 | Concept 2 | Concept 3 |
|---|---|---|---|---|
| **Design Criteria** | Weighting Factor |  |  |  |
| Light Weight | 0.25 | 6 / 1.50 | 7 / 1.75 | 2 / 4.50 |
| Ease of Manufacture | 0.40 | 8 / 3.20 | 5 / 2.00 | 2 / 0.80 |
| Low Cost | 0.35 | 8 / 2.80 | 6 / 2.10 | 3 / 1.05 |
| **Totals** | **1.00** | **7.50** | **5.85** | **6.35** |

- ***Question 3: What is the total summation of weighting factor in the matrix above?***
- ***Question4: What does "6" represent for Concept 1 for Light Weight Criteria?***
- ***Question 5: How the "3.20" is calculated for Concept 2 for Ease of Manufacture criteria?***
- ***Question 5: How the "6.35" is calculated for Concept 3?***

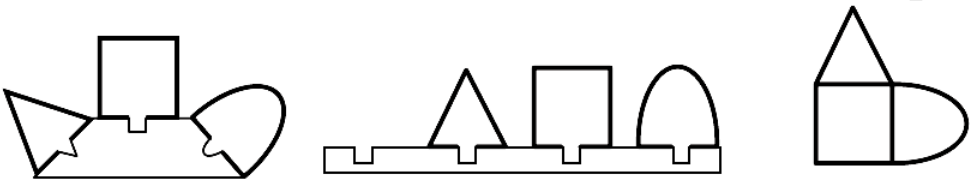
## B- Embodiment Design Phase (E.D.)

- E.D. phase covers form design, arrangement of physical elements, design for manufacture and assembly, materials and manufacturing process selection and Industrial design.
- E.D. is the design process steps that based on creating transferring the concept design into functional products or physical model.

- The embodiment process is the bridge between the conceptual stage of the design process and the detail design stage.

### 5- Product Architectures (PA)

- PA is the design process step describing how physical parts are arranged.
- Modularity



Slot-modular architecture | Bus-modular architecture | Sectional-modular architecture

**Ethics: What ethical issues might be involved in the Product Architectural Step?**
**Think about issues related to PA and might affect design outcomes or operation. Example: if a sport car body is made from fiberglass materials to make it light, fast, and attractive. This might reduce safety and expose passengers to additional risk during accidents (this example is also applicable to configuration design)**

### 6- Configuration Design

- Sizing of Parts: Step 5 will give the overall geometry of designed product; this step will go in details to descript the smaller elements sizing and dimensions.
- Selection of materials: select if wood, metal, plastic, paper..etc for various parts.
- Selection of manufacturing process: if it handmade, machine made, special process

### 7- Parametric Design (Basic and simplified sense) – This is the analysis step of design.

- "**Parametric Design is a very broad term**, but it usually refers to the design parameters which considered as **any measurable design factors** that defines a system functions or determines its performance" [*OJA*]
- Example: If a rubber powered airplane is designed, then, it could be determined that maximum flying time is 20 seconds using light wood.
- If an elevator is design, then maximum capacity is 500 kg for example
- Robust Design: Is this design suitable for user? How could it be improved?
- Service issue check: what is the total deflection of beam after designing the beam?

- **Ethics: What ethical issues might be involved in the Parametric Design Step?**
- **Example case: engineers during the NASA challenger case did not have data to support their claims which assume that field seal will not function well in cold weather.**

**8- Detailed Design**

- This is a details design drawing and description about the intended design.

## Summary of Engineering Design Process

| | Design Process Detail Activities and Major Subsequent Steps |
|---|---|
| **Conceptual Design Phase** | **A- Start Conceptual Design** |
| | **1- Define Problems**<br>a- Recognize design needs and requirements<br>b- Define Product Development Specifications (**PDS**)<br>c- Define project plan<br>d- Define **QFD Stage 1** |
| | **2- Gather Information:** Internet, Technical Articles, Market products, consultants |
| | **3- Concept Generation:** Creativity Methods, Brainstorming, Functional models |
| | **4- Evaluation & Concept Selection** (decision matrix, Pugh matrix,…etc)<br>a- Decision Matrix<br>b- Pugh Matrix<br>c- Selecting Criteria<br>d- **Cost Estimate 1**: estimate cost of concept selected |
| **Embodiment Design Phase** | **B- Start Embodiment Design** |
| | Define **QFD Stage 2 (redefine or improve stage 1)** |
| | **5- Product Architecture**<br>a- Arrangement of physical parts<br>b- Modularity |
| | **6- Configuration Design**<br>a- Engineering analysis: **Form** Function – **Geometry** – **Manufacture** Process – Materials<br>b- **Cost Estimate 2**: Estimate cost of embodiment design |
| | **7- Parametric Design**<br>a- set design tolerance parameters<br>b- Robust design |
| | **Finish embodiment design** |
| | **8-** Start **Detail Design**<br>a- Order external required part: e.g. for airplane design order plastic fan<br>b- Finish detail design<br>c- Manufacture of **prototypes**<br>d- **Testing of product**<br>e- **Cost Estimate 3**: estimate cost of detail design<br>f- **Cost Estimate 4**: estimate cost of external required parts from outside venders<br>g- If no modification needed, send detail design for **manufacturing** |

**Major Design Phases**

**Eight steps design process**

## Comments:

1- **Communications** between different design parties is conducted by several methods: meetings, QFD is one way of transferring of information, drawing and graphs is another way, and detail design is also communication between parties in different entities and way of expressing final design subject.
2- **Design is a trial and error process (iteration process). Some authors refer to this process as a redesign or redefining or refining design parameters such as requirements and specifications. This implement in above table as (QFD stage 1 and 2 and parametric design step and prototype sub-step in Detail Design step**
3- **Design specifications are subjected for review and improvement during the engineering design process.**

# Sketches in Design: Note the level of details

**Concepts Generation Step : Sample Sketch**

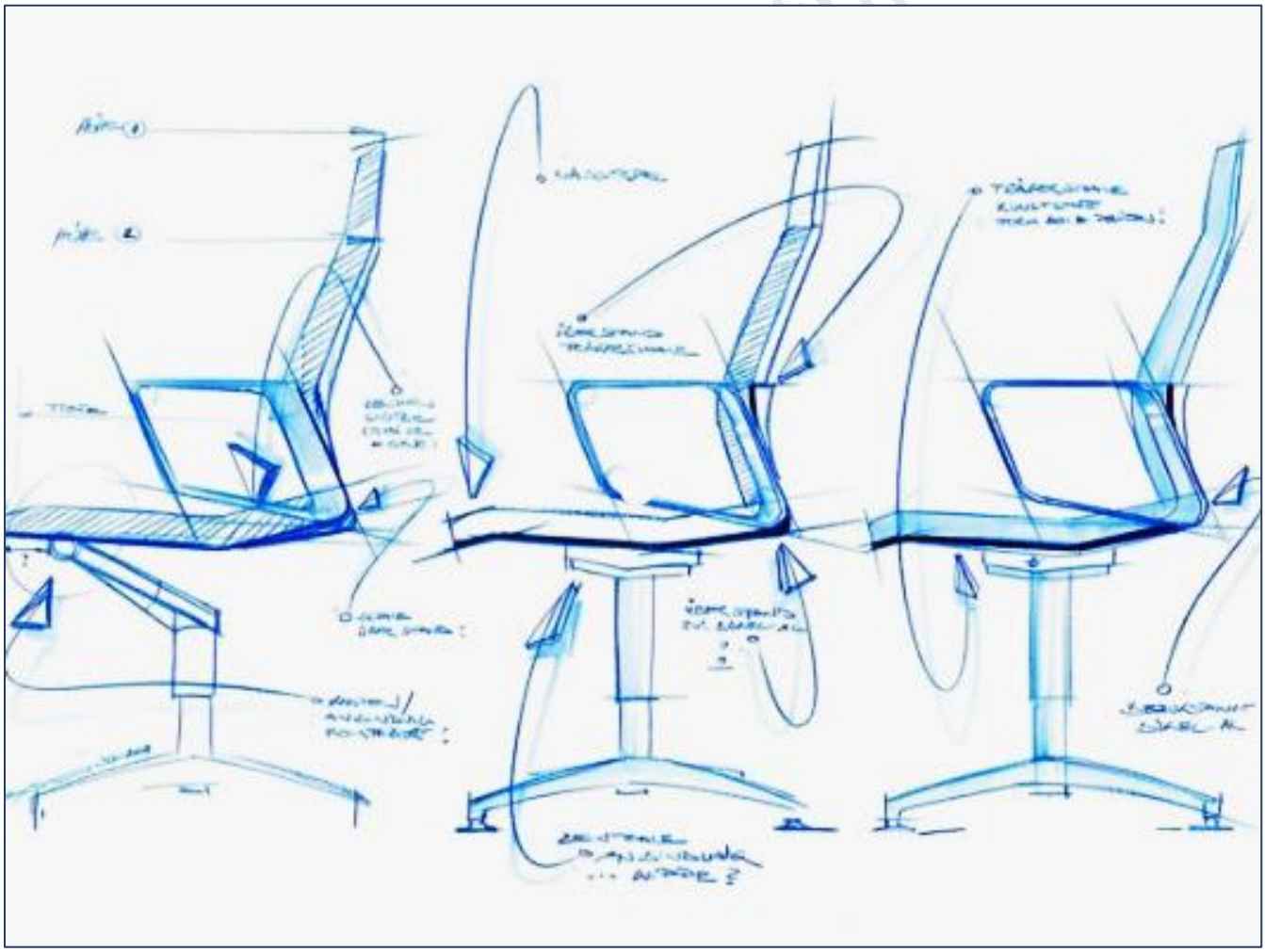


Figure 1A

**Product Architecture Step sample sketches:**

Figure 2A

**Detailed Design: Sketch**

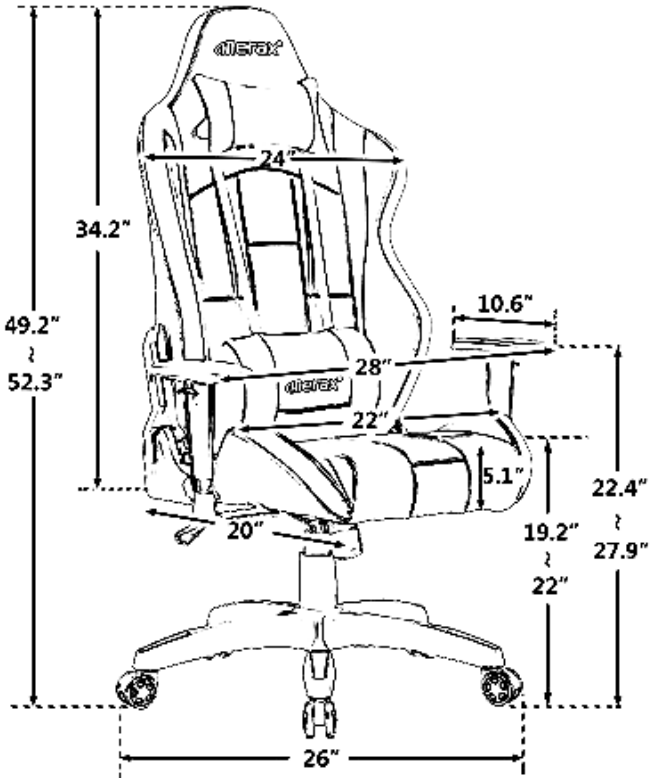



Figure 3A