Lecture (Jan. 8th, 2019)

The Design Process

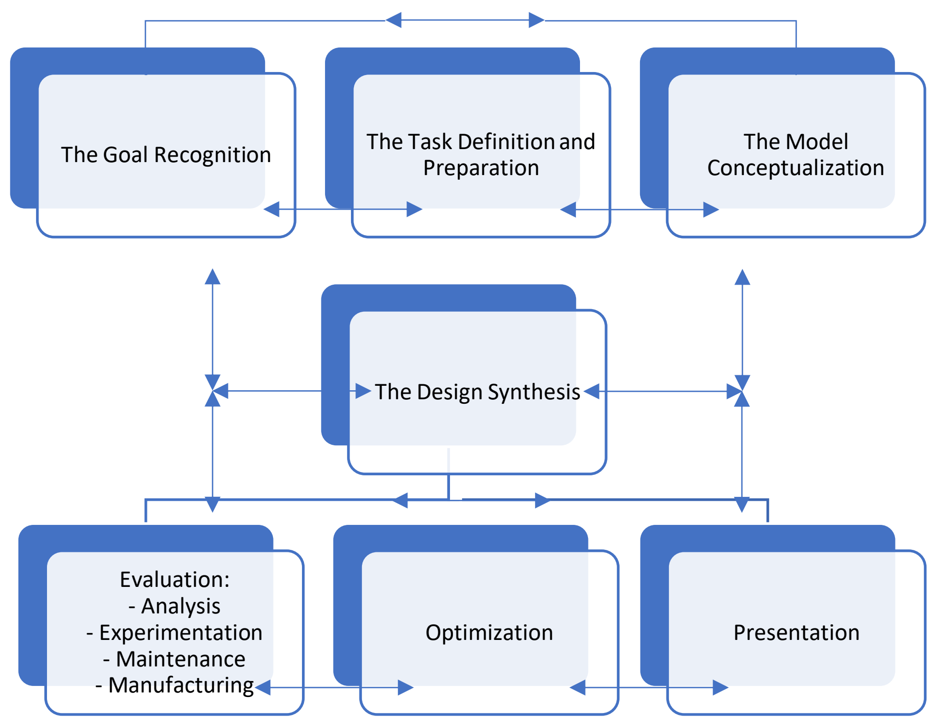
Horizontal Structure of Design

The horizontal structure of design may be considered to involve the following 8 stages:

1. Recognition
2. Definition
3. Preparation
4. Conceptualization
5. Synthesis
6. Evaluation
7. Optimization
8. Presentation

These stages are all inter-related. Reconsideration, re-decision, reformulation, re-examination and re-computation are continuously carried out as needed at any stage of the design.

Design Process Flow Chart



1. Recognition: The need
2. Definition: The problem exactly identified and defined.
3. Preparation: All pertinent information must be collected. Data, formal knowledge, and empirical know-how must be gathered, reviewed, and organized. Where anything is lacking, the gap must be filled in which the proper assumptions, compromises, and sound engineering judgement.

4. Conceptualization: Consideration of alternatives. No alternative arrangement that holds promise of probable success can be omitted.
5. Synthesis: At this stage, details must be conceptualized. Exact mechanisms are synthesized to supply the required motions, dynamic characteristics and time sequences. Components must be selected, material decided upon, fabricating process, etc…
6. Evaluation or Analysis: The designs, models, or possibly analogs must now be analyzed; critical parameters must be checked to see that all is satisfactory. This is performed on all alternatives not previously eliminated. The best design is then selected.
7. Optimization: Such as reliability, economy, weight, and space limitations, and life requirements can be very important factors. The design may thus have to be optimized with respect to the particular criterion.
8. Communication, both verbal and graphic, becomes of prime importance at this stage, because the design has no value until utilized.

<u>Chronological or Vertical Structure of Design</u>

A project must often be carried through the following design and planning phases:

1. Feasibility study: A technical success can easily go bankrupt when a financially sound need is not realized. However, the product must exist at least on paper if its need and feasibility are to be established.
2. Preliminary design: solutions that may have been suggested during the feasibility phase are considered. The surviving alternatives are synthesized sufficiently to reveal their overall features. The specific design concepts are thoroughly evaluated.
3. Detail design: Capacities are exactly sized, dimensions calculated, wear account for, parts detailed, tolerances established, and treatments completely detailed, and clearly described. It is now a producible design.

Lecture (Jan. 10th, 2019)

Decision Tree

Assume that three solutions exist to a primary problem. Should two sub-problems arise in the case of each solution, six choices are generated. If all six result in two new possible paths each, the number of decisions rises to twelve, an so it can continue.

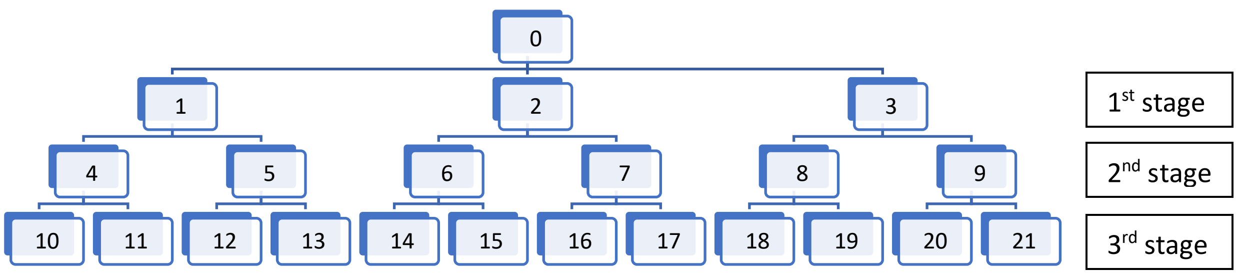
If there are m possibilities at the first stage and $(m \pm i)$ at each other stage, then the total number of required decisions is:

$$1 \cdot m_1(m \pm i)_2(m \pm i)_3 \dots (m \pm i)_n$$

Therefore, for the above example we have:

$$1 \cdot 3(3-1)(3-1) = 1 \cdot 3 \cdot 2 \cdot 2 = 12$$

The tree is shown below:



For the example above, consider the following:
line from 0 to 1 (m_1)
line from 1 to 4 $(m-i)_2$
line from 4 to 10 $(m-i)_3$

If the decision paths could flow from each first stage point to each second stage point, then $(m+i)_2 = (3+3)$ and the number of decision paths becomes:

$$1 \cdot 3(3+3)(3-1) = 36$$

If in addition each second stage point could connect to each third stage point, then:

$$1 \cdot 3(3+3)(3+3) = 108$$

Decision-Making

In making a decision a choice must be made among several possible acts by considering the consequences that may result as each act is applied to the problem at hand. Decisions are made under:

1- Certainty, where the action is known to lead to specific consequences.
2- Risk, when the action leads to specific outcomes that occurs with only known probability.
3- Uncertainty, where the action results in consequences that have unknown probabilities.

Arriving at a conclusion as to which alternative solutions, answer, decision, or design is best in a particular situation is a weighty and not absolutely defined mater. A systematic approach is, nevertheless, much more likely to lead to a more appropriate decision than in mere guessing or even contemplating.

One of the more satisfactory methods of decision-making is based on the Bayesian model which will be demonstrated by the following example:

Example (1.1): A large counterweight is to be made. Two questions needing decision confront the design engineers. Should the counterweight be cast or forged, and should it be made square or round in cross section?

Solution (1.1): The consequence matrix is established as shown below. These consequences are obviously based on a knowledge of the process of casting and forging involved as well as considerations of the relative strengths of different sections.

	Square	Round
Cast	Cheapest	Cheaper
Forged	Faster	Stronger

The desirabilities appear to be as shown in the following matrix. A desirability range other than 0-1 is used to illustrate its validity.

	Square	Round
Cast	2.0	1.0
Forged	0.5	1.5

The probabilities are judged in normalized form:

	Square	Round
Cast	0.4	0.6
Forged	0.5	0.5

Thus, the expected desirabilities are:

Cast: $2 \cdot 0.4 + 1 \cdot 0.6 = 1.4$
Forged: $0.5 \cdot 0.5 + 1.5 \cdot 0.5 = 1.0$

The better choice then seems to be to cast the counterweight. And since there appears a fair chance that the square section will prove cheaper, it is decided upon.

Codes and Standards

Standards: A standard is a set of specifications for parts materials, or processes intended to achieve uniformity, efficiency, and a specified quality.

Code: A code is a set of specifications for the analysis, design, manufacture, and construction of something. The purpose of a code is to achieve a specified degree of safety, efficiency, and performance or quality.

See section 1.6 in your textbook.

Reading assignment: Sections 1.1 to 1.11, and section 1.14
Assignment #1: 1.7, 1.8, 1.9, 1.12, 1.23