- Design objectives or objectives: features of behaviors that the design is expected to have.
- Constraints: limits or restrictions on the features or behaviors of the design. *A design is unacceptable is any constraint is void.*
- Functions: things that the design is supposed to do.

For the second ladder (from the left) of Figure 1.5 (actual image is different, but it's similar to the ladder below):

List 2 objectives;

- Should be portable (not a free-standing structure).
- Should be safe (or must be safe).

List 3 constraints; and

- Must be able to support an adult.
- Must be portable by a single person.
- Must not slip on wet surface (eventually.. coefficient of friction must be x, must be made of this material, etc.).

List 3 functions.

- Stable structure.
- It must be free-standing.
- It must not be a conductor of electricity (could also be a constraint).

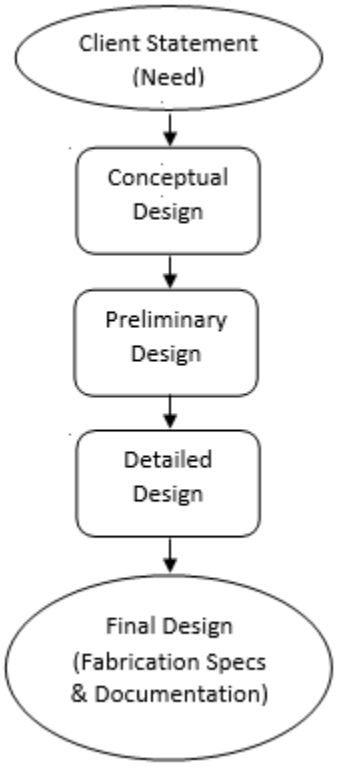
More Terminologies

- Metric: a scale on which the achievement of design objectives can be measures and assessed.
- Specifications: a scale on which the achievement of design functions can be measured. They are engineering statements of the extents to which functions are performed by design.

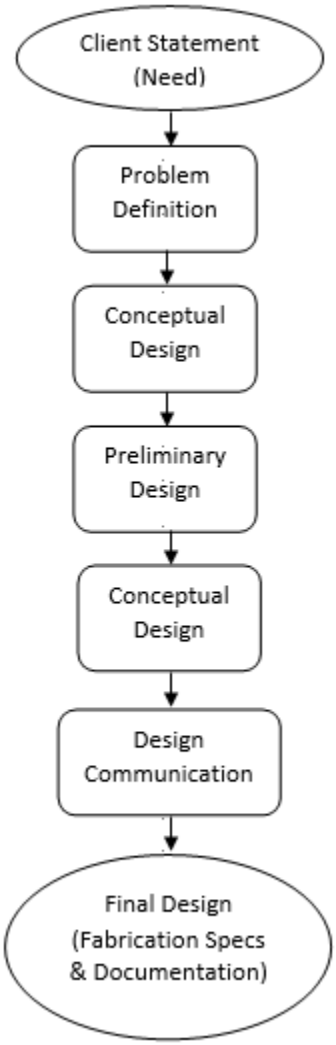
Objectives are typically things like features we see on advertisements.

The Traditional or Conventional Design Process

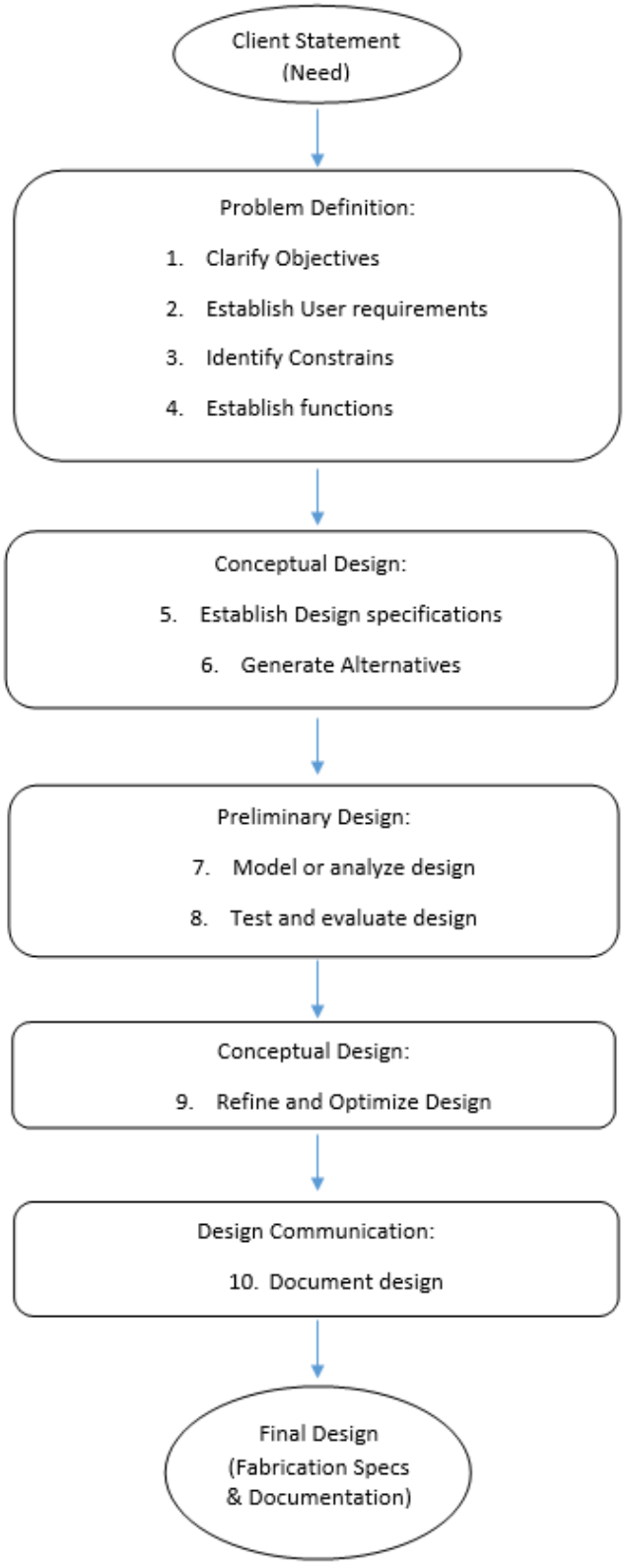
- There are other processes.
- The traditional or conventional process is mostly sequential but often iterative.
- A number of descriptions are available, ranging from three to seven stages.
- The following three figures are from the first edition textbook:
    - Figure 2.1



- Figure 2.2


Client Statement
(Need)
Problem
Definition
Conceptual
Design
Preliminary
Design
Conceptual
Design
Design
Communication
Final Design
(Fabrication Specs
& Documentation)

- Figure 2.3


Client Statement
(Need)
Problem Definition:
1. Clarify Objectives
2. Establish User requirements
3. Identify Constrains
4. Establish functions
Conceptual Design:
5. Establish Design specifications
6. Generate Alternatives
Preliminary Design:
7. Model or analyze design
8. Test and evaluate design
Conceptual Design:
9. Refine and Optimize Design
Design Communication:
10. Document design
Final Design
(Fabrication Specs
& Documentation)

- Figure 2.3 above is in fact an expanded five-stage
- The three-stage may be simplistic for beginners.
- Figure 2.1 of the text together with Sec. 2.2 shows the expanded five-stage process.
- Stage 1: Defining the problem, or framing the problem.

  Know: a statement from the client

  Four tasks:
  1. Clarify client's objectives
  2. Establish user requirements
  3. Identify constraints
  4. Establish principal functions

  Outcome: lists of customer requirements, objectives, constraints and principal functions.

- Stage 2: Conceptual design which is to generate different concepts or alternatives of design that will achieve the objectives, meet the constraints and perform the functions.

  Know: the outcome of stage 1.

  Two tasks:

  5. Establish design specifications
  6. Generate design alternatives

  Outcome: a chosen design.

- Stage 3: Preliminary design where major subsystems are analyzed; prototypes may be built and analyzed; prototypes may be built and tested; and the design may be evaluated and revised.

  Know: the chosen design at the end of Stage 2.

  Two tasks:

  7. Model of analyze the design
  8. Test and evaluate the design

  Outcome: a design that is deemed feasible.

- Stage 4: Detailed design during which the entire system is analyzed such that the bill of materials is ready and all the parts are found to be safe.

  Know: the design at the end of Stage 3.

  One task:

9. Refine and optimize the design

Outcome: assembly drawing, parts drawings, bill of materials.

- Stage 5: Design communication which means delivering the final design to the client.

  Know: the outcome of Stage 4.

  One task:

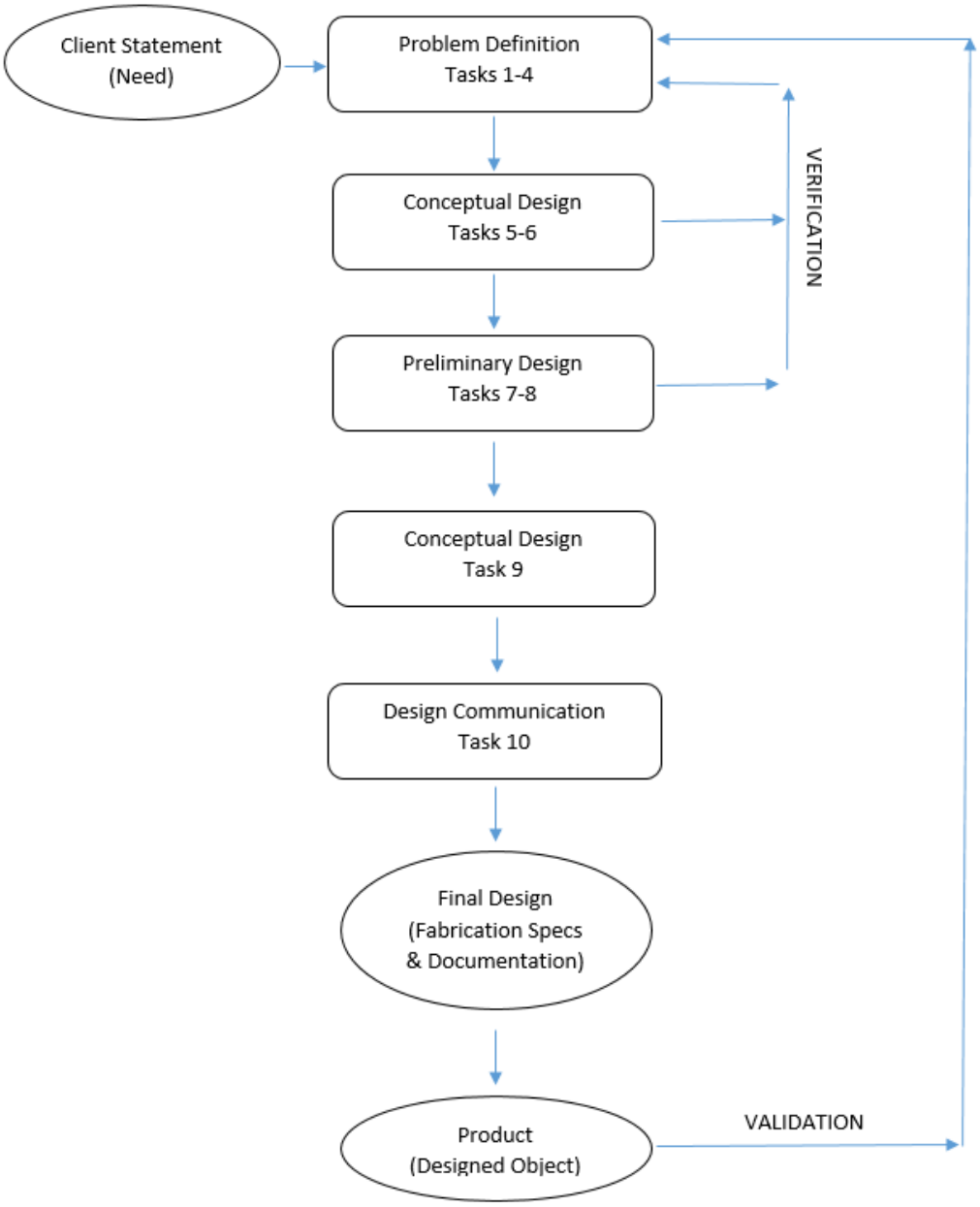
  10. document the design

  Outcome: a written report detailing the design process, exhibiting the final design (including assembly drawing, parts drawings, bill of materials), and where specified, fabrication specifications.

A Few Comments Regarding the Traditional Design Process

The traditional or conventional process is mostly sequential but often iterative, see Figure 2.4 of the first edition.

- Figure 2.4



- It is open-ended; there are usually several acceptable solutions.
- Design problems are typically ill-structured; design solutions cannot be found by solely applying math formulas or algorithms.
- Since design involves decision making, it is not entirely objective, in the early stages in particular.

- Other decision processes include, for example, concurrent design, axiomatic design, etc.

Example: A design team is asked to design a safe ladder. During the design process, a list of questions arises. A partial list of the questions is given below. For each question, identify the task number that the question would most likely be asked or considered.

"Design a safe ladder" is the so-called client statement.

- How is the ladder to be used? (1)
- How high should someone on the ladder be able to reach? (5)
- How much weight should the ladder support? (2) (5)
- Should the ladder be portable? (1) (2)
- What are the jurisdictions where the ladder is to be used? (2) (3)
- How much should it cost? (1) (5)
- What are the targeted markets for this ladder? (1)
- Will the ladder be made of wood, aluminum, or fibreglass? (6)
- Can the ladder lean against a supporting surface? (4)
- Must the ladder be expandable and retractable? (4)
- What is the "design load" on a step? (5)
- What is the maximum stress in a step when supporting the "design load"? (7) (9)
- How does the bending deflection of a loaded step vary with the material of which the step is
- made? (9)
- Can the ladder be assembled? (7)
- Is the ladder safe as it is actually designed? (8)
- Is the design economically feasible? (8)
- Is there a more economic design? (6) (9)
- Is there a more efficient design (e.g., less material)? (9)

In-class assignment:
For the "personal mobility device to transport people unable to use their legs" (see the lower-right photo of Figure 1.3), list as many objectives, constraints and functions as time permits. You are to, work as groups of 4; hand in your lists at the end of class; and include your names and student numbers on the top of your page(s).

<u>Overview of Design Tools</u>

- Each stage of the design process is aided by a number of design tools

- Design teams need to manage team dynamics and the project, and do so in a professional and ethical manner.

Pre-Stage 1: Understanding then detailing client's requirements

- Clarifying the problem (Sec 3.1)
- List of design attributes and objectives. (Sec. 3.2.1)

Stage 1: Defining the problem
Four tasks:

1. Clarify client's objectives
2. Establish user requirements
3. Identify constraints
4. Establish principal functions

Stage 1 – Design Tools:

- Objective tree (Sec. 4.1.1)
- Pairwise comparison chart (Sec 4.3)
- Metrics to measure the achievement of objectives (Sec. 4.4)
- Objectives and constraints tree (Sec 5.2)
- Function-means tree (Sec. 6.2.4)

Stage 2: Conceptual design
Two tasks:

5. Establish design specifications
6. Generate design alternatives

Stage 2 – Design Tools:

- Performance specification method (Sec. 6.3)
- House of Quality (Sec. 6.3.4)
- Morphological chart (Sec. 7.1.1)

Stage 3: Preliminary design
Two tasks:

7. Model of analyze the design

8. Test and evaluate the design

Stage 4: Detailed design:
One task:

9. Refine and optimize the design

Stages 3 & 4 - Design Tools:

- Discipline-specific engineering sciences and engineering design.

Stage 5: Design communication

One task:

10. Document the design

Stage 5 – Design Tools:

- Engineering graphics, manufacture, communications

Design Teams and Project Management

- Team dynamics (Ch. 15)
  Stages of working as a team
  Conflicts
  Leadership and membership

- Managing a project (Ch. 16)
  Work breakdown structures
  Team calendar
  Gantt chart

- Ethics in design (Ch. 17)

Design Team Dynamics (Ch. 15)

- Stage of working as a team

Forming: getting to know each other and becoming oriented to the tasks at hand
Storming: internal “power struggle”
Norming: norms established
Performing:
Adjourning:

- Conflict resolution

  Ignoring/avoiding, smoothing, forcing and compromising:
  - Not successful strategies

  Constructive engagement/conflict:
  - open-minded about others’ points of view
  - The roots of conflicts
  - win-win solutions

- Leadership and membership

  Leadership:
  - facilitator
  - consensus

  Membership:
  - attending meetings
  - adhering to schedules/timelines
  - informing others of progress
  - being collegiate