Stage 1 – Design Tools:

- Objectives 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)

Problem Definition: Identifying Constraints (Ch. 5)

- Identifying constraints (Sec. 5.1)
- Objectives-constraints tree (Sec. 5.2)

- Constraints are limits/restrictions on the design's behaviors.
- They can be expressed in a binary (Yes-or-No)
- They are "lines" that can not be crossed.

- Differences between expressing an objective and a constraint:

  For example,
  A ladder design should meet the requirements under Occupational Health and Safety Act (of Ontario) – *Objective*
  A ladder design must meet the requirements under Occupational Health and Safety Act (of Ontario) – *Constraint*

  *in the text, OSHA = Occupational Safety and Health Administration

- Too many constraints may limit options available in the early stage of the design process.

  For example, deflection in ladder steps in limited to 0.05 in.

- Consider limits/restrictions on the product/design as a whole rather than on parts of it.
- Be cautious about treating the same feature as objective and constraint at the same time.

  For example, low cost as an objective; cost can not exceed dollar amount as a constraint

- Be cautious of "double constraining".

  For example,

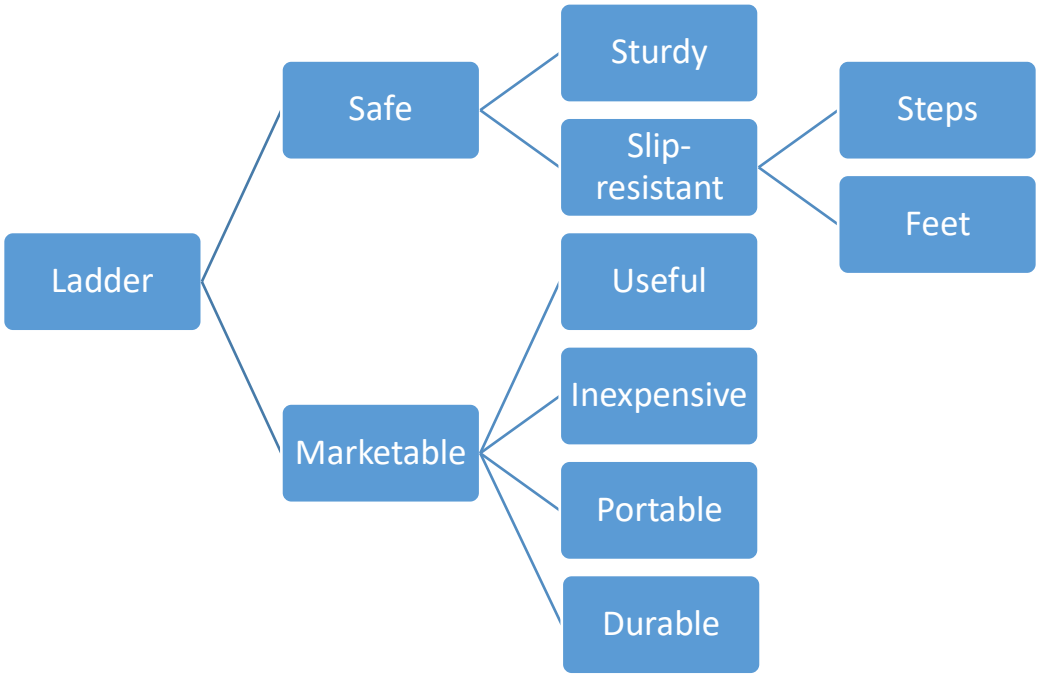
  Must meet requirements under Occupational Health and Safety Act (of Ontario) as a constraint.

  Must not slip as a constraint.

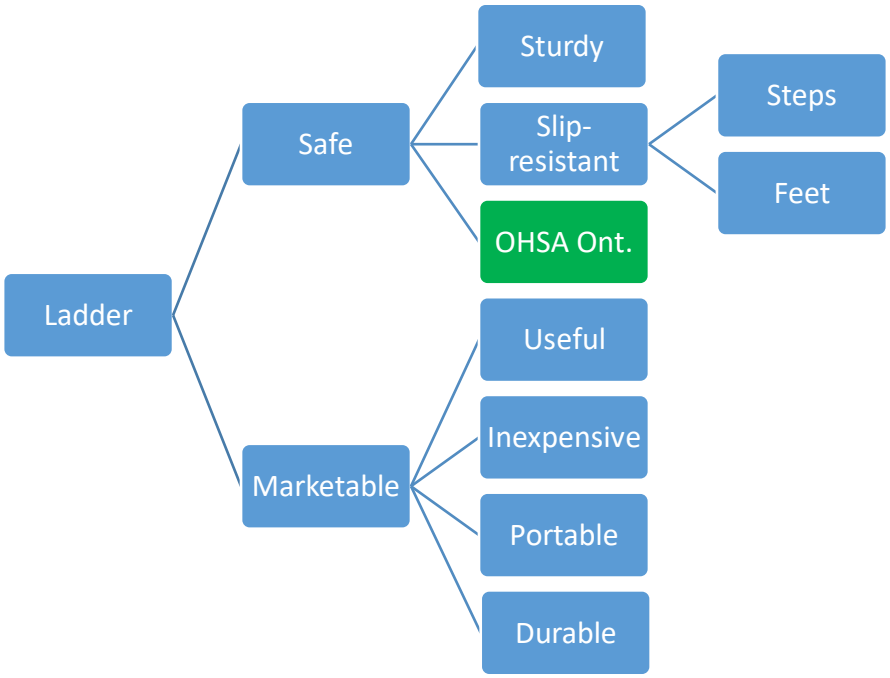
  - Keep the one that's more stringent and/or wider in scope.

- Displaying constraints: as a list or by the objectives-constraints tree.

Example objective tree for ladder design:



Example objective tree for ladder design (added constraint in green):



Problem Definition: Establishing Functions (Ch. 6)

- Establishing function (Sec. 6.1)
- Tools for establishing function (Sec. 6.2)
- Function-means tree (Sec. 6.2.4)

Establishing Functions (Sec. 6.1)

- Objectives and constraints do not have a clear "cut"
- Functions and objectives may be easily confounded, for both the novice and the experienced.
- An objective is about "being"; a function is about "doing".
- In engineering design, functions refer to things that a device or a system is supposed to do.
- Typically, functions involve the transformation or transfer or flow of energy, materials or information. See Sec. 6.1.1 for detailed explanations.
- How to express functions: by an action verb coupled with a noun or an object, or the so-called noun combination.

  For example, lift an object; measure a temperature

- The object in verb-noun combination should be ass general as possible.

  For example: "resist forces due to gravity" instead of "support books".

- There are basic functions and secondary functions.

- Basic functions are the overall functions the design must perform.
- Secondary functions are, (1) functions needing to perform a basic function; or (2) functions resulting from performing the basic functions.
- Secondary functions can be further categorized as required functions or unwanted functions.

  For example, an overhead projector
  Basic function: to project images
  Secondary functions: to convert energy, to generate light, to adjust focus
  Unwanted secondary functions: to generate heat, to generate noise

Functional Analysis: Tools for Establishing Functions (Sec. 6.2)

- Four methods are available in the text for determining functions of a design.

  Black boxes and glass boxes (Sec. 6.2.1);
  Dissection or reverse engineering (Sec. 6.2.2);
  Enumeration (Sec. 6.2.3); and
  Function-means trees (Sec. 6.2.4)

- Our focus: enumeration and function-means trees
- Enumeration (Sec. 6.2.3) is perhaps the most basic and most obvious method of establishing functions.
- Enumeration means to enumerate, or to list functions that can be readily identified.
- There are two ways/tricks to enumerate.

- The first is to imagine what would happen if part or all of the design (a device, a system, etc.) vanished.
- The second is to consider how the design would be used and/or maintained over its lifetime.
- The two ways can be used jointly.

  For example, a highway traffic bridge

  Obvious function: act as a conduit for cars and trucks
  Other functions:
  support any loads placed on it
  support its own weight
  connect to road networks
  separate traffic by direction
  provide maintenance personnel easy access to all parts of the bridge

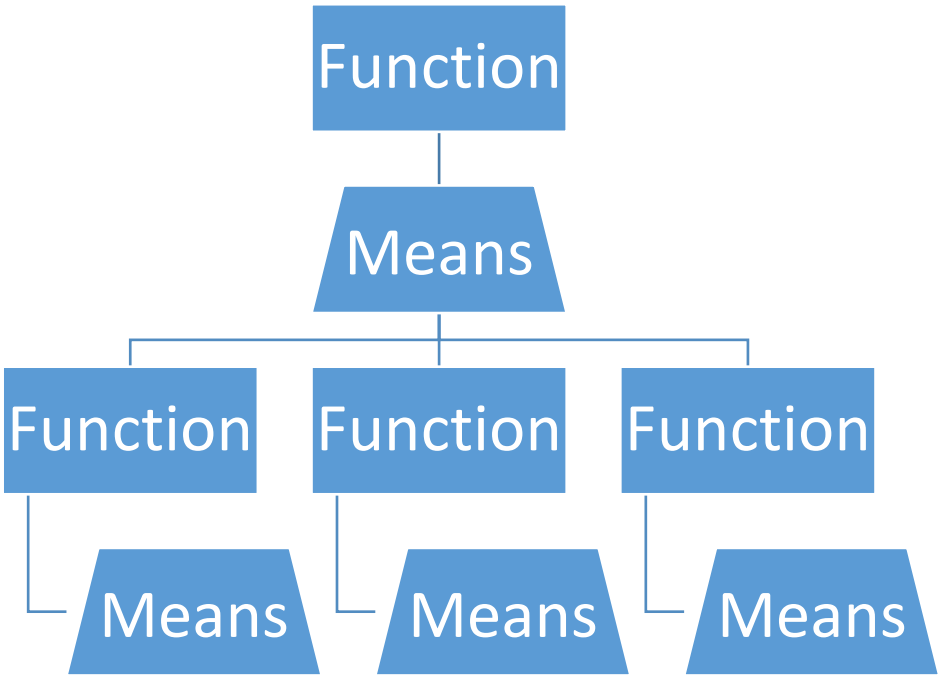
  For example: a reusable juice container

  Obvious functions: contain liquid
  Other functions:
  fill the container
  close the container after opening
  empty the container
  resist forces induced by transportation
  resist volume changes induced by extreme temperatures

Functional Analysis: Tools for Establishing Functions (Sec. 6.2)

- Function-means tree (Sec. 6.2.4) is a graphical representation of the basic and secondary functions (and sub-functions) associated with a design.
- Top level shows the basic function; each of the succeeding levels alternates between means and the secondary functions made necessary by the means.
- Functions are shown as rectangles and means as trapezoids. Different fonts may be used in conjunction with different shapes. See, for example, Figure 6.4.
- The tree is to relate *what* the design must do (a function) to *how* we may do it (means).

Example for Function-Means tree:



Additional notes:

QFD – Quality Function Deployment

A design is good, only if the customer thinks the design is good.

For every objective you must have a metric that is measurable.

Hoq – House of quality.

Reading Assignments:

S. 5.1, 5.2 (End of material for Midterm)
S. 6.1, 6.2.3, 6.2.4, 6.2.5