Introduction to Engineering Design Processes

XYZ – 487 Senior Design

School of Engineering
Mercer University

Loren Sumner

Refs:

ABET Criteria for Accrediting Engineering Programs 2012-13, criterion 5

Haik and Shahin, Engineering Design Process, 2nd ed., CENGAGE Learning, 2011.

Kroll, Condoor, and Jansson, Innovative Conceptual Design, Theory and Applications of Parameter Analysis, Cambridge, 2001

A Design process seeks a preferred solution

- Design problems are open ended and typically complicated
  - Open-ended problems have many possible feasible solutions
  - Problems involve many different needs and performance characteristics (various measures of success)
- A Design process seeks a preferred solution in some way
  - This requires more than an educated guess among feasible alternatives but a credible and substantiated better solution.
- A Design process constitutes a series of questions, investigations, and decisions

Engineering Design applies engineering principles

- It is a decision-making process leading to the specification of a (device, system, and/or process) that meets stated functionality and performance objectives.

- It applies knowledge of the
  - basic sciences,
  - mathematics, and
  - engineering

  to optimally convert resources for a desirable solution

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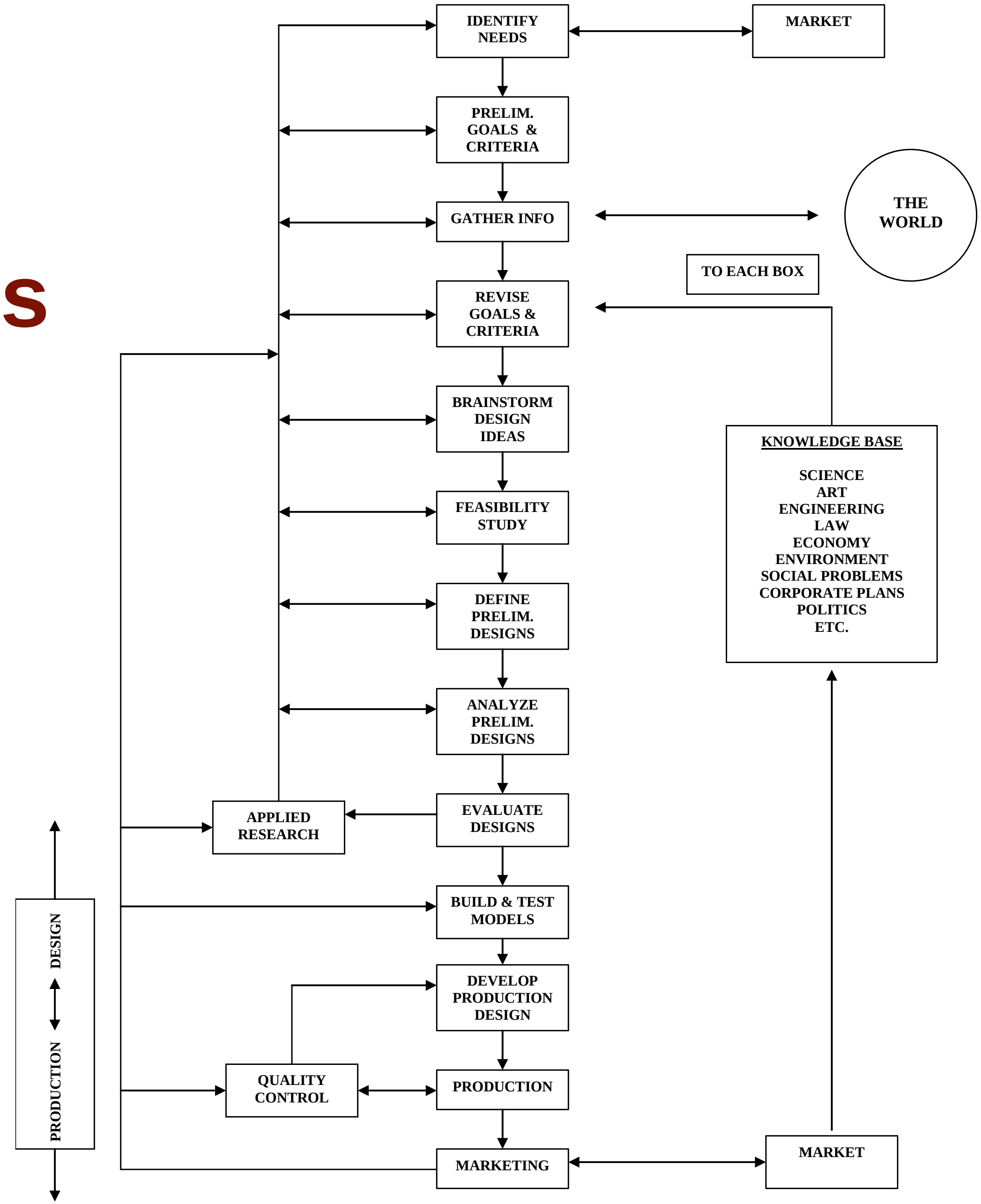
Haik and Shahin, Engineering Design Process, 2^{nd} ed., CENGAGE Learning, 2011.

Possible Deliverables of Engineering Design

- Computer Software Files, Data files, Written Programs, etc
- Prototype, instrumentation, tools, etc
- Documentations,
  - Working drawings
  - Detailed set of specifications of final product and components
  - Recommendations, Substantiated Decisions
  - Explanations (needs analysis, performance predictions, etc)
  - Report of background research (technology review)
  - Findings (from analyses, technology reviews, etc)
  - Graphics of results, concepts, budget, etc
  - Interpretation of Findings
  - Instructions and/or hardware manuals

A Design Process



Another Design Process

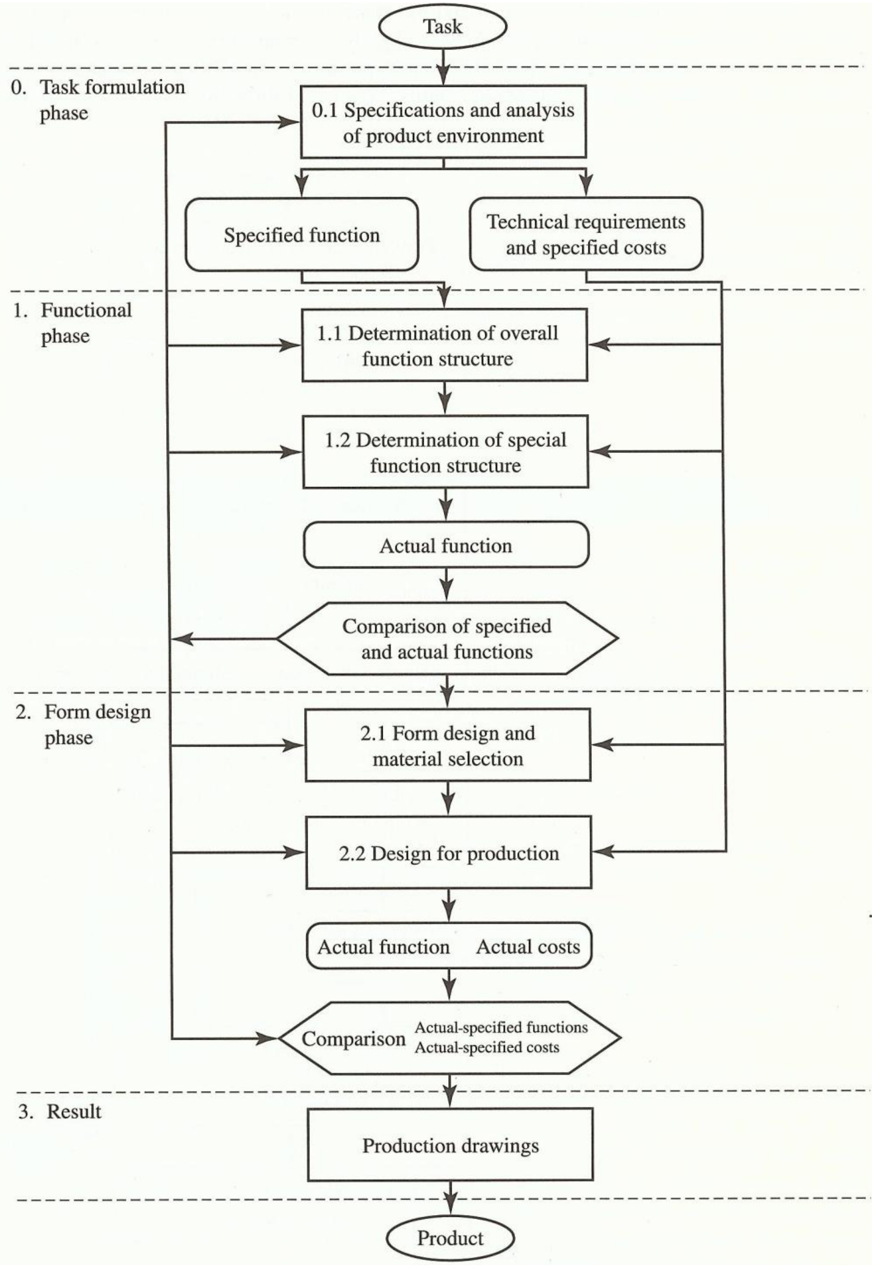


Figure 1.2 Design process map. ("Design Process Map" from ENGINEERING DESIGN: A SYNTHESIS OF VIEWS by C.L. Dym. Copyright © 1994. Reprinted with the permission of Cambridge University Press.)

Typical Design Processes

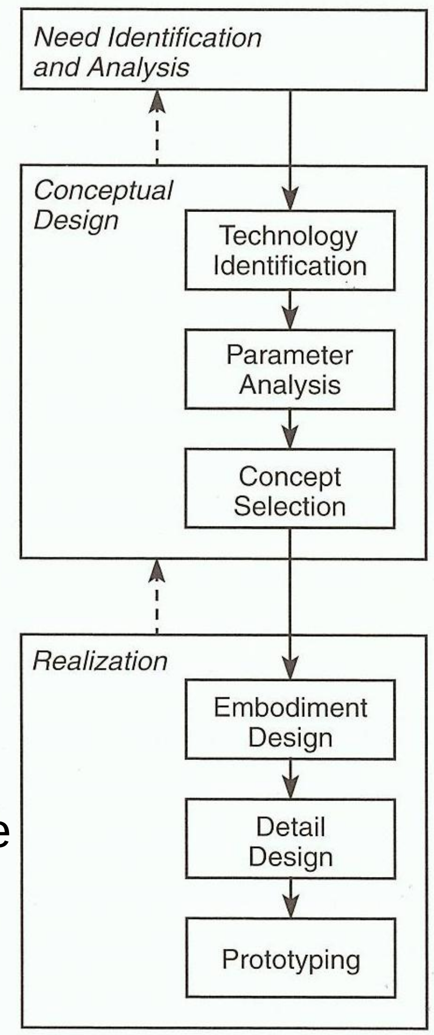


Figure 1.1 Overview of the engineering design process.

Creating a high-quality idea

Background research

Brainstorming

Merit Analysis

Engineering Analysis – predictions, calculations, etc. leading to final specs

Realizing a high-quality device

Details for clear definition

Final Specs (PDR) – end 487

Prototyping(Testing) - XYZ 488

Kroll, Condoor, and Jansson, Innovative Conceptual Design, Theory and Applications of Parameter Analysis, Cambridge, 2001

Needs Identification and Analysis

- Discovering/verifying the “real” needs
- Find and remove preconceptions
- Analyze the needs as to not preclude solutions due to a biased understanding
- Effectiveness of the conceptual design depends on how well the need is understood
- Important to overtly ensure objectivity in the early stages
- Develop engineering requirements and objectives for the project
- Plan a design process to arrive at a preferred solution

Engineering: Demonstrated application of what you've learned at MUSE

- Analog Filter Design
- Bioremediation
- Biological Fluids
- Biomechanics
- Chemical Processes
- Diagnostic Imaging
- Digital Logic and Comp. Organization
- Dynamics
- Electrical Fundamentals/ Circuits
- Electromagnetic Field Theory
- Engineering Design
- Engineering Economy
- Ergonomics
- Feedback Controls
- Fluid Mechanics/ Hydraulics
- Heat Transfer
- Human Factors Engineering
- Instrumentation/ Data acquisition
- Manufacturability
- Materials
- Mirocomputer Fundamentals
- Probability and Statistics
- Power Electronics
- Robotics
- Signal Processing
- Solid Mechanics/ Structural analysis
- Quality Control
- Statics and Solid Mechanics
- Thermodynamics
- Vibrations

Topics are comparable with all accredited engineering schools across the country.

Basics of Decision Making

1. Clarify the issue needing a specific solution
2. Generate alternatives
3. Develop criteria to evaluate alternatives
4. Identify criteria importance
5. Evaluate
6. Decide next step
    a. Refine, add, alternatives
    b. Refine criteria and evaluation
    c. Choose an alternative to invest resources

Design Criteria

- Developed from performance specifications
  - Ensure compliance with client’s requirements
  - Use to discriminate between design ideas
  - Choose the idea to develop (w/ engineering analysis) into a specific device
- Two Types
  - Feasibility Criteria - Eliminate infeasible ideas
  - Merit Criteria - Compare merit of feasible ideas

Feasibility Criteria

- Factors that limit the scope of a project
- Normally expressed as constraints
  - unit must weigh less than 100 lbs.
  - unit must accelerate to a velocity of 60 mph in less than 10 seconds.
- Go / No-Go Criteria (Feasible / Not-Feasible)
- Project requirements are a primary source

Feasibility Analysis

- Eliminate some of the design concepts
- Reveal ways that other alternatives may overcome their limitations
- Produces at least two feasible alternatives
  - In practice, this will not always occur
  - For your projects – probably should
- A single table comparing each design to the feasibility criteria with pass/fail (√ or X) notation is a common approach
  - Good visual of why designs are succeeding of failing

Merit Criteria

- Specific while still providing a basis for choosing between alternatives
- Examples include:
  - low unit production cost, low shipping cost, low storage cost, etc.
  - high acceleration, high velocity, high efficiency, etc.
- Relate closely to performance specs
- Contribute to overall project goals

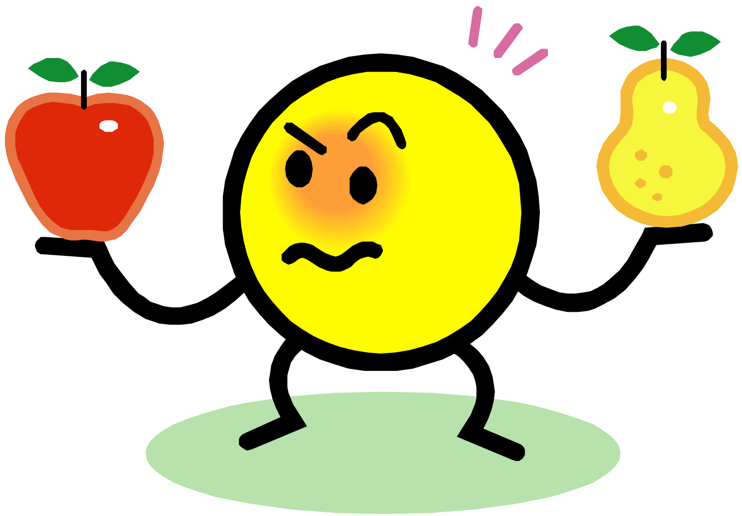
Merit Analysis

Which concept is the most meritorious?

- Provide a logical method for selecting an alternative to develop
- Reference merit criteria – quantifiable factors that promote discrimination between **FEASIBLE** design alternatives.
- Should be presented in a form which will facilitate the decision making process
- Substantiates & facilitates good decisions

Lots of decision making tools

Principal-based decision making
PMI (Plus/Minus/Implications)
Probabilistic Risk Assessment & Risk- Based
Pareto Analysis
Cost/Benefit
Grid Analysis
Paired Comparison
Decision trees
Six Thinking Hats
Force Field
…



The Decision Matrix – Pugh's Method

	Weight (%)	Alt #1 Features	Alt #1 Merit Factor	Alt #1 Total Merit	Alt #2 Features	Alt #2 Merit Factor	Alt #2 Total Merit	Alt #3 Features	Alt #3 Merit Factor	Alt #3 Total Merit
Functionality	40	7	7	280	9	9	360	8	8	320
Production cost	30	$1000/unit	6	180	$500/unit	8	240	$750/unit	7	210
Operating cost	15	$2.00/hr	6	90	$4.00/hr	2	30	$3.00/hr	4	60
System weight	10	60 lbs	6	60	70 lbs	2	20	50 lbs	10	100
Aesthetics	5	10	3	15	50	7	35	25	5	25
Total	100			625			685			715