Mechanical Engineering Design Project

MECH 390

Lecture 1

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materials for classes, tutorials and laboratory

Engineering Today and Tomorrow

- Engineering profession along with technology has been changing in a way that companies need engineers who can be very adaptive in complex dynamic work environment by being **innovative, problem solver, critical thinker, good team player** in diverse teams.

Future belongs to those engineers, who constantly seek new knowledge and skills.

Gear shift issue

Old design

New design

What was missing from the new design?

- Function?
- Performance?
- Agreeable shape/ gorgeous touch?
- Comfort?
- Safety?
- Reliability?
- Ergonomics?
- Acceptance of the consumer?
- Cost?

What is the learned lesson?

- Safety first
- Further issues –
  - Why engineers need a license to practice?
  - What the license provides a practicing engineer?
  - Liabilities? Who covers the loss due to errors or flaws in design?
- In case of a trial, what evidence one could bring to prove that a design was carried out according to the regulations, standards and the common science?

Who is responsible for a design flaw that slipped un-noticed

- Difficult to foresee all the scenarios that a product will be subject to
- The consequences of misuse may be hidden in the analysis phase
- The ability to preview all possible dangerous situations will play a major role in the success of a product
- The design trend – design a platform and not just a product
- Is it a group responsibility?
- If the consequences are serious, somebody will be in the position to pay

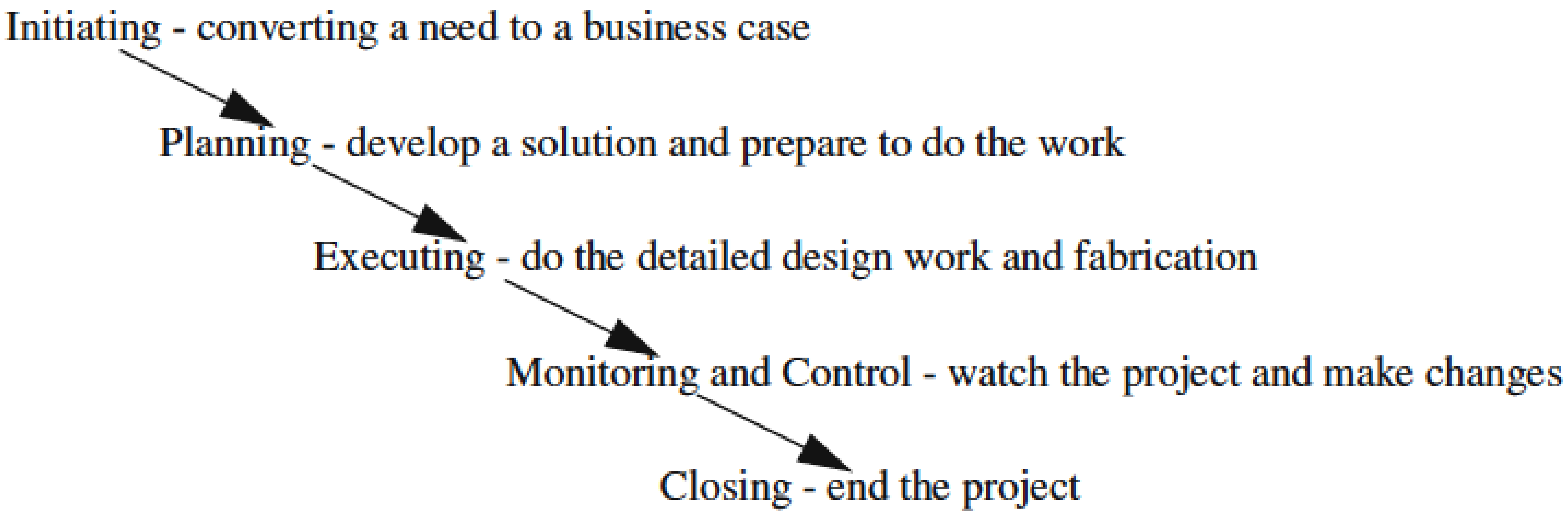
The requirements of a product

- Any new design is “tested” by the users
- Their “verdict” makes the product successful
- Some of the requirements of a product:
  - Functional performance
  - Reliability
  - Appearance
  - Robustness
  - Maintenance
  - Human factors
  - Environmental friendliness
  - Price

Creation of a product

- A completely new product
- A substitute to an existing product (why?)
- A new version/size/class of a product
- All design follow same flow:
  - Initiation – generated by a need
  - Planning the product and the design process (life of the product, customers, extension of objectives, life extension, protection, etc)
  - Execution of the project (usually few teams collaborate)
  - Monitoring and control (problems may come up)
  - Closing

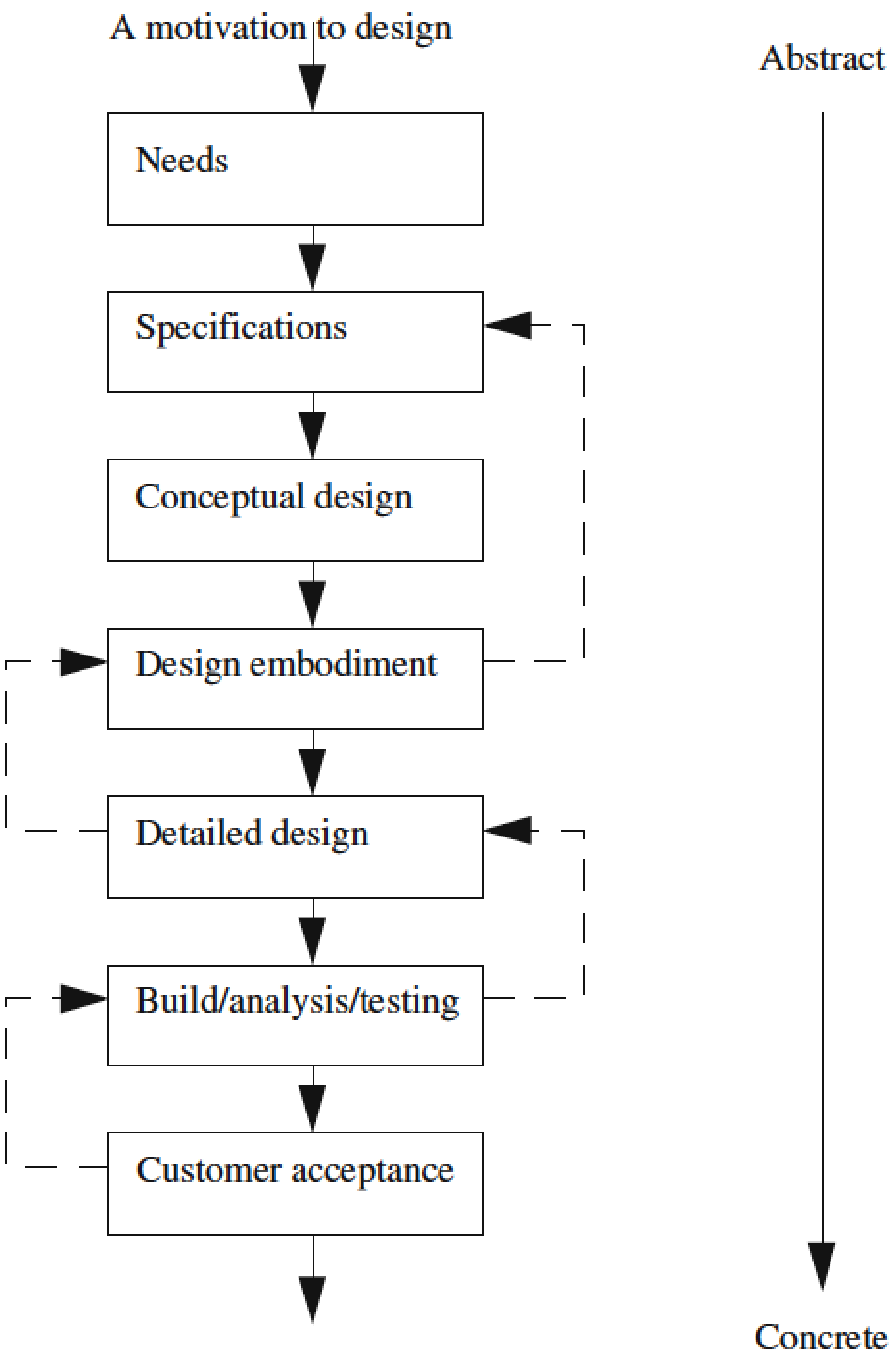
The slide of a project



Resources, effort, benefits, all follow specific paths

The seven steps project

- Clear steps (start/end)
- Backtracking
- Vaguely detailed
- In real project the steps are blended
- Needs would not change but the means to achieve them may change
- If needs change, that is a new project

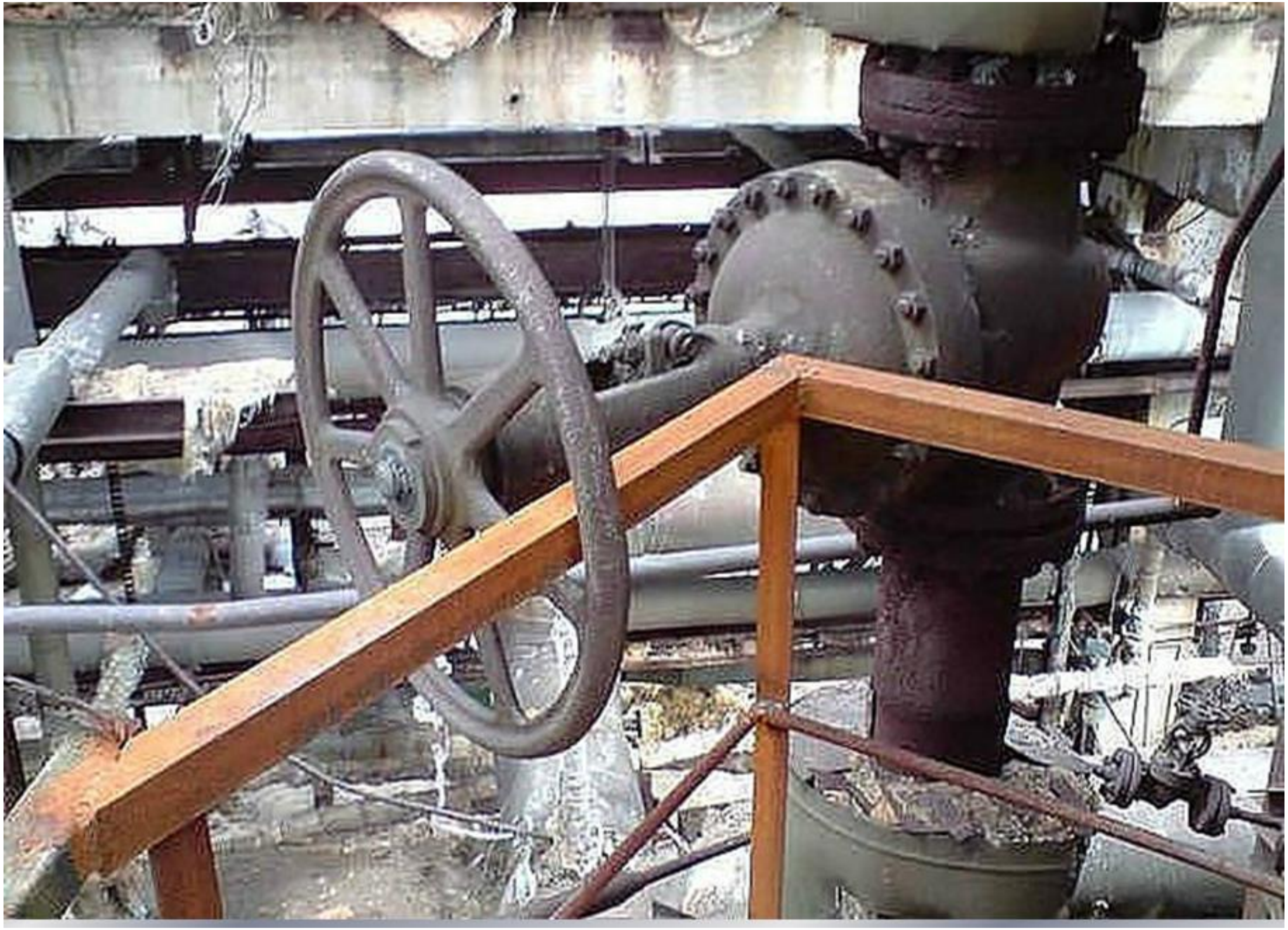


The embodiment of a project

- Selection of the best concepts:
  - Configuration
  - Format
  - Framework
  - Hierarchy
  - Composition
  - Form
  - Software code (version)
  - Mechanical sketches
  - Calculation/equations
  - Test data
  - Electrical schematics
  - Data sheet of sourced components
  - Flow charts
  - State diagrams/timing diagrams
  - Physical prototypes
  - For sourcing components
  - Formal process diagrams
  - 3D models
  - Assembly hierarchy diagrams
  - Assembly specifications
  - List of all parts
  - List of critical suppliers

The conceptual component

- Previous experiences may lead to a general scheme of a design
- The concept must be feasible and clearly detailed and easy to be understood by the others
- A good design is simple to start with
- Features are added after the fundamental function is achieved
- A pro-active approach is recommended – towards the functionality and safety when using the product, capability to add features and improve performance
- Preview scenarios that would may occur when one is using the product (consequences, impact of malfunctioning, etc)



We will talk about

- This course is completely different from all the other classes – it looks like what you will be doing throughout your engineering professional career
- The requirements of the course
- What is expected from you
- The specifics of this class
- The course week by week
- The learned lesson from this class (expected)
- The expected results of the course
- The final project
- The documentation of the project
- The presentation
- Design principles and the metrics

What is expected from you

- To prove in depth thinking and to apply the engineering skills acquired so far in a creative effort – the final project
- Use your imagination and communicate the ideas using the most suitable methods (writing, drawing, presentation, etc)
- Read and try to understand the provided documentation on moodle. If you find other interesting documentation, please feel free to share it with us
- Identify and use the **standards and regulations/codes** besides calculations when take a design decision
- Each decision MUST be given an explanation which is also well documented with a proof
- Study the content of the textbook to acquire the basics of engineering design skills and be able to mark good grade in the class tests

What else is expected…

- Pay attention to the lectures to be able to mark well in the class tests– attendance to the class is highly recommended
- Actively participate in the tutorials to be able to complete the tutorial materials well and on time. Use your imagination and group work techniques to come up with a feasible design, model
- Start early the research for the essay on the selected technology
- Do your best to gathering the data to complete the required documentation of the project on time
- Prepare and present your team work in a good and clear formal presentation at the end of the course
- **There is no formal final for this course**

Graduate attributes

- Our engineering program is accredited by the CEAB (Canadian Engineering Accreditation Board)
- Specific requirements apart from engineering learning is required form you (and us)
- These requirements are the graduate attributes
- They are skills that are essential in your engineering career
- The performance in the attributes is a metric for the course and not students
- The results are not included in any evaluation and are transparent to the students

The attributes for this course

ATTRIBUTE	INDICATOR	LEVEL OF KNOWLEDGE
Investigation *An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.*	Background and Hypothesis Formulation	ADVANCED
	Designing Experiments	ADVANCED
	Conducting Experiments and Collection of Data	ADVANCED
	Analysis and Interpretation of Data	ADVANCED
Design *An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.*	Define the objective	INTERMEDIATE
	Idea generation and selection	INTERMEDIATE
	Detailed design	INTERMEDIATE
	Validation and implementation	INTERMEDIATE
Individual and team work *An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.*	Cooperation and work ethics	ADVANCED
	Contribution: Practical/Conceptual	ADVANCED

Some recommendations

- The tutorials – make the most use of them; ask the tutors any question – hopefully they will be able to answer
- Ask the tutors to give you help in using specific software tools
- Ask the tutors to give you support in developing the models of the system
- The course is making use of the information that you have acquired in MECH 211, MECH 244, MECH 311, MECH 313, MECH 343, MECH 344, ENGR 242, ENGR 243 and not only.
- The tasks as formulated are way different from those where a sole answer was good – in this course open end type of questions are formulated and answer of this kind are expected

Some recommendations (cont'd)

- The design tasks are vaguely formulated and the constraints may be fuzzily expressed – this is always the case
- You need to set the tasks and the constraints of a structured fashion that will enable you and your group to state tasks and design steps that are achievable
- Each of the defined task and its solution need to be properly documented and proved
- The proof needs to be such expressed and presented to be easy to understand by the other colleagues and tutors as well as the supervisors
- For the first time you need to organize the study a textbook by yourself as a requirement and yield two tests on that material
- For the first time you will link the calculations with a practical design expresses in drawings
- You may need to return to a previous stage of the design and re-calculate or re-draw given the new information found during the process – design is an iterative process

Course Outline

This course focuses on Mechanical Engineering Design Project, which includes:

- Recognizing and defining open ended engineering design problems
- Generating creative concepts and solutions
- Project planning
- Decision making for optimum design
- Modeling and analysis
- Prototyping and testing/verification
- Communication via engineering reports and presentations

1. Students will work in teams to complete a Design Project. (40%)
2. Students will take one midterm exam. (20%)
3. Students will complete 10 tutorial assignments. (20%)
4. Students will take 5 or more quizzes randomly distributed throughout the semesters (20%).

Success for MECH 390

- Pay attention to the lectures and to be able to do well in the class exam and quizzes.
- Attendance to the class is highly recommended.
- Study the provided documentation on the course website.
- Study the content of the textbook to acquire the basics of engineering design skills.
- Actively participate in the tutorials to be able to complete the tutorial materials well and on time.
- To apply/use the engineering skills acquired so far in a creative effort –the design project

Success for MECH 390

- Use your imagination and communicate the ideas using the most suitable methods (writing, drawing, presentation, etc)
- Identify and use the standards besides calculations when take a design decision.
- Each decision/assumption MUST be given an explanation which is also well documented with a proof.
- Plan in project activities.
- Do your best to gathering all data to complete the required documentation of the project on time.
- Prepare a final project report and present your team work in a good and clear formal presentation at the end of the course
- There is no final exam for this course.

Specifics of MECH 390 course

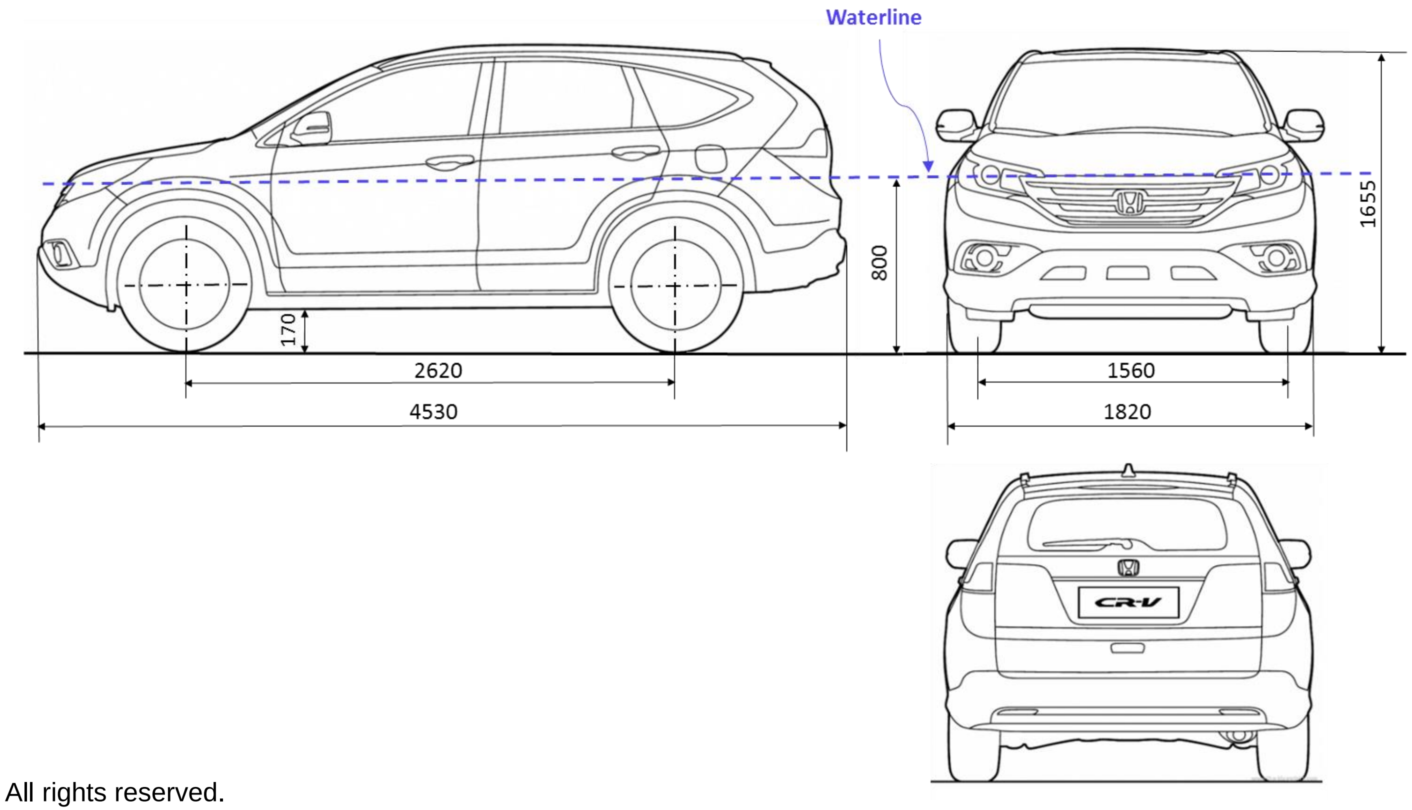
- This is the first course where you “practice” more than you study.
- You will learn to work in teams and you will have targeted objectives.
- You will learn about the limitations of time or resources and hopefully will be able to do it right in the capstone.
- You will be able to evaluate how realistic are your initial plans.
- If you do not learn from mistakes you will never be able to perform.
- Set realistic objectives –you have 12 weeks to work on the project.

Design Project

- The primary goal of the Design Project is to create/design and build/verify “ Design an Amphibian System for HONDA CRV”
- The project will require imagination, knowledge, capacity of synthesis, analytical skills, planning, teamwork, etc.
- The tutorials will provide the environment to help you gain skills and knowledge for the design project.
- Please consider this project as an integrated design activity.

Main Design Project

Objective: The design of Honda 4x4 CRV (2014 model) vehicle will be retrofitted to be fully amphibious and propelled in the water at maximum speed of 10 km/h (5.4 knots) by propeller(s) mounted one either side and/or the rear of the vehicle:



MECH 390 course Grading

- The one midterm exam (20% of the final grade)
  - It will be based on the textbook and materials discussed in the class.
  - The exam will be held during lecture hours on the week of March 5th .

- The quizzes (20% of the final grade)
  - 5 or more surprise quizzes randomly distributed over the course of 13 weeks.
  - No prior information regarding the date or the material for quizzes shall be given.

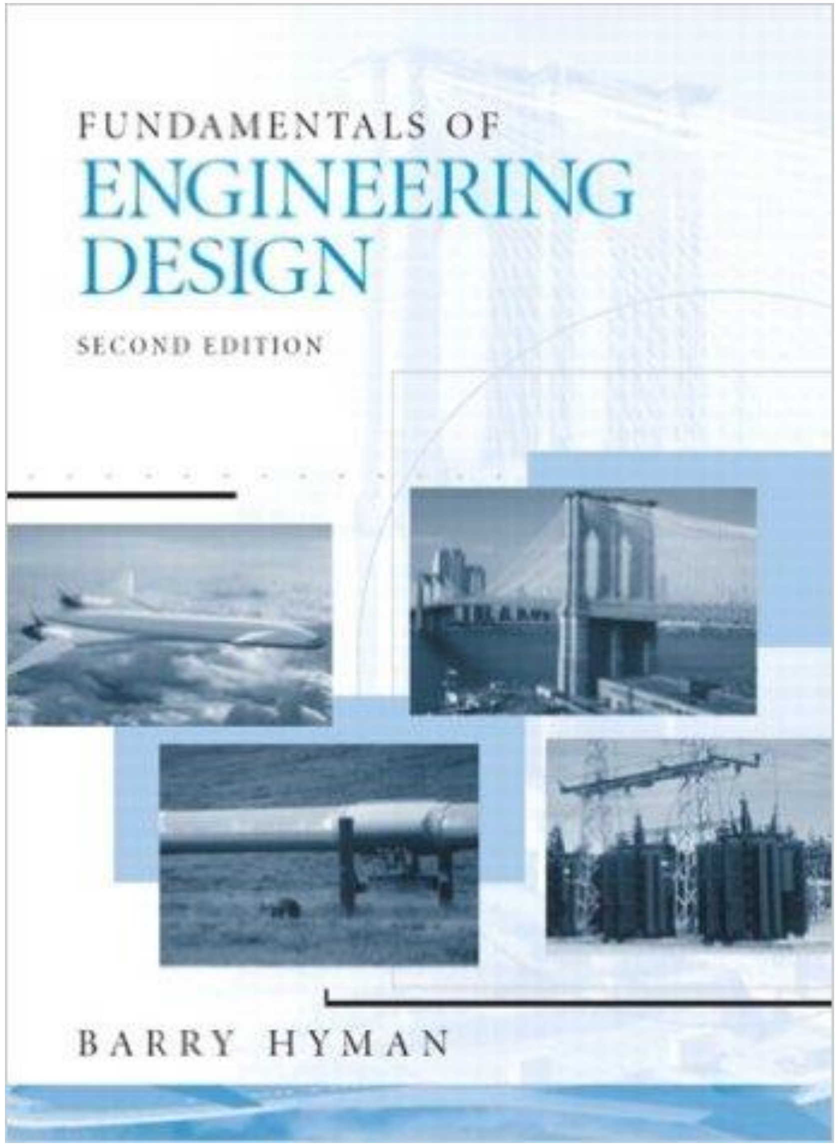
MECH 390 course Grading

- The tutorials (20% of the final grade)
  - Start week #2, the week of January 15
  - Tutorials are scheduled in H-1065 / H-835
  - During the first tutorial, teams will be formed by 4 or 5 members
  - A plan will be made –weekly plan that will enable the completion of the project.
  - The tutorials will be run by TAs with experience in design
  - Each tutorial assignment counts for 2%.

MECH 390 course Grading

- The Design Project (30% of the final grade)
  - The content of the project is provided in the course outline.
  - The submission will be on the day teams present their work.
  - A good project will provide the reader all the details that will be convincing enough that the design is good/optimum.
  - The optimization of the project design is of more importance than the complexity.
  - The evaluation is carried out by the instructor and prorated among team members based on the peer confidential evaluations.
- Final presentation (10% of the final grade)
  - The presentation day –Monday April 16th and Tuesday April 17th, 2018
  - Prepare about 12 -15 minutes talk (max. 3 min per presenter)

The textbook



- It includes 10 chapters
- Most of it will be covered in lectures
- Some you can read on your own
- In addition, the course will have some case studies

COURSE LECTURES

Introduction to Engineering Design	Chapters 1 and 2 (Text Book)
Quadcopter Dynamics Simulation and Control	Note
Probabilistic Considerations in Design	Chapter 5 (Textbook)
Project Planning	Chapter 7 (Textbook)
Engineering Economics	Chapter 8 (Textbook)
Decision making	Chapter 9 (Textbook)
Optimum Design	Chapter 10 (Text book) and Note
Case Studies	Note

Characteristics of an Engineering Science Problem

- Problem statement is compact and well-posed
- Problem has a readily identifiable closure
- Solution is unique and compact
- Problem uses specialized knowledge

Typical Engineering Science Problem Statement

A simply supported steel beam with a 3” diameter circular cross-section is loaded as shown. Determine the maximum stress and deflection.

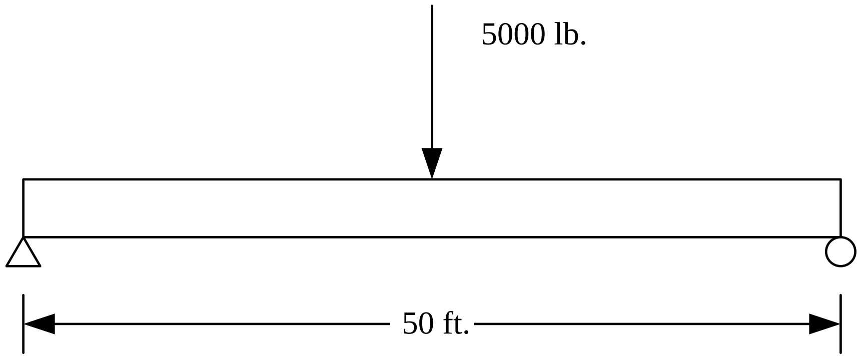


Fig. 1.1

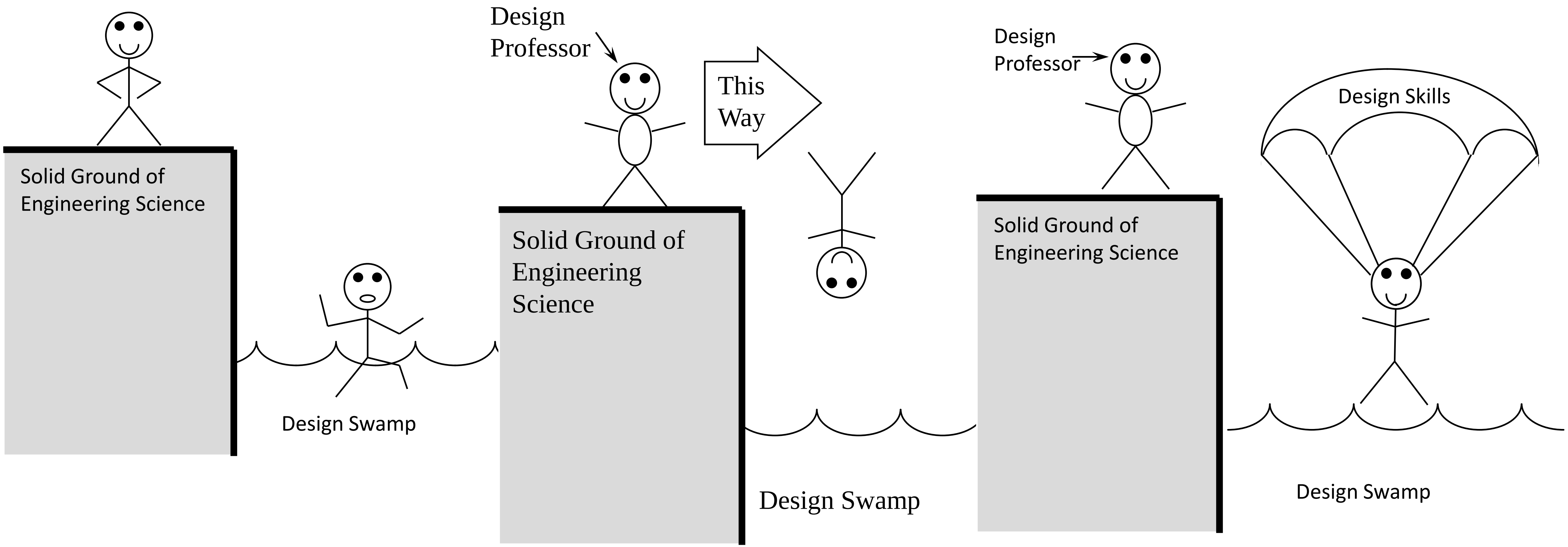
Characteristics of an Engineering Design Problem

- Problem statement is incomplete, ambiguous, and self-contradictory
- Problem does not have a readily identifiable closure
- Solutions are neither unique nor compact
- Problem requires integration of knowledge from many fields

Typical Engineering Design Problem Statement

Design a system for lifting and moving loads of up to 5000 lb in a manufacturing facility . The facility has an unobstructed span of 50 ft. The lifting system should be inexpensive and satisfy all relevant safety standards.

Topography of Engineering Science and Engineering Design*



ABET Definition of Design

- Engineering design is the process of devising a system, component, or process to meet desired needs.
- It is a decision-making process (often iterative), in which the basic sciences and mathematics, and engineering sciences are applied to convert resources optimally to meet a stated objective.
- Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation.

Nine Step Model of Design Process

1. Recognizing the need
2. Defining the problem
3. Planning the project
4. Gathering information
5. Conceptualizing alternative approaches
6. Evaluating the alternatives
7. Selecting the preferred alternative
8. Communicating the design
9. Implementing the preferred design

Step 1: Recognizing the Need

Sandra: “Jane, we need you to design a stronger bumper for our new passenger car.”

Jane: “Why do we need a stronger bumper?”

Sandra: “Well, our current bumper gets easily damaged in low-speed collisions, such as those that occur in parking lots.”

Jane: “Well, a stronger bumper may be the way to go, but there may be better approaches. For example, what about a more flexible bumper that absorbs the impact but then returns to its original shape?”

Sandra: “I never thought of that. I guess I was jumping to conclusions. Let’s restate the need as “there is too much damage to bumpers in low-speed collisions.” That should give you more flexibility in exploring alternative design approaches.”

Step 2: Definition of the Problem

Once need is established, problem defended

Goal

Objective

constraint

Step 3: Planning the Project

Plan for Bumper Design Project

Task	Starting Date	Completion Date	Cost ($)
Preliminary Design	July 1	July 10	1,000
Build Prototype	July 8	July 15	2,000
Test Prototype	July 13	July 17	1,500
Final Design	July 20	July 31	3,000

Table 1.2

Step 4: Gathering Information

Information regarding similar projects and solutions already in place

Constraints based on codes and standards

If it is a new area

Theoretical design

Experimental verification

Develop new models to evaluate alternatives

Step 5: Conceptualizing alternatives

Creativity and imagination

Wide range of design options first as defined for step 2 constraints

Out of the box thinking – away from analytical thinking

Step 6: Evaluating alternatives

Analyze each option to see if the design constraints are met

More analytical

Solid ground in the design swamp

Step 7: Selecting the Best Alternative

If in the bumper design, cost, drivability, damage control, and recyclability are goals at this point one has to choose which one is more important than the other

So as a designer, you should be able to choose from the 3 below such that clients (your boss's) preferences / values are reflected

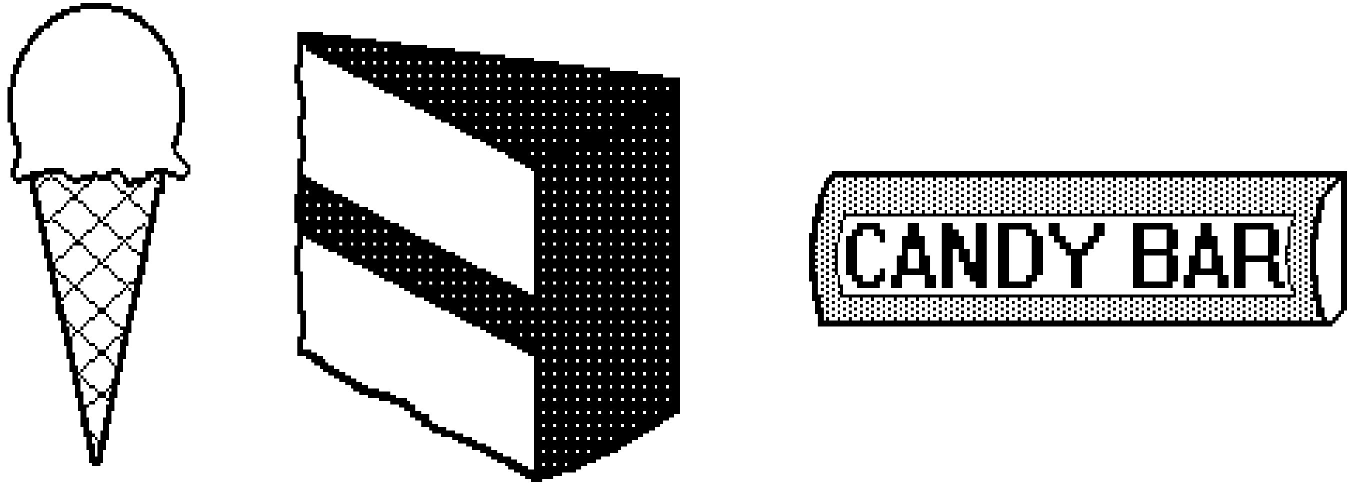
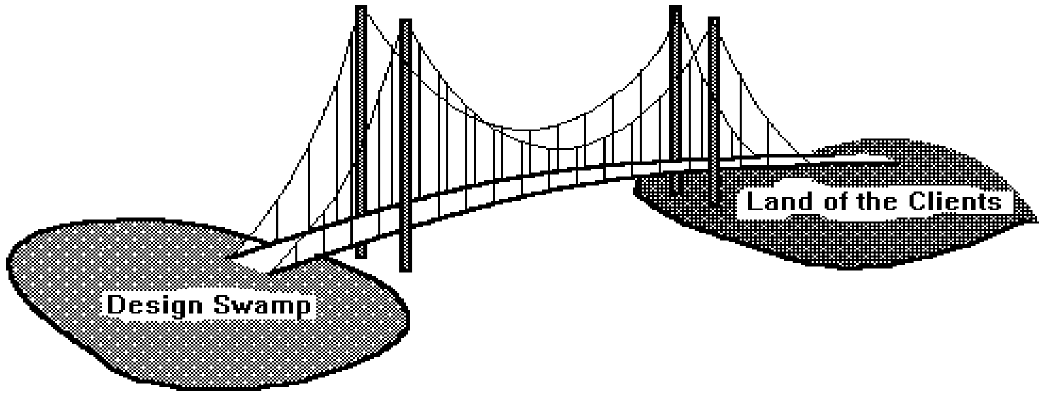


Fig. 1.7

Step 8: Communicating the Design



Record for the engineer to justify and reconstruct what he/she did and why he/she did the way it was done

Clears fog and serves as a bridge

Takes hard work to develop this skill

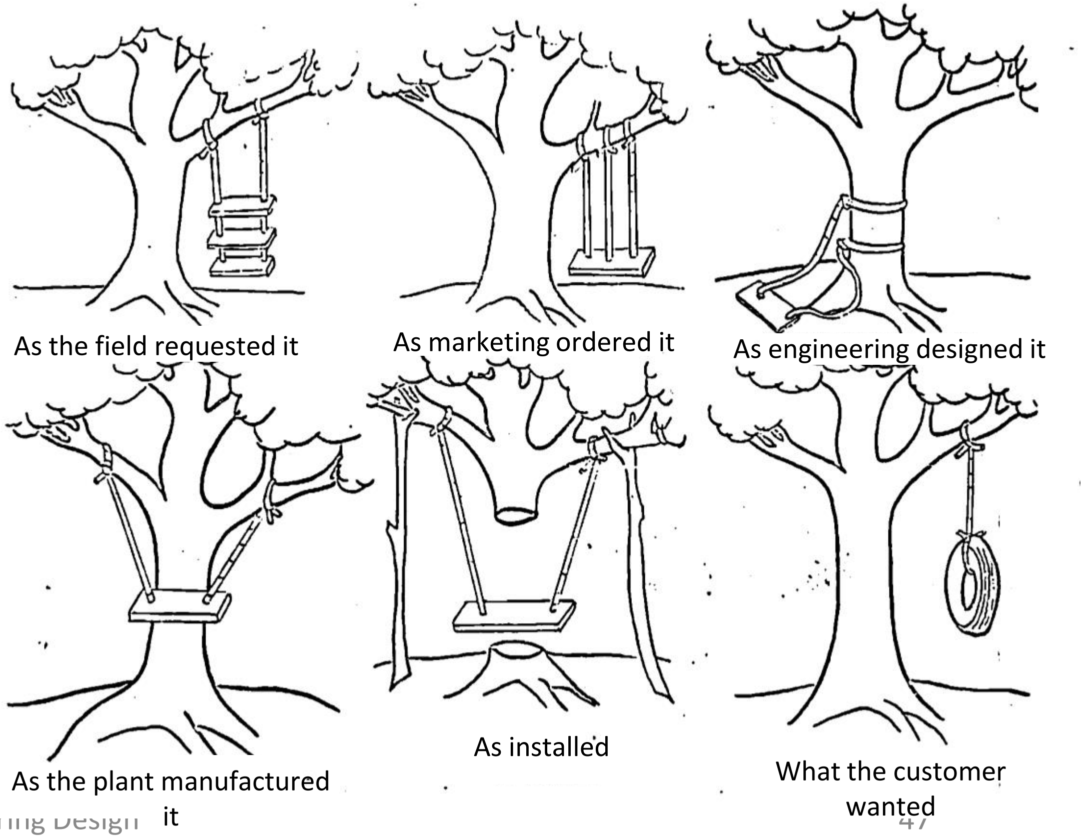
Step 9: Implementing preferred design

Translation of design concepts into actions

- Over the wall

To

- design for manufacturing
- design for assembly



Engineering system design

Three-level Diagram of Automobile Bumper/Bracket System

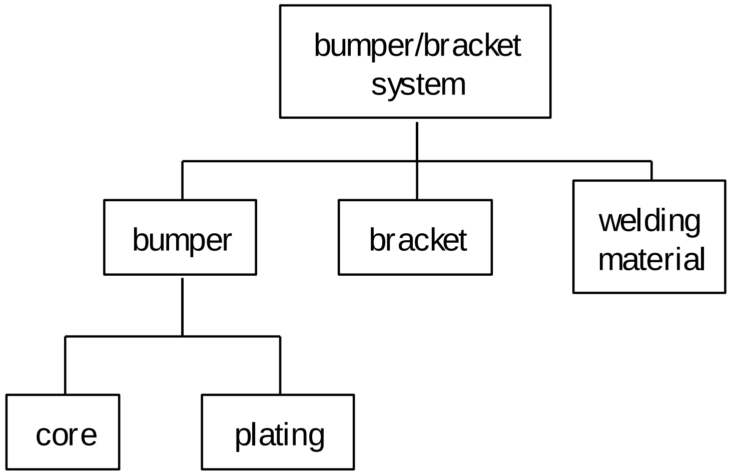


Fig. 1.9

Five-level Diagram Including Bumper/Bracket Subsystem

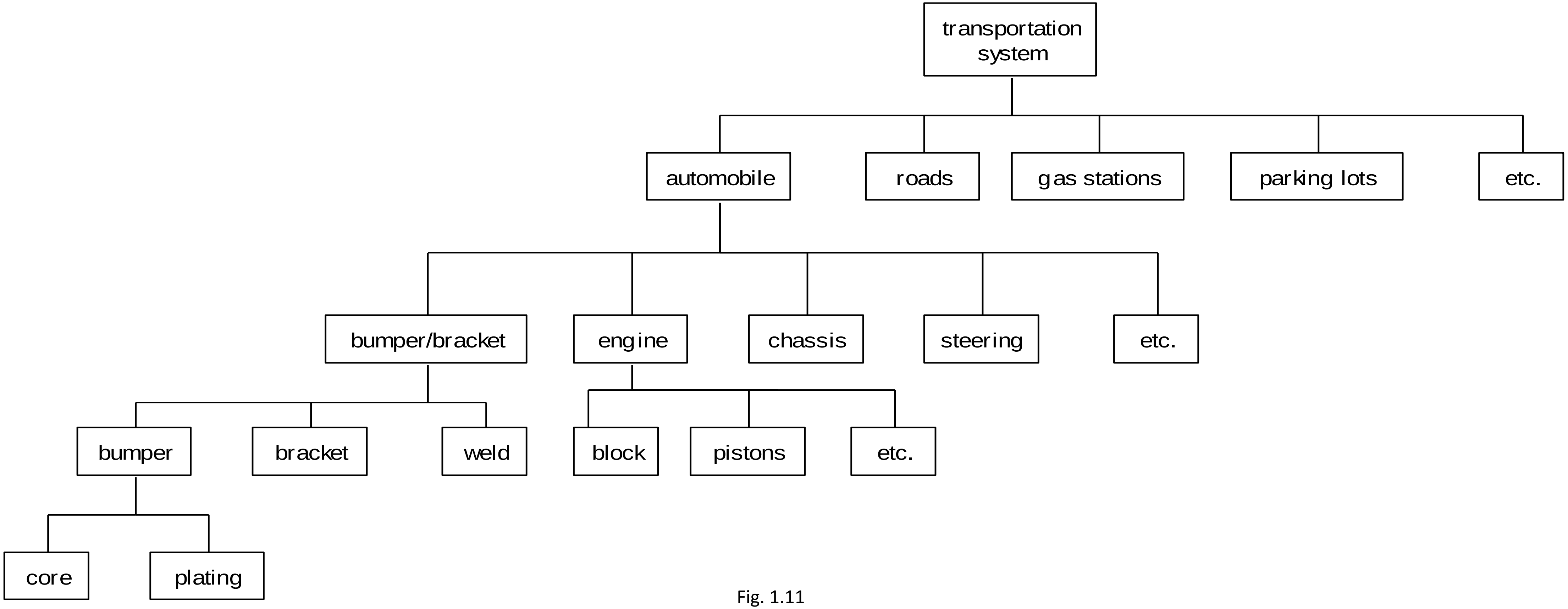


Fig. 1.11

System Concepts

- System: collection of elements that interact to fulfill a function
- Boundaries: separate system from environment
- Components: smallest identifiable element of system
- Subsystems: collection of components

Six-level Diagram Including Bumper/bracket Subsystem

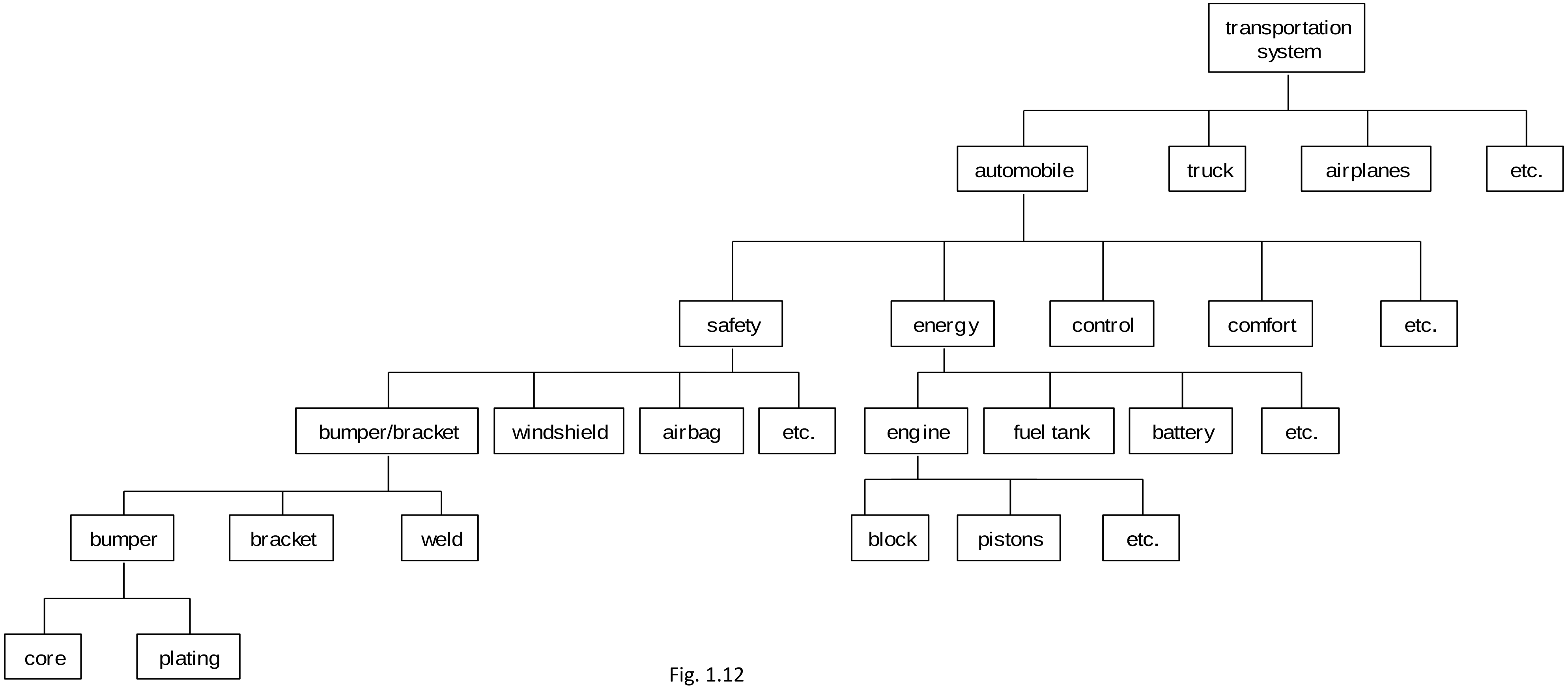
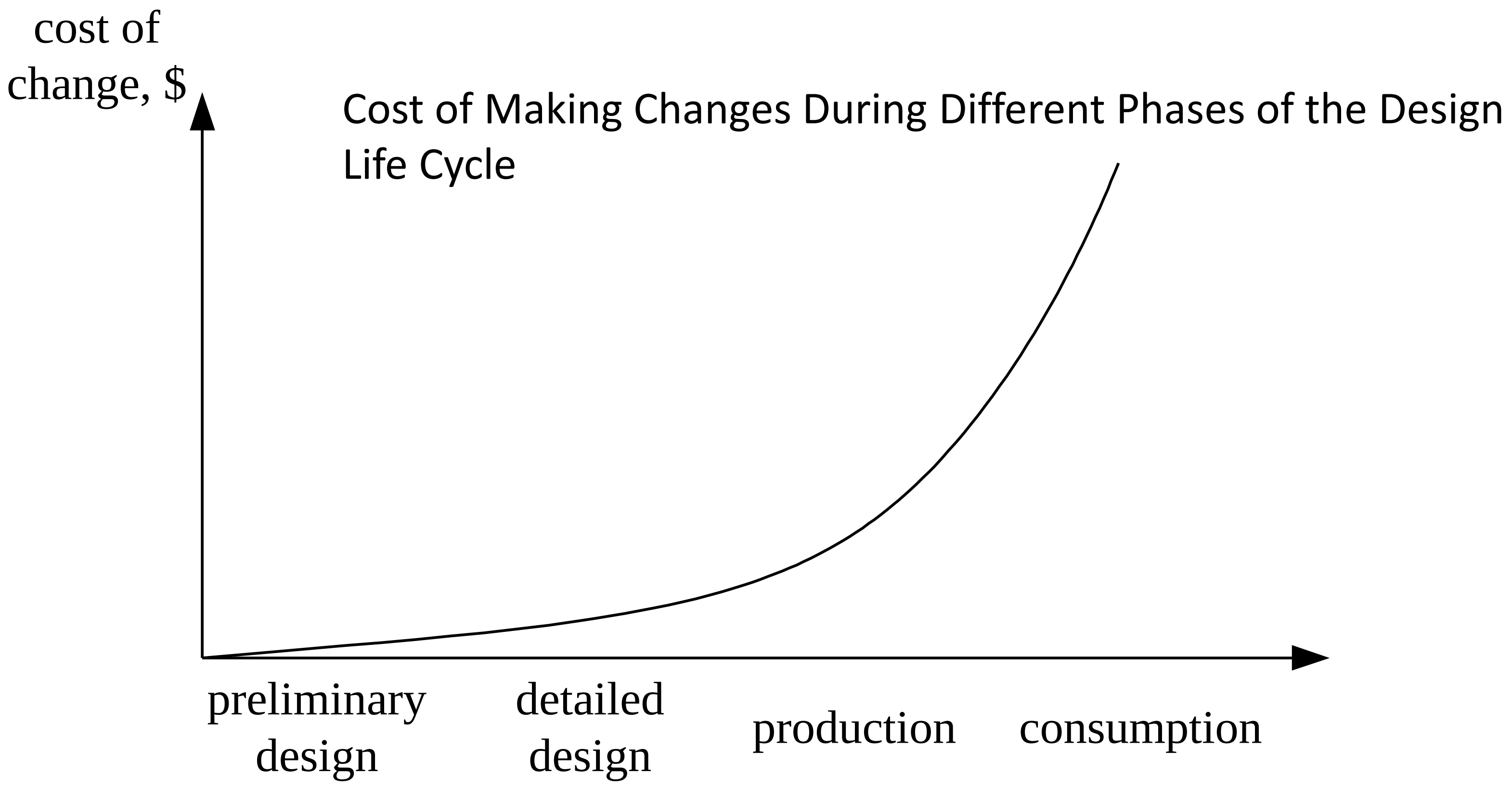


Fig. 1.12

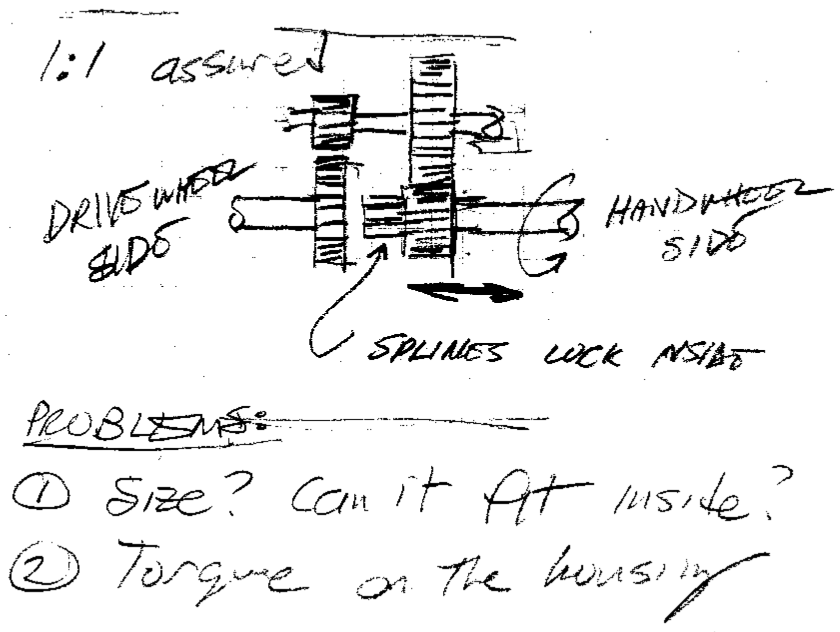
Life Cycle of Engineering Designs

Simon's 8 step of the Design Life Cycle

1. Needs analysis
2. Feasibility study
3. Preliminary design
4. Detailed design
5. Production
6. Distribution
7. Consumption
8. Retirement



Preliminary Design Ideas



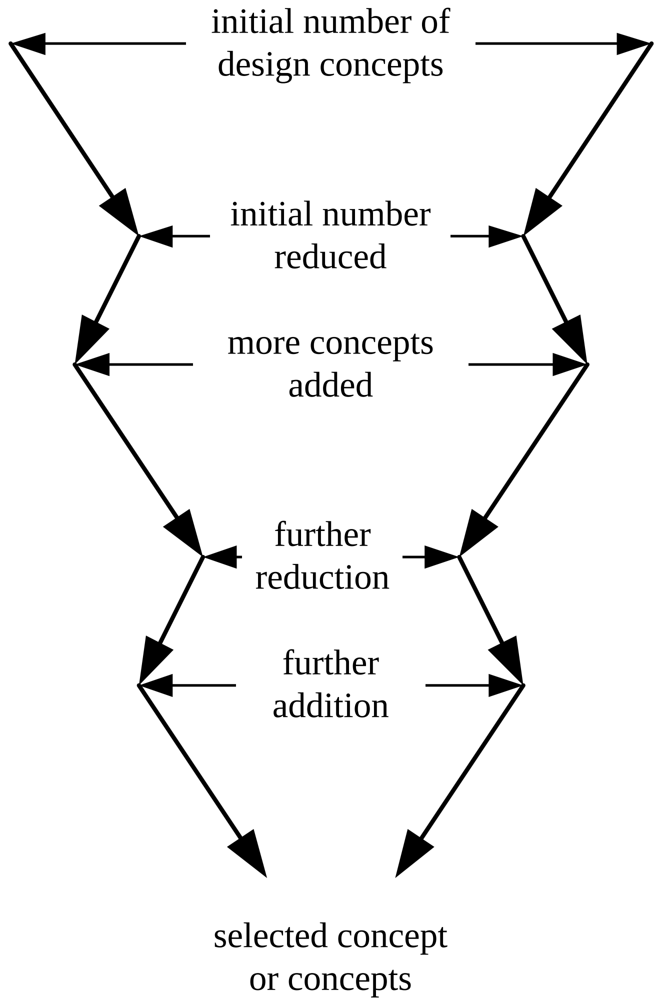


Fig 1.16

Detailed Design

- Models and Prototypes
- Rapid Prototyping
- Production Prototypes
- Testing

Production

- Design for Manufacturing and Assembly

- Taguchi Method

Overview of System Life Cycle

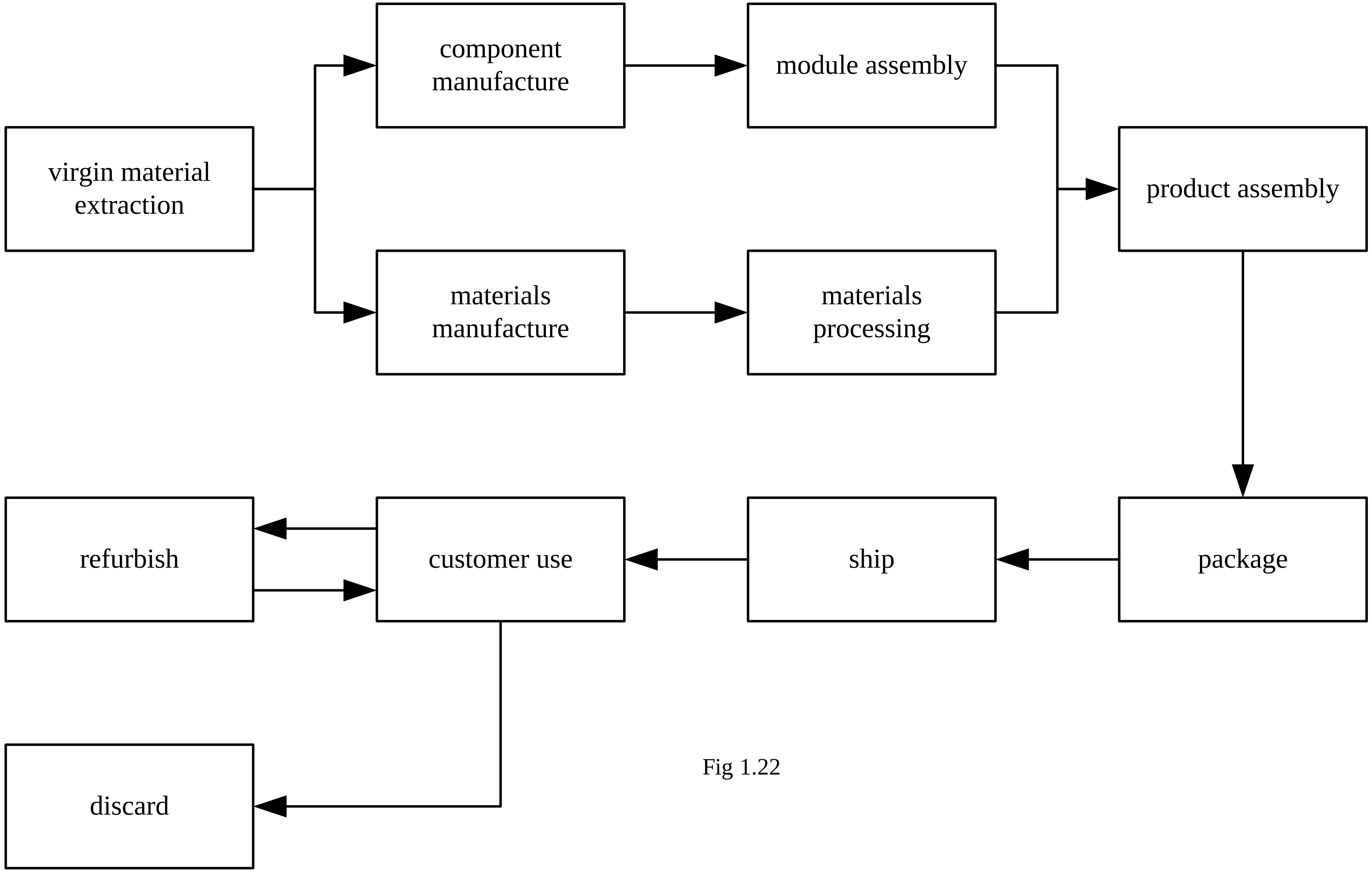


Fig 1.22

Inputs and Outputs at Typical Stage of Life Cycle

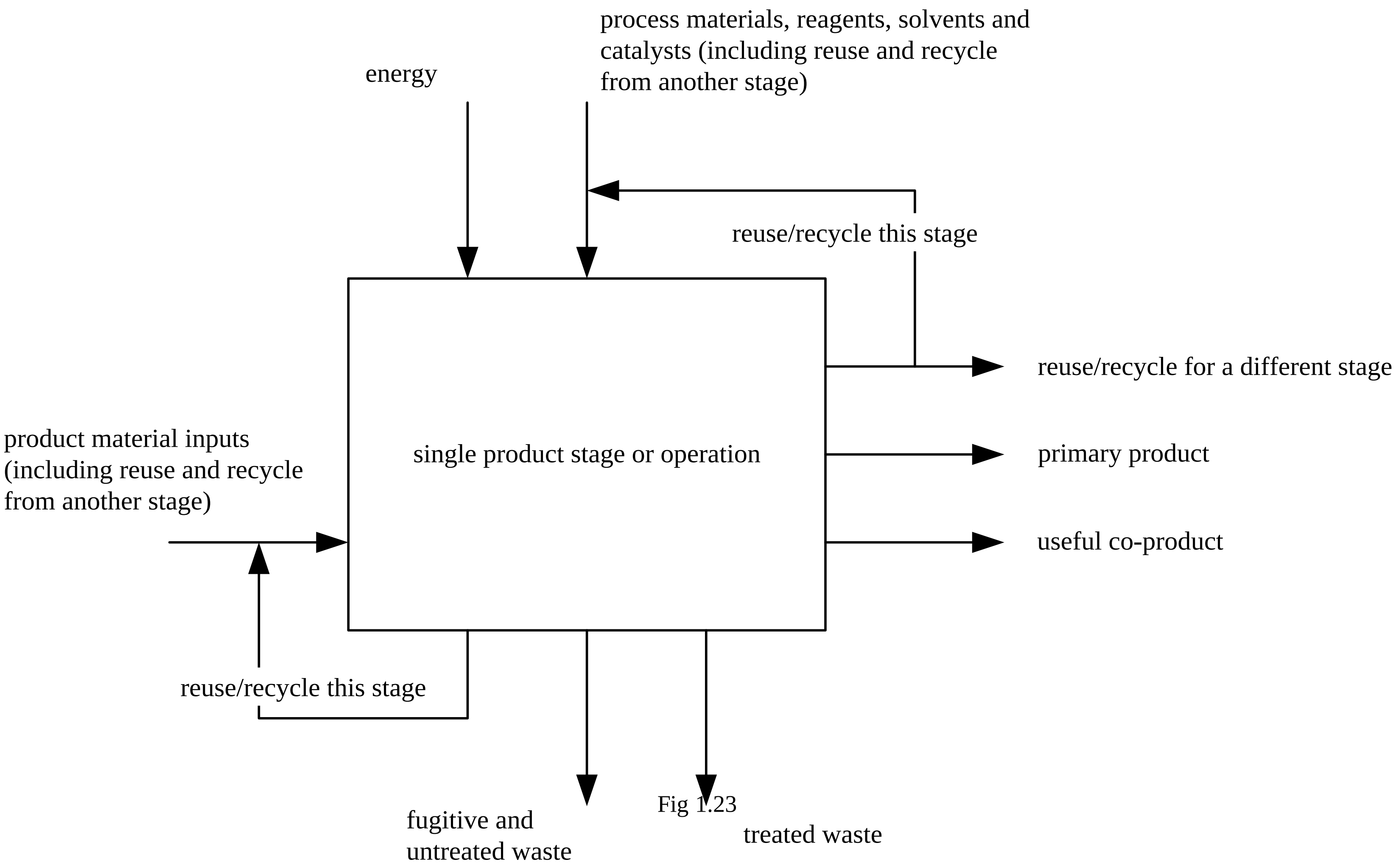


Fig 1.23

Formulating Design Problems
(from 9-step model of design process)

- Step 1 - Recognizing the Need

- Step 2 - Defining the Problem
  - Goals
  - Objectives
  - Constraints

Recognizing the Need

- Describes a current situation that is unsatisfactory.
- Should be written in a negative tone
- Establishes improvement in current situation as the ultimate purpose of the project.

Format Need Statement

Sandra: “Jane, we need you to design a stronger bumper for our new passenger car.”

Jane: “Why do we need a stronger bumper?” (asking questions help)

Sandra: “Well, our current bumper gets easily damaged in low-speed collisions, such as those that occur in parking lots.”

Jane: “Well, a stronger bumper may be the way to go, but there may be better approaches. For example, what about a more flexible bumper that absorbs the impact but then returns to its original shape?”

Sandra: “I never thought of that. I guess I was jumping to conclusions. Let’s restate the need as “there is too much damage to bumpers in low-speed collisions.” That should give you more flexibility in exploring alternative design approaches.”

Market assessment

Not all design is defined by customer or market demand. Can be pushed into the market

PC and Post it

IBM Mac and Iphone

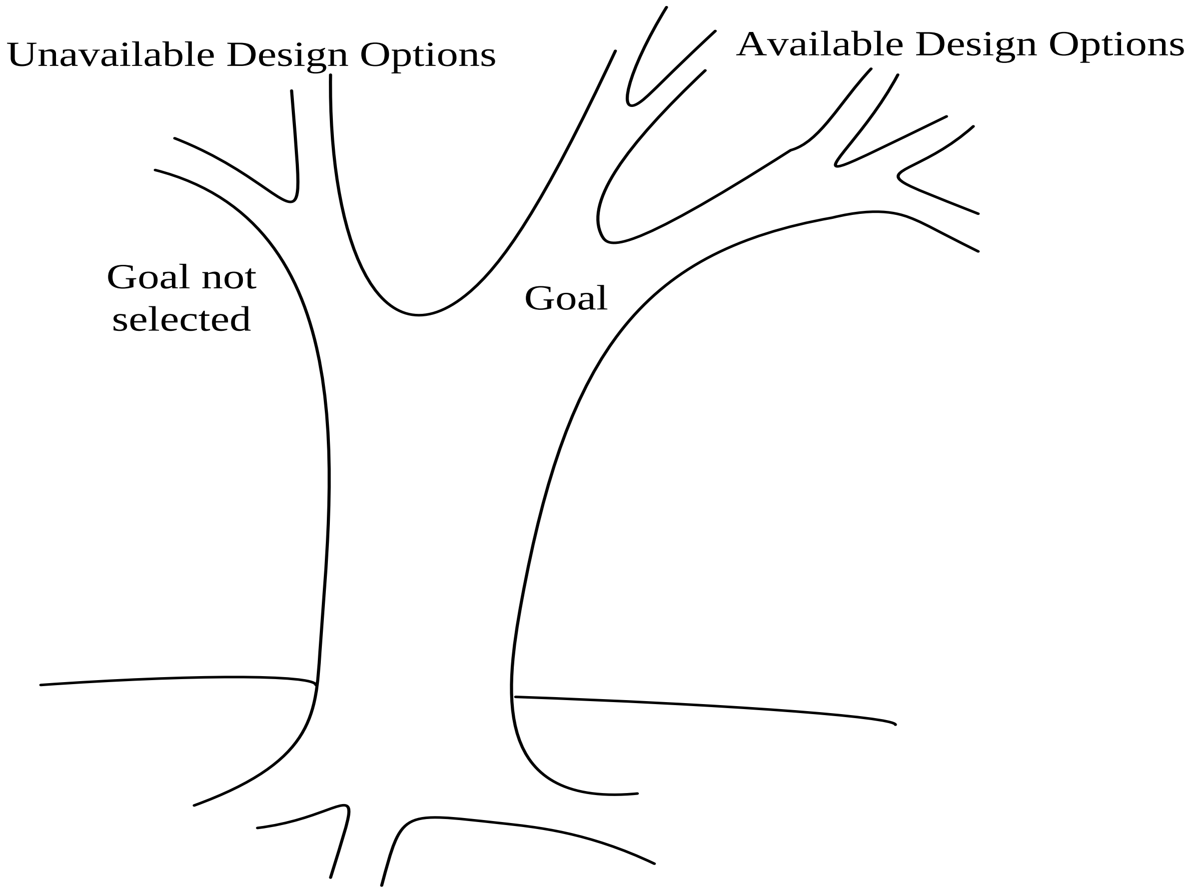
Recognizing the Need -Automobile Bumper Problem

- There is too much damage to bumpers in low-speed collisions
- Brief, general, and ideal response to the Need.
- Answer the question "How are we going to address this Need?"
- Is so ideal that it could never be achieved, or so general that we cannot determine when it is achieved.
- Its selection establishes the general direction of the design effort.

Goal for Automobile Bumper Problem

- Design an improved automobile bumper

- Design a radar-based collision avoidance system
- Add bumper-high rubber strips to parking lot structures
- Place concrete “curbs” in all parking stalls
- Reduce automobile use
- Redesign parking lot traffic patterns
- Establish minimum speed in parking lots



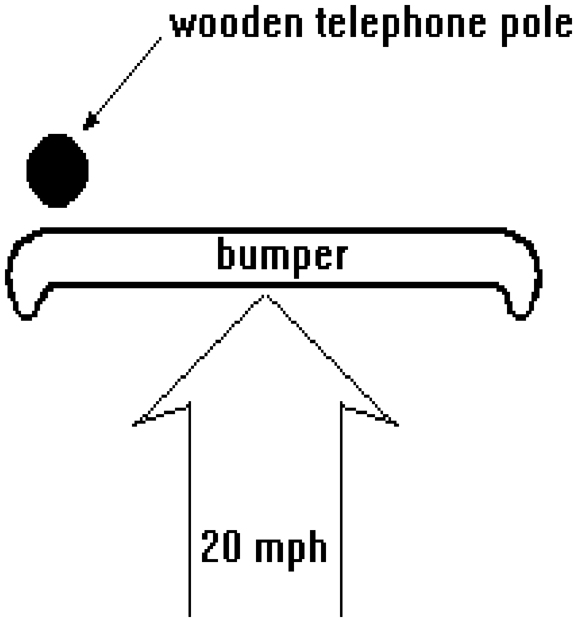
Scope of Goal Statement

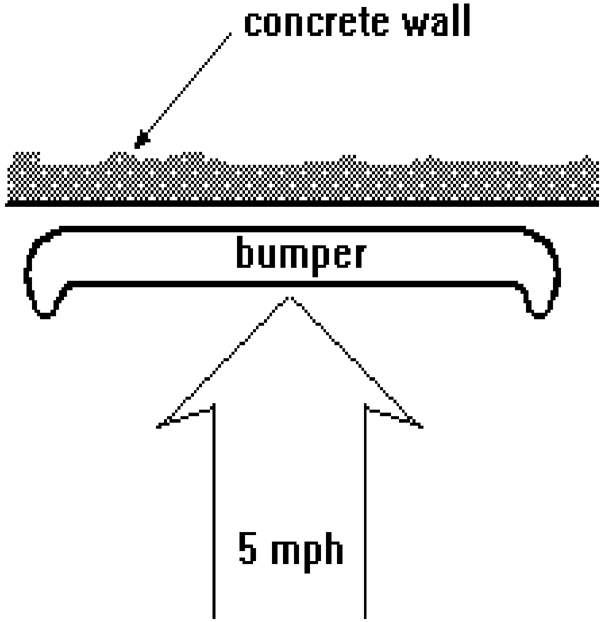
- Need Statement:
  - *child-proof pill bottles are too difficult for people with arthritis to open*.

- Several potential Goal Statements :
  - *design a child-proof pill bottle that is easier to open*
  - *design a child-proof pill container that is easier to open*
  - *design a child-proof pill system for dispensing pills*
  - *design a child-proof system for dispensing medication*

Defining the Problem-Objectives

- Quantifiable expectations of performance.
- Establish operating environment
- Indicators of progress toward achieving Goal.
- Define the performance characteristics of the design that are of most interest to the client
- Facilitate determination of which alternative designs best meets expectations.





Objectives for Automobile Bumper Problem

- Design an inexpensive front bumper so the car can withstand a 5 mph head-on collision with a fixed concrete wall without significantly damaging the bumper or other parts of the car, or making the car inoperative. In addition, at the end of the useful life of the bumper, it must be easily recyclable.
  - inexpensive
  - no significant damage to bumper
  - no significant damage to other parts
  - easily recyclable
  - operative

Basis for, and Units of, Measuring Objectives

Objective	Measurement Basis	Units
Inexpensive	Unit manufacturing cost for a production run of 50,000	dollars
No significant damage to bumper	Distance bumper is pushed into body	inches
No significant damage to other parts	Repair cost	dollars
Easily recyclable	Amount of aluminum	lb
Retain maneuverability	Turning radius	ft
Retain braking capability	Braking distance	ft

Table 2.1

Defining the Problem-Constraints

- Constraints establish permissible range - design and performance parameters
- yes/no constraints – immeasurable as in go or no go
    - (must use 3/8”-24 UNF SAE grade 5 bolts)
- equality constraints
    - (must be 18” high)
- inequality constraints - one sided
    - cannot weigh more than 50 lb
    - must hold at least 50 lbs of steam
- inequality constraints - two sided
- must be between 12” and 15” long)

Complete (Revised) Problem Statement for Automobile Bumper Project

- Goal
  - Design an improved front bumper
- Objectives (with operating environments, basis for measurement, and units)
  - Inexpensive
  - No significant damaging to bumper
  - No significant damaging to other parts
  - Easily recyclable
  - Retain maneuverability
  - Retain braking capability
- Constraints
  - Should be installed 18" up from the ground.
  - Weight of the bumper cannot exceed 50 lb.
  - Mounting brackets must be between 8.0" and 12.5" from the center
  - Lights must work after collision
  - Radiator must not leak after collision
  - Doors must work after collision

Trade-offs Between Objectives and Constraints

- Restating the problem in a slightly different way can result in some objectives becoming constraints and vice-versa.

- the **objective** “not causing significant damage” can be reworded as a **constraint** “not costing more than $200 to repair”.

- It may be desirable to include both in the problem statement.

Unambiguous Objectives

- All objectives must be unambiguous
- Use longer definitions if necessary to remove ambiguity
- Objectives should be fully documented
- All objectives should have units
- Spend at least twice as much time on developing objectives than you would like to

Transforming Objectives into Criteria

- Objectives
  - Quantifiable expectations of performance

- Criteria
  - Value-free compact descriptors of performance associated with objectives

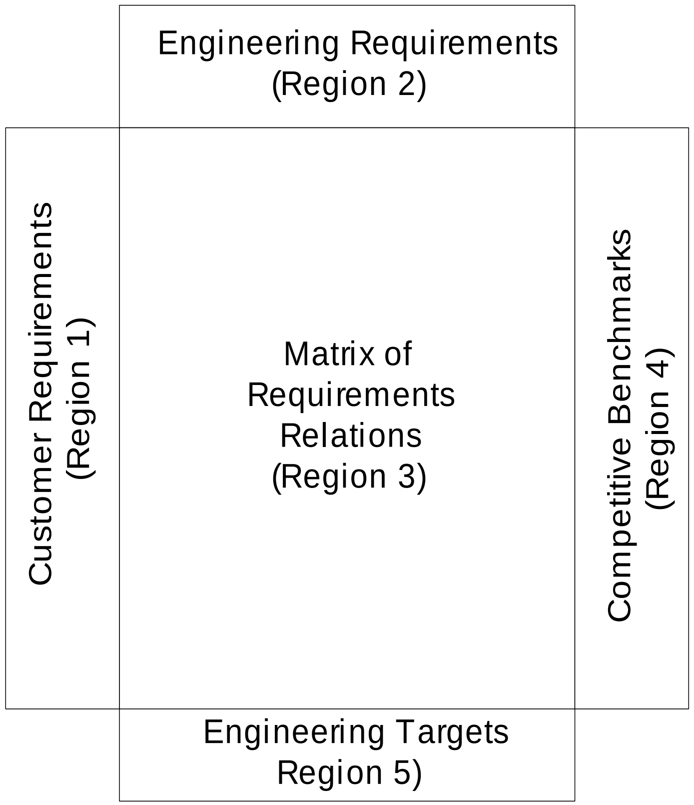
Objectives and Criteria for Automobile Bumper

Objective	Units	Criteria
Inexpensive	dollars	cost
No significant damage to bumper	inches	Amount of damage to bumper
No significant damage to other parts	dollars	Amount of damage to other parts
Easily recyclable		Recyclability
	lb	
Retain maneuverability	ft	Maneuverability
Retain braking capability	ft	Braking capability

Table 2.2

Structure of Quality Function Deployment Chart

- Matching customer requirement to engg design performance parameters
  - Strategic arrangement of all aspects of the product according to customer demands



QFD Chart for a Shopping Cart*

Customer Requirements	Engineering Requirements							Bench marks	
	storage capacity	size of child's seat	length of two stacked carts	height of bottom of basket	frame stiffness	yield strength	torque required to turn	Competitor A	Competitor B
lasts a long time					x	x		o	
holds sufficient groceries	x	x						o	
stackable			x					o	
steers easily							x		o
sturdy frame					x			o	
unloads easily at checkout				x				o	
inexpensive						x		o	
space for a toddler		x							o
Units	in^3	in^2	in.	in.	lb/in	psi	in-lb		
Engineering Targets									

Problem Formulation Terminology

- Need
- Goal
- Objectives
- Constraints
- Criteria
- Attributes
- Characteristics
- Functions
- Specifications
- Performance Specifications
- Design Specifications
- Customer Requirements
- Engineering Requirements
- Design Parameters
- Performance Parameters