

CIEG -125 Introduction to Civil Engineering

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University of Delaware
Fall 2005
Lecture 9

Today's class

- Presentations – Groups 13, 14 and 15
- Engineering Design
- The Engineering Method and Team-based Creative Problem Solving
- An exercise (Basis for Project 2/ Report 2 – a group project)

The Engineering Method and Team-based Creative Problem Solving

CIEG-125 Introduction to Civil
Engineering
Fall 2005

Outline

- Engineering Design
- The Engineering Method for Solving Problems
- Teams and Team Composition
- In class exercises

Engineering Design

Engineering design is a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints.

Engineering Design Thinking, Teaching, and Learning --
http://www.asee.org/about/publications/jee/upload/2005jee_sample.htm

Skills often associated with good designers – the ability to:

- tolerate ambiguity that shows up in viewing design as inquiry or as an iterative loop of divergent-convergent thinking;
- maintain sight of the big picture by including systems thinking and systems design;
- handle uncertainty;
- make decisions;
- think as part of a team in a social process; and
- think and communicate in the several languages of design.

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The Engineering Method

- Recognize and Understand the Problem
- Accumulate Data and Verify Accuracy
- Identify Appropriate Principles/Theories
- Make Necessary Assumptions
- Solve the Problem
- Analyze, Verify and Evaluate the Solution
- Implement the Solution

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Characteristics of problems

- Open-ended
- Ill-defined
- Poorly formulated
- Multiple solutions possible
- Associated uncertainty
- Social influences
- Abstract elements
- Complex
- Immediacy

Examples

- poor water quality
- bad traffic
- lack of affordable housing
- earthquake/hurricane damage

Analyze & Define Objectives

- Determine if problem exists
- If so, collect as much information/data as possible related to problem
- Talk with people familiar with problem
- View the problem first hand
- Confirm all findings
- Produce a problem definition statement

Use Defining Questions Like:

- What makes this a problem?
- What makes this problem different?
- How was the problem discovered?
- What events caused this problem?
- What changes occurred that might be causes?
- What threats does problem pose for whom?
- Is problem related to other problems?
- Can problem be decomposed?
- Are there constraints to solution to problem?

Kepner-Tregoe (KT) Analysis

	IS	IS NOT	DISTINCTION	CAUSE
Identify: What:	What is the problem?	What is not the problem?	Is versus is not?	Possible cause?
Locate: Where:	Where is the problem found?	Where is the problem not found?	Difference in locations?	Possible cause?
Timing: When:	When does the problem occur?	When does the problem not occur?	Difference in timing?	Possible cause?
	When was it first observed?	When was it last observed?	Distinction between observations?	Possible cause?
Magnitude: Extend?	How far does the problem extend?	How localized is the problem?	Distinction?	Possible cause?
	How many units are affected?	How many units are not affected?	Distinction?	Possible cause?
	How much of any unit is affected?	How much of anyone unit is not affected?	Distinction?	Possible cause?

Example

- You are a field inspector for a large construction project in charge of concrete quality control
- You must receive concrete from several concrete firms, A, B and C
- Occasionally, you must reject B's concrete because its slump is too high causing expensive delays

Example - KT Analysis

- What is the problem? Excessive slump.
- Where is problem? Firm B's operation.
- Where isn't problem? Firms A and C
- Difference? A and C cover aggregate
- When does problem occur? After storms
- When doesn't it occur? Sunny weather
- B is likely putting too much water in its concrete because it is not considering excess water in aggregate

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Data Collection and Verification

- For a given problem, keep a notebook:
 - general information about problem
 - specific data collected about problem
 - results of data analyses (e.g., statistical analyses, simulations, fault-tree analysis)
 - things tried that didn't work
- This will eventually be assembled into a briefing document

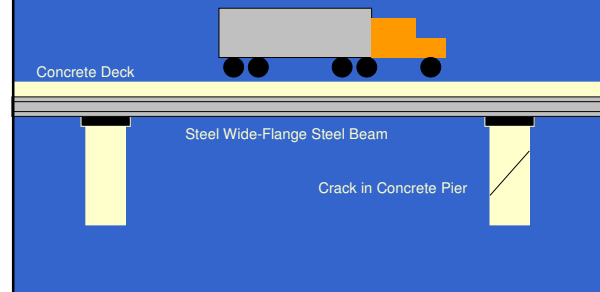
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Identifying Relevant Principles

- Theories/principles are models of how natural physical, chemical or biological systems behave.
- When faced with a problem, we must determine what models exist to describe the behavior of the system we are debugging
- If no models exist, then we as engineers seek to develop such models

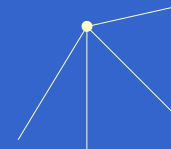
- For example, what principles might we bring to bear on this problem?



Assumptions

- Engineers make assumptions
 - To be able to use or create a model of how a system behaves,
 - we need to make assumptions that simplify the problem so it can be modeled
- To use any model, we need to know:
 - what assumptions were made?
 - are those assumptions appropriate?

- For Example, the real connection in a truss as shown at the left is often modeled as shown on the right.



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Solving the Problem

- Solving a problem does not just mean equation manipulation!
- Almost always you have to explore a variety of solution alternatives.
- Thus, you must generate, or synthesize, these alternative solutions to a problem.

Synthesis Objective

- Generate multiple solutions to a defined problem that are:
 - functional
 - safe
 - economical
 - elegant
 -

Synthesis Strategies

- trial and error
- logical deduction
- extrapolation
- diagnosis
- classification
- metaphorical thinking
- step by step planning
- discovery
- means ends analysis
- transfer old solutions to new problems
- brainstorming
- abstracting similarities
- experimentation
- modeling

Creativity

- Not usually associated with engineering
- Originated in the Renaissance in the arts
- Innovation is acceptable in engineering
- Evolutionary changes occur all the time
- Needs an unconstrained mind

Synthesis

- Mental manipulations to generate ideas:

- | | | | |
|------------|--------------|--------------|-------------|
| •combine | •minify | •less of | •condense |
| •merge | •duplicate | •copy | •divide |
| •add | •separate | •interchange | •who else |
| •transpose | •vice versa | •multiply | •where else |
| •reverse | •upside down | •increase | •substitute |
| •magnify | •exaggerate | •shrink | •..... |
| •subtract | •omit | | |

Synthesis - continued

- Examples
 - ball point pen -- roll on deodorant
 - car batteries -- rechargeable flashlights
 - sawdust keeping ice frozen in the summer -- household insulation

Brainstorming

- Rules
- Guidelines
- Example Session

Brainstorming Rules

- Generate as many solutions as possible (quantity counts)
- Wild ideas are encouraged
- No criticism allowed - judgement is deferred until later.

Brainstorming Process

- Brief the team and post the problem definition statement
- Review the rules
- Explain the procedure
- Do a creative warm-up exercise
- Conduct the session
- End - collect ideas
- Thank and dismiss the team

Another tool: Osborn's Questions

- Adapt? Can the product be used for other uses?
- Modify? Can the meaning, material, color, shape or odor be changed?
- Magnify? Can a new ingredient be added? Can it be made stronger, thicker, higher, longer?

Osborn's Questions, con't.

- Minify? Can it be split up? Can something be taken out? Can it be shorter, thinner, lower, weaker?
- Substitute? Who else, where else, or what else? Can another material or a different approach be used?
- Rearrange? Can parts be interchanged? Are there other patterns, layouts, configurations?
- Combine? Combine parts, units or ideas? Blend, compromise?

Brainstorming Exercise

- A very large (500,000 sq ft = 10 football fields) sludge pond is part of a wastewater treatment plant. The liquid in the plant is very viscous and sticky. From time to time, unwanted floating objects (dead animal, branches, etc) appear on the pond and must be removed. Covering the pond is not an option. Devise a solution.
- Initial ideas: use a crane, place a net over the pond, build a rail system above the pond, build a fence around the pond.

Brainstorming using Osborn's Questions

- Modify - change treatment process to eliminate sludge, add something to breakdown branches and dead animals, change properties of pond sludge.
- Magnify-Minify - Shallow pond so people can wade, narrow but deeper pond so "floaters" can be reached from the edge or pond can be covered.
- Substitute - Build in a different location, use tanks instead of a pond, use anaerobic digesters
- Rearrange - Add grinder to cut "floaters" up, revegetate surrounding countryside, bring in vultures and scavengers.

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Solution Analysis Objectives

- Determine that proposed solutions are functional and safe
- Determine cost and other characteristics of the solution(s)
- Determine that solution is for real problem
- All consequences considered, e.g. environmentally responsible

Solution Analysis Techniques

- Mathematical analysis e.g. calculation of strength
- Simulation e.g. impact of longer merging lanes on a freeway
- Experimentation e.g. effectiveness of remediation procedures on a polluted soil
- Categorization, data summaries, attribute listings e.g. estimation of the number of replacement windows needed in Pittsburgh.

Evaluation Objectives

- Ranking the proposed solutions based on satisfaction of criteria
- Usually, this involves determining the relative importance of the various criteria
- E.g., good, fast, cheap....pick any two!

KT Decision Making Process

- Define objectives or criteria
- Specify objectives as musts and wants
- For each solution, if any "must" is not satisfied it is defined as "NO GO"
- For each objective assign a weight (1-10) to each "want" indicating its importance.
- For each "GO" solution assign a rating (1-10) indicating how closely it satisfies a "want."
- Score each attribute = weight * rating and sum

Example - New Windows

		Brand A		Brand B	
	Weight	Rating	Score	Rating	Score
Cost	9	8	72	7	63
Maint	8	9	72	6	56
Eff'c'y	5	5	25	9	45
			169		164

Choose A!

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Implementation

- Acquiring Approval
- Planning
- Carrying Through
- Following up

Acquiring Approval

- Presentation - report and oral
 - clearly state problem & supporting data
 - clearly identify solutions considered
 - clearly indicate decision criteria used
 - make your ideas easy to accept
 - be brief and to the point
 - be understandable and well organized
 - be enthusiastic

Planning

- Time and resource allocation
- Schedule of activities
- Identification of project critical activities that need to be monitored closely
- Plan for tracking costs

Carrying Through

- Monitor progress
- Think ahead
- Continue to challenge assumptions
- Make sure plans are followed where appropriate

Following up

- Re-evaluate the solution and assumptions
- Revise problem statement, assumptions and analysis if appropriate
- Iterate if appropriate

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Teamwork

- Why use teams? - Advantages
- Disadvantages
- Team Development

Why use teams? - Advantages

- more resources
- interaction leads to more ideas
- identifies opportunities and takes greater risks
- better acceptance of solutions
- opportunity for leadership and growth

Disadvantages

- greater effort needed
- relatively low efficiency
- conflict and hostility can be counter productive
- group thinking

Engineering Heuristics – Examples

- Identify the weak link and Allocate resources to the weak link
- Freeze the design--at some stage in the project (when about 75% of the time or resources are used up) the design must be frozen
- Discuss the process and ask meta-level questions, e.g., What are we doing? Why are we doing it? How does it help?

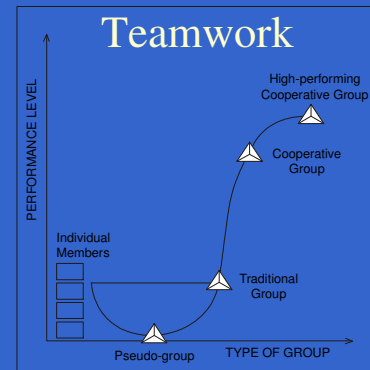
Top Three Main Engineering Work Activities (Burton, Parker & LeBold, 1998)

Engineering Total	Civil/Architectural
• Design – 36%	1. Management – 45%
• Computer applications – 31%	2. Design – 39%
• Management – 29%	3. Computer applications – 20%

Burton, L., Parker, L., & LeBold, W. 1998. U.S. engineering career trends. *ASEE Prism*, 7(9), 18-21.

Design team failure is usually due to failed team dynamics (Leifer, Koseff & Lenshow, 1995).

It's the soft stuff that's hard, the hard stuff is easy (Doug Wilde, quoted in Leifer, 1997)



A team is a small number of people with complementary skills who are committed to a common purpose, performance goals, and approach for which they hold themselves mutually accountable

- SMALL NUMBER
- COMPLEMENTARY SKILLS
- COMMON PURPOSE & PERFORMANCE GOALS
- COMMON APPROACH
- MUTUAL ACCOUNTABILITY

--Katzenbach & Smith (1993)
The Wisdom of Teams

Team Development

- Individual traits
 - intelligence
 - openness
 - communication skills
 -
- Build team from individuals with different skills and thinking styles

Ground Rules for Teams

- EVERY member is responsible for the team's progress and success
- Attend all time meetings and be on time
- Come prepared
- Carry out assignments on schedule
- Listen to and show respect for the contributions of other members; be an active listener.
- CONSTRUCTIVELY criticize ideas not persons

Ground Rules for Teams cont

- Resolve conflicts constructively
- Pay attention, avoid disruptive behavior
- Avoid disruptive side conversations
- Only one person speaks at a time
- Everyone participates, no one dominates
- Be succinct, avoid long anecdotes and examples

Ground Rules for Teams cont

- No rank
- Respect those not present
- Ask questions when you do not understand
- Attend to your personal comfort needs at any time but minimize team disruption
- HAVE FUN!

Possible situations

- Avoid antagonism to the process
- Cooperation – consensus and agreement
- Willingness to synthesize after the debate/discussion
- Willingness to accept outcomes but not compromise opinions

Source: Saaty

A Brainstorming Session

In your teams – your assignment is to:

- Brainstorm
- Decide on a solution
- Build
- Test

Engineering Design – Team Exercise

The engineering method is design under constraints
Wm. Wulf, President, National Academy of Engineering

Team Member Roles:

- Task Recorder
- Pay attention to the Group Process
- Materials Manager

Engineering Project

Hands-On Construction Project

Simply-Supported Beam

Groups of 3-5 (based on your ethics presentations)

Simply Supported Beam

Specification: Free Span > 65 cm
Concentrated Load located at Beam Center

Final Design May Contain ONLY:
One sheet of beam material
One file folder label

Beam may NOT be attached to supports

Materials

- One can of soda for each group member
- 1 sheet of paper
- 1 file folder label
- One piece of candy for each group member
- 2 cable ties
- 1 paper plate

Process

- Find your group members
- Find a place to work (inside or outside)
- Work out roles
- Send your material manager to get materials
- Design
- Build
- Photograph
- Test

Group Processing Plus/Delta Format

Plus (+) Things That Group Did Well	Delta (Δ) Things Group Could Improve

Report 2. Due 11/14/05

- One report per group.
- The report focuses on process NOT product
- Must include a group photo with your finished product. (Yukun has a camera and I have a camera).
- See Handout
 - Document design process
 - Document construction process
 - Assess your design
 - Describe the team interactions
 - Use table to assess strengths and weaknesses
 - Describe what you would do differently (focus on the team)