

EE493
ENGINEERING DESIGN-1

Concept Generation
Problem Solving Tools and Techniques

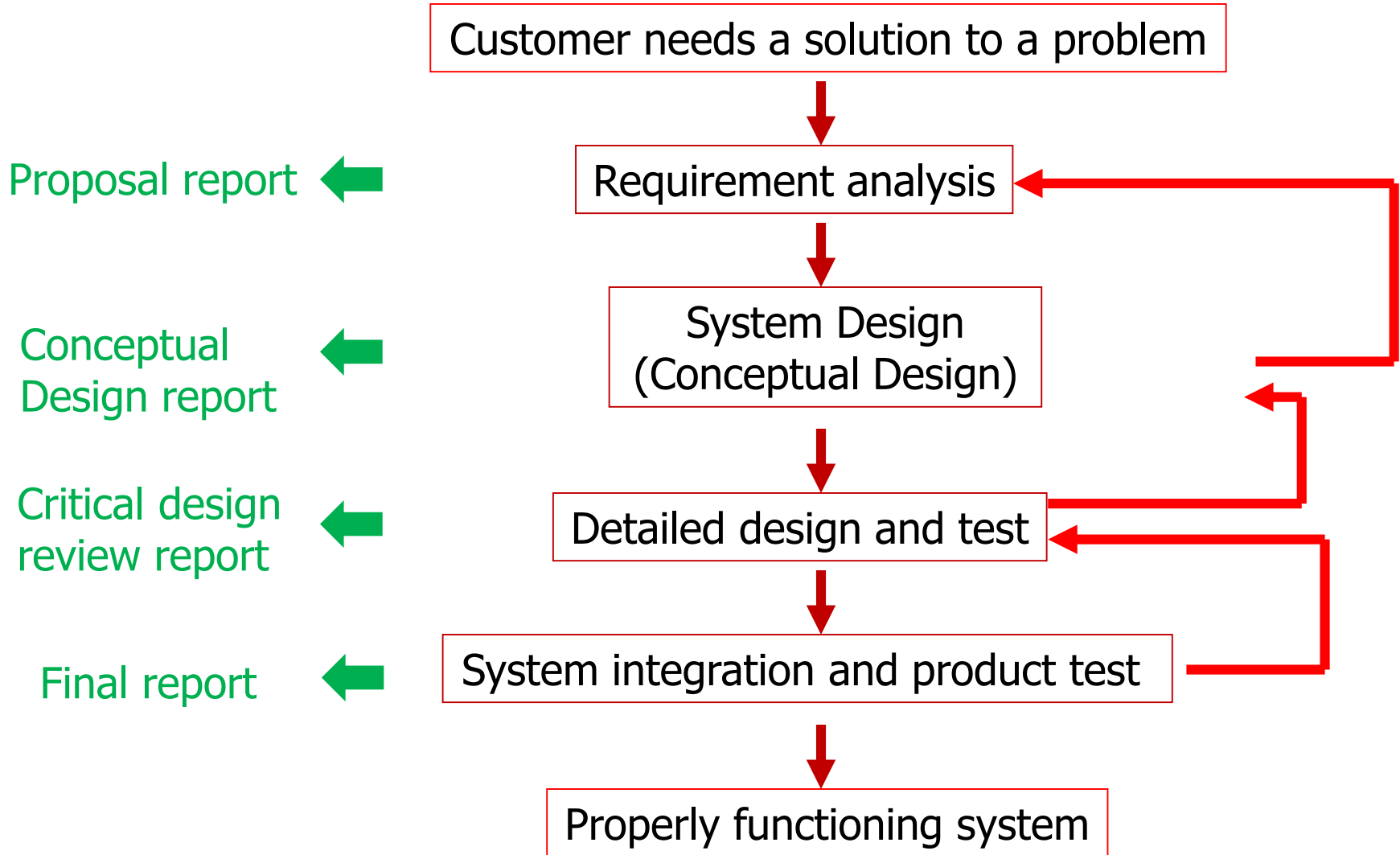
Wednesday, October 2019



Outline

- Design Process
- Generating Ideas for Design Process
- Evaluation & Reaching Consensus
- Words of Wisdom and Lessons Learned

Design Process



System Design

- Conceptualization
- Synthesis
- Analysis
- Evaluation



Conceptualization

- Understand the problem
- Develop a rough, early form of solution
 - An idea or notion that can be a solution
 - Primitive solutions, no definite form or character
 - Lack organization and structure
- Brainstorming for idea generation:
 - Seek quantity of concepts not quality
 - No judgement or analysis of concepts



Synthesis

- Create a well-defined structure for the concept
 - Sufficient detail that helps analysis
- Preliminary design
 - Block diagram of the system, each block will be designed in the detailed design later



Analysis

- Determine if the synthesized system meets the objectives
- Analyze (simulations or experiments)
 - Develop mathematical model for the blocks
 - Build up real hardware to prototype ideas
- Determine the risks and analyze hidden or explicit systematic error sources
- Go back to synthesis, refine a solution
- Analyze again



Evaluation

- Evaluate the alternative solutions
 - Grade each solution with respect to objectives according to analysis results
- Choose one solution

- Don't get 'fixated' on an early solution concept
- Don't concentrate on exploring single sub-solutions in depth



Generating Ideas

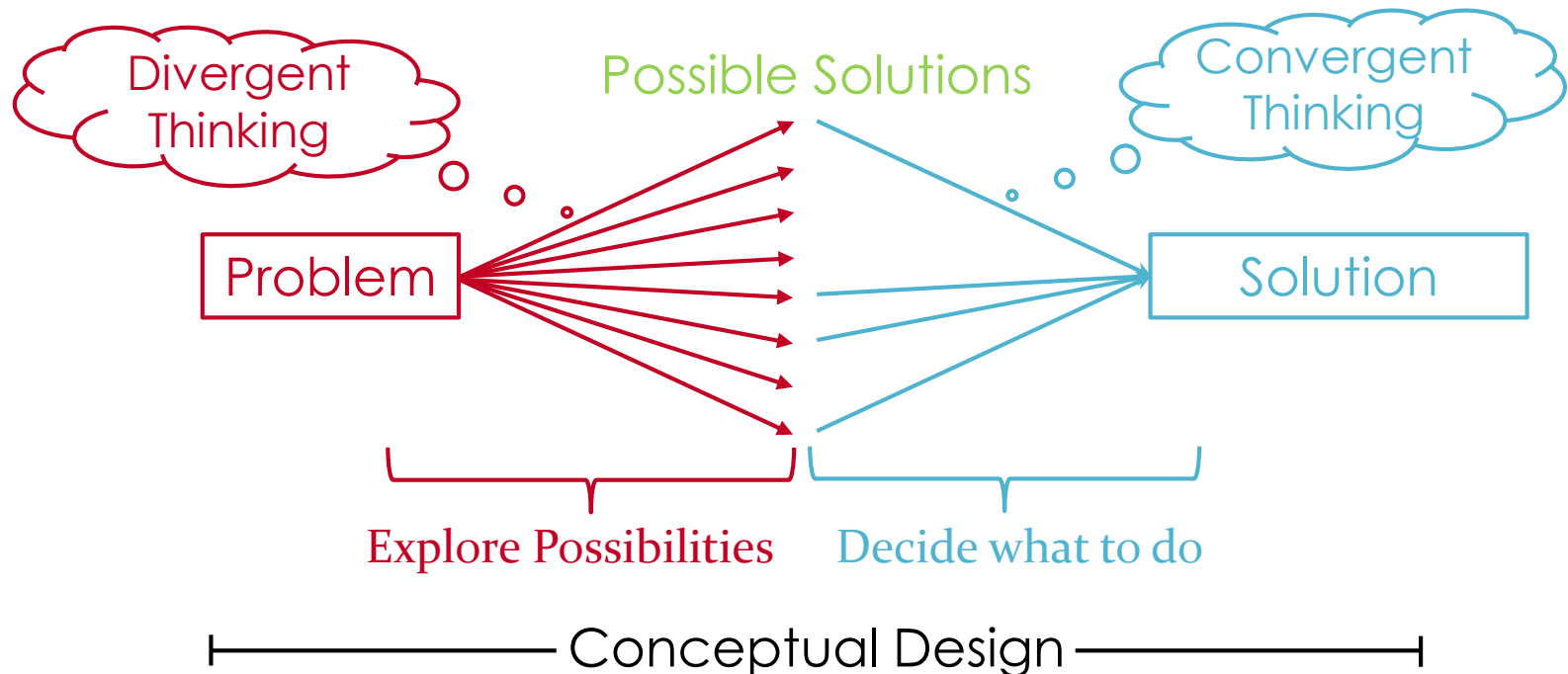


Concept/Idea Generation

- Divergent vs. Convergent Thinking
 - Divergent Thinking: Solving an abstract or new problem that has many possible solutions.
 - Example: Devise a structure to protect an egg from breaking
 - Convergent Thinking: Solving a well-defined, straightforward answer to a problem.

Concept/Idea Generation

- Divergent and convergent thinking are both required in a product design cycle.



Divergent Thinking vs. Convergent Thinking

- Question: My home is 20 km from work. My car runs on gasoline with an average of 10 liters/100km. I would like to reduce my expenses.
- Convergent thinking question: Which of the three vehicles are the best replacement for my car?
 - a. Car A: 8 liters/100 km, natural gas-gasoline hybrid
 - b. Car B: 5 liters/100 km, diesel
 - c. Car C: Electric car
- Divergent thinking question: What choices do I have to cut my expenses?
 - Open ended question, multiple answers:
 - Use public transportation
 - Work from home
 - Do not work. Gambling?
 - ...

Creative Thinking Methods - Brainstorming






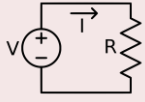




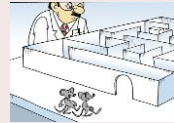
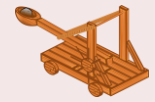
- Short and effective session for obtaining solutions
- Widely accepted method
- Groups of 4-8 people are the most successful
- A session may last half an hour or so
- **Free expression** is essential. Criticism of the ideas must be avoided. Nothing should be said to **discourage** a group member from speaking.
- The members of the group are **equal**. No one should try to impress, support or discourage other member of the group.
- Often, group needs a few minutes to break the natural reserved attitude.
- Mostly, brainstorming is fun
- Always, brainstorming gives surprisingly high number of ideas

Brainstorming Example

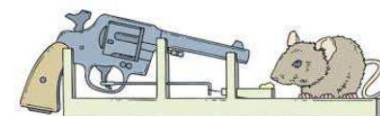
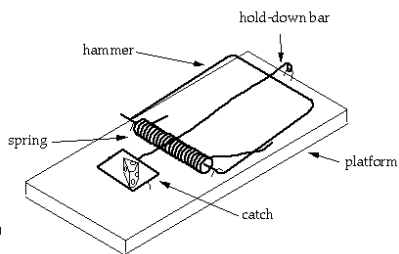
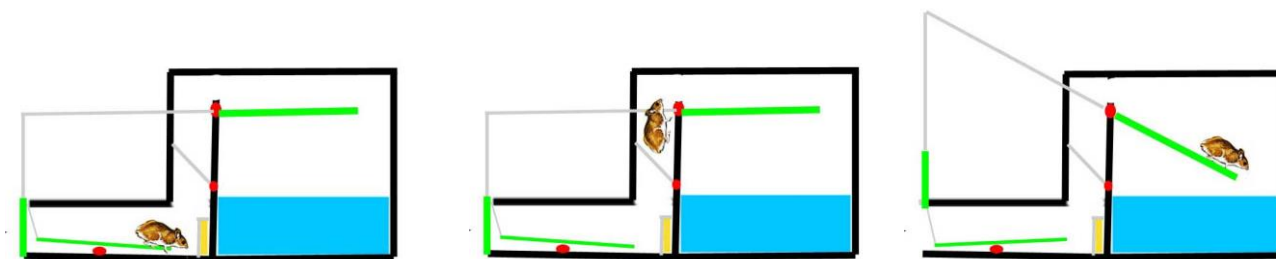
- Mousetrap
- Generate as many ideas for each of four sub-blocks in a mousetrap

| |
|---------------|
| Attract mouse |
| Stop mouse |
| Store mouse |
| Export mouse |

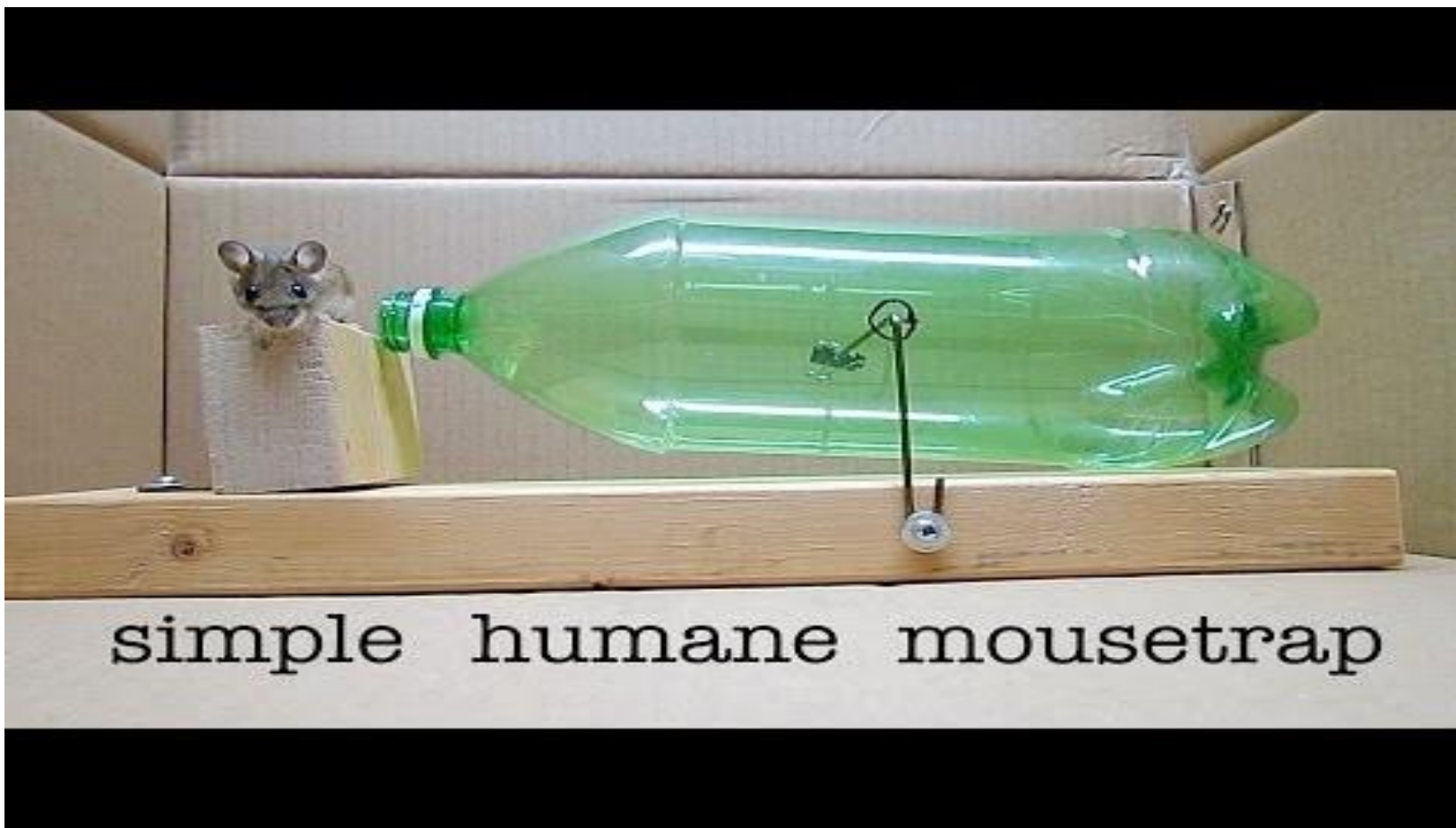
Mousetrap

| | Solution Idea | | |
|----------------------|--|---|---|
| Attract mouse | Cheese tunnel  | Squeaks  | Pheromones  |
| Stop mouse | Exterminate  | Block Exit  | High Voltage  |
| Keep mouse | Box  | Cage  | Maze  |
| Export mouse | Release  | Find a job  | Catapult  |

Mouse Trap – Propose Alternatives



Mousetrap



Creative Thinking Methods

- **Reverse Brainstorming:**

- Instead of asking “How can we solve this problem?”, ask “How can we create this problem?”.
- Once reverse solutions are discussed, now reverse these ideas for the original problem.
- Example: Particle Filtering

Creative Thinking Methods

- **Brainwriting:**

The 5 · 3 · 4 Method is one way to begin generating design alternatives.

- 5 team members
- 3 ideas each (described in words or pictures)
- 4 other team members review each design idea
- No discussions allowed during the process
- Can be modified to $N \cdot K \cdot (N-1)$

Reaching Consensus



Consensus

- Consensus is of paramount importance.
- After the meeting you should hear:
 - I feel that you understand my point of view
 - I feel that I understand your point of view
 - I agree on the way we make decisions
 - Whether or not I prefer this decision, I will support it because **it was reached openly and fairly.**

Meeting Rules

- You should develop a list of meeting ground rules:
 - Punctual attendance
 - Respect for agenda
 - Active listening
 - No one-on-one side meetings.
 - Willingness to reach consensus
 - Freedom to disagree

Tools for Reaching Consensus

- How do we reach a consensus?
 - Balance sheets
 - List reduction
 - Weighted voting
 - Pairwise comparisons
 - And many more...

Balance Sheets

- Can be used to identify and review the pro's and con's of a variety of options

| + (pros) | - (cons) |
|--|--|
| Positive aspects of each alternative | Negative aspects of each alternative |

List Reduction

- A way of processing the output of a brainstorming session
- Used to reduce a large list of items to a manageable few
- **Method:**
 - Display the list of items to be reduced
 - Vote for the items on the list.
 - As each item is called out by the meeting leader
 - Anyone wants to keep the item in the list raises hand (No limit on how many items one can choose)
 - When the first round of voting is over, the items with the largest number of votes are circled.
 - Continue the voting until a “manageable” number of items is achieved.
- Requirement:
 - Everyone in the group must have a clear understanding of all items in the list

Pairwise comparisons

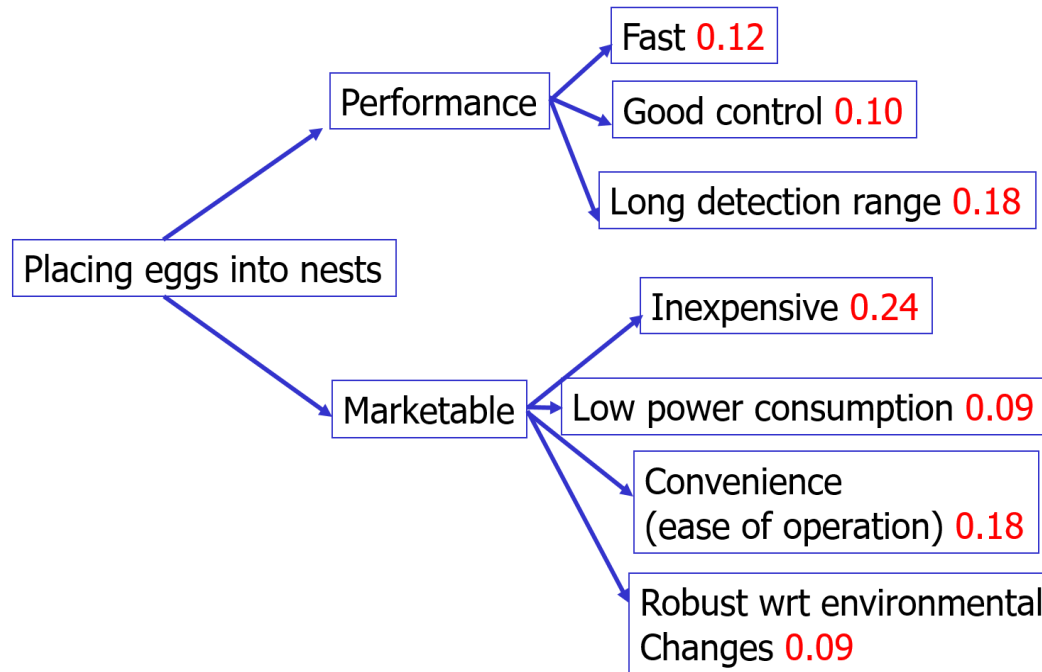
- Used, when it is difficult to compare multiple choices.
- Multiple options are elaborated by simple comparison
- Only two options/criteria are compared at a time.



Pairwise comparisons

- One can use pairwise comparisons technique to assess objectives.

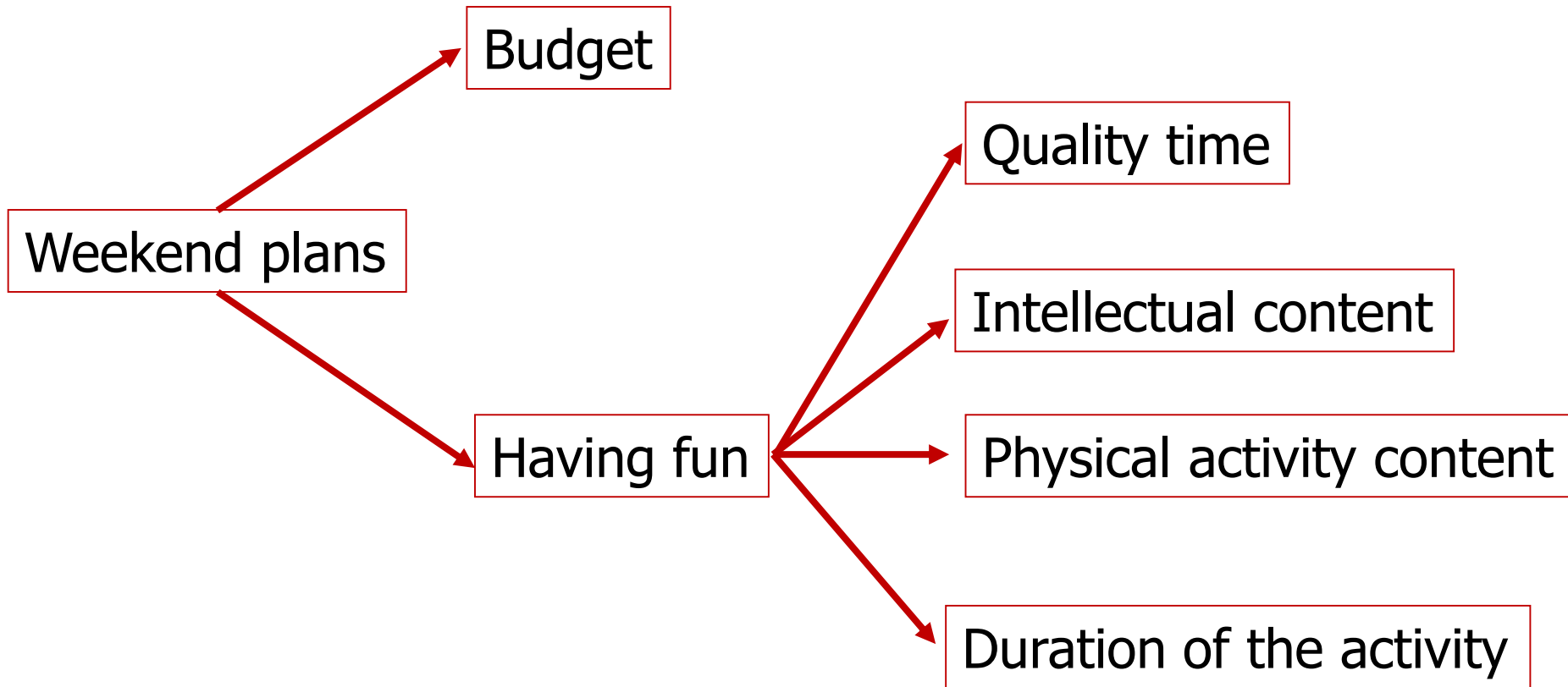
Weighted Objective trees



Pairwise comparisons

- **Example:** To choose a plan for the weekend
 - Alternatives
 - Watching a movie (WM)
 - Visiting Ankara castle and museums around (AC)
 - Cooking a dinner together (CD)
 - Biking at Eymir (BE)
 - Objectives
 - Minimize cost
 - Maximize fun
 - Quality time
 - Intellectual content
 - Physical activity content
 - Duration of the activity

Objective trees



Ranking objectives

Pairwise comparison charts

| | QT Quality Time | IC Intellectual content | PA Physical activity | D Duration | Total |
|----|-----------------------|-------------------------------|----------------------------|---------------|-------|
| QT | - | 1/2 | 0 | 1 | 1.5 |
| IC | 1/2 | - | 1 | 1 | 2.5 |
| PA | 1 | 0 | - | 1 | 2 |
| D | 0 | 0 | 0 | - | 0 |

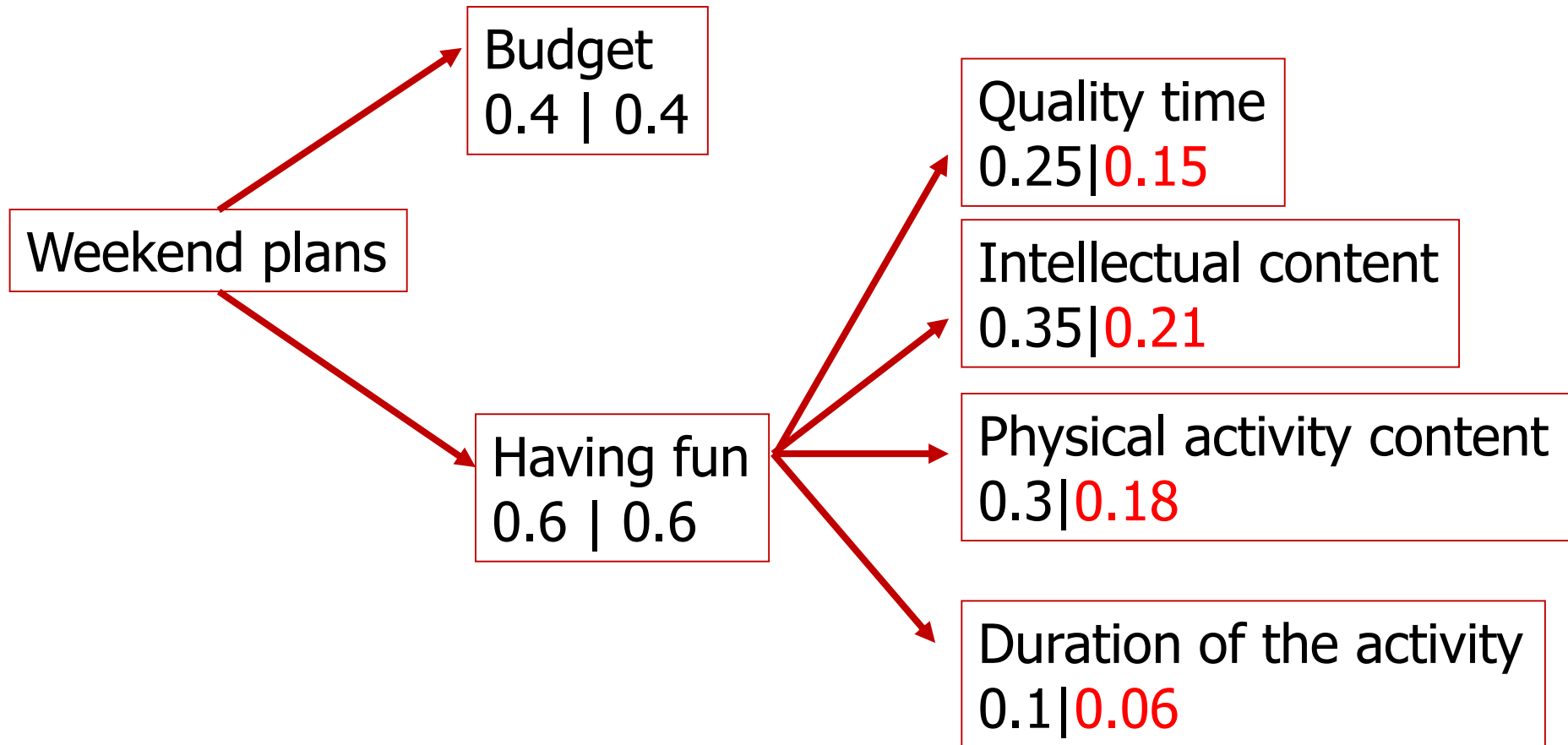


Weighted objectives

| | Ranking points | Add 1 | Weighted objectives |
|----|----------------|--------|---------------------|
| QT | 1.5 | 2.5 | $2.5/10=0.25$ |
| IC | 2.5 | 3.5 | $3.5/10=0.35$ |
| PA | 2 | 3 | $3/10=0.3$ |
| D | 0 | 1 | $1/10=0.1$ |
| | | Sum=10 | Sum=1 |



Weighted objective trees



Evaluation

| | B 0.4 | QT 0.15 | IC 0.21 | PA 0.18 | D 0.06 | Total |
|----|----------|------------|------------|------------|-----------|-------|
| WM | 2 0.8 | 4 0.6 | 8 1.68 | 0 0 | 10 0.6 | 3.68 |
| AC | 4 1.6 | 8 1.2 | 10 2.1 | 8 1.44 | 2 0.12 | 6.46 |
| CD | 8 3.2 | 10 1.5 | 6 1.26 | 2 0.36 | 4 0.24 | 6.56 |
| BE | 6 2.4 | 2 0.30 | 2 0.42 | 10 1.8 | 8 0.32 | 5.24 |

10: Excellent, 8: Good, 6: Satis., 4: Av., 2: Unacceptable, 0: Failure



Pairwise Comparison

- Pairs can also be weighted
 - Compare each item and score the difference
 - Instead of 0, 0.5 or 1 points you can define a different scale
 - Eg: **0**: no difference, **3** major difference

| | A | B | C | D |
|---------------------|---|------|------|------|
| A: Image Processing | | B, 3 | A, 1 | D, 3 |
| B: Electronics | | | C, 2 | D, 2 |
| C: Mechanics | | | | D, 0 |
| D: Fun | | | | |

Write the winner and the score

Sum up the score of each item

Weights:

A=1 (9.1 %)

B= 3 (27.3 %)

C=2 (18.2 %)

D=5 (45.5 %)

Words of wisdom and lessons learned

Murphy's Laws

- They are not myth, more applicable than the law of gravitational forces
- A quick list that I have seen over and over again
 - Anything that can go wrong, will go wrong.
 - If there is a possibility of several things going wrong, the one that will go wrong, is the one that will cause the most damage.
 - If everything seems to be going well, you have obviously overlooked something.
 - Any assumption you make will be the root cause of the failure
 - Time to complete a job is at least twice longer than what you had estimated.

Words of wisdom

- Do not simply assume anything
 - Anything you assume would be alright is probably will not be “that alright”
- Any test/simulation you think is redundant will cause you problems
- Estimating the duration of a task:
 - Make an estimate assuming you will not be able to work full time on the task.
 - Multiply that with two.
- Be courteous to each other
 - There could be tension during the crunch time
 - You do not have to love your team-mates
- Presentation and documentation is boring but
 - It is the most important task

Never give up!



How About the Positive?

- Engineering is fun!
 - Seeing a product come to life from a crude drawing is very satisfying



Thank you for your attention.