EE493
ENGINEERING DESIGN-1

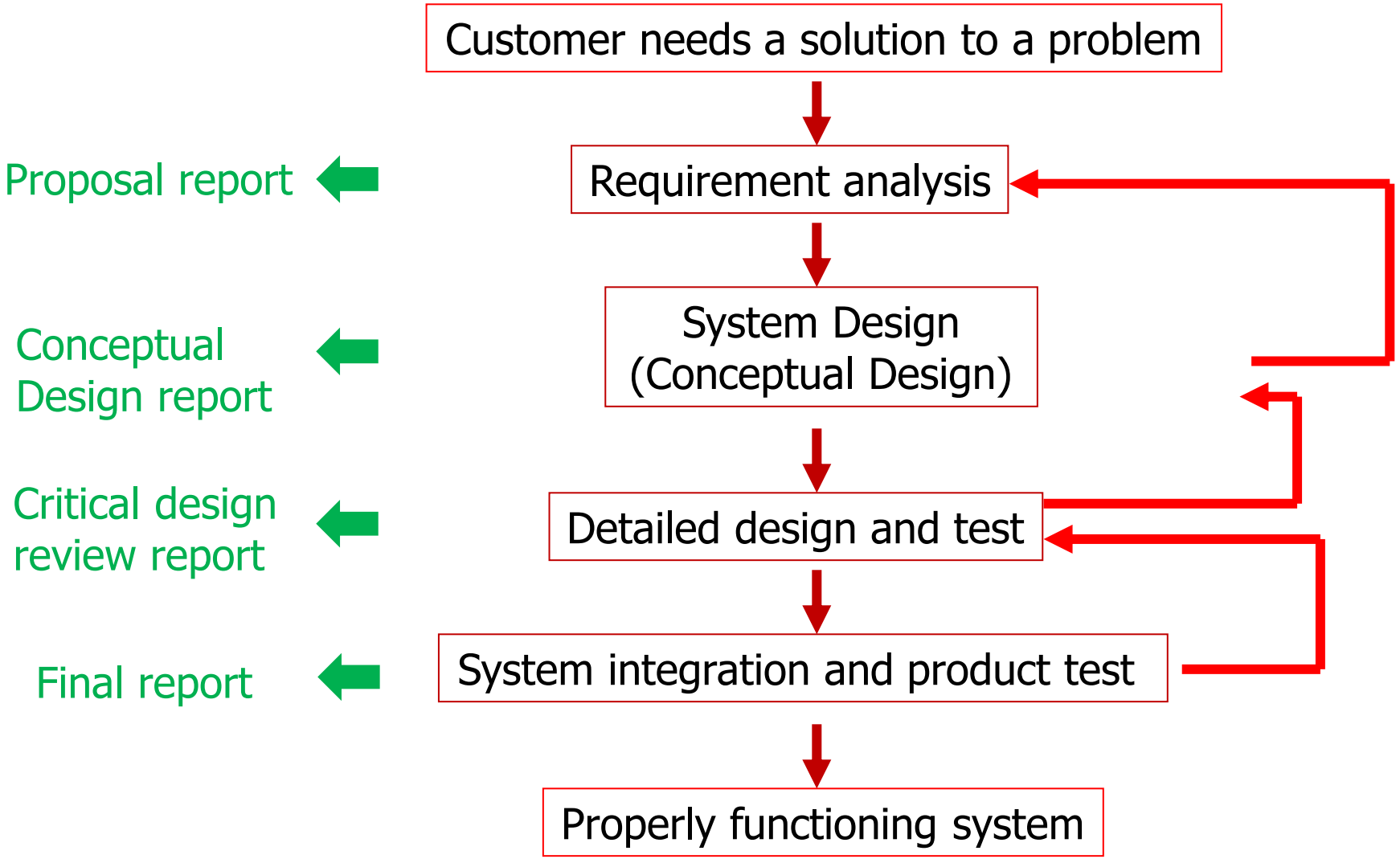
Concept Generation
Problem Solving Tools and Techniques

Nov. 19, 2022

Outline

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

Design Process



System Design

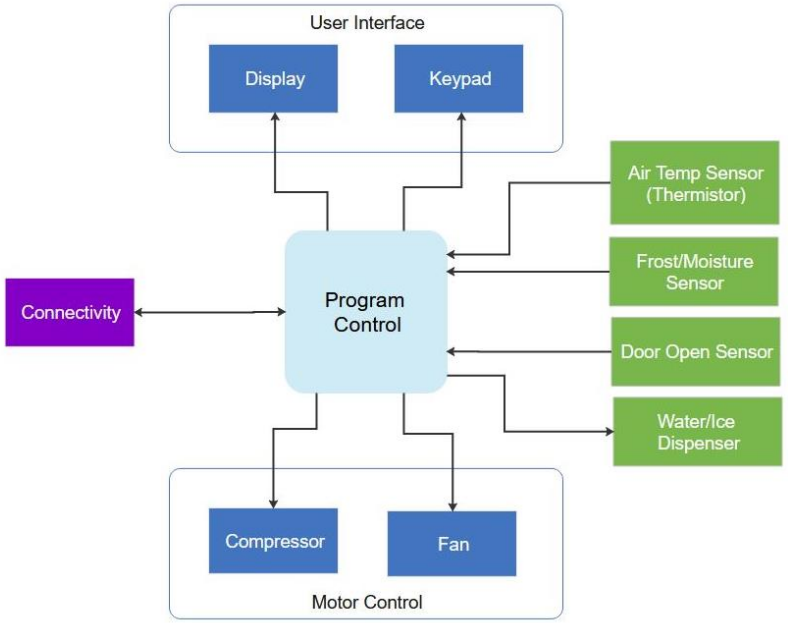
- Conceptualization
- Synthesis
- Analysis
- Evaluation

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 from time 0
  - No judgement or analysis of concepts

Synthesis

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



Analysis

- For each solution
- 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

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 sub-system level solutions in depth

- After choosing a solution, later
  - Go back to synthesis, refine a solution
  - Analyze again

Generating Ideas

We'll come to that later

Reaching Consensus

Consensus - 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

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.**

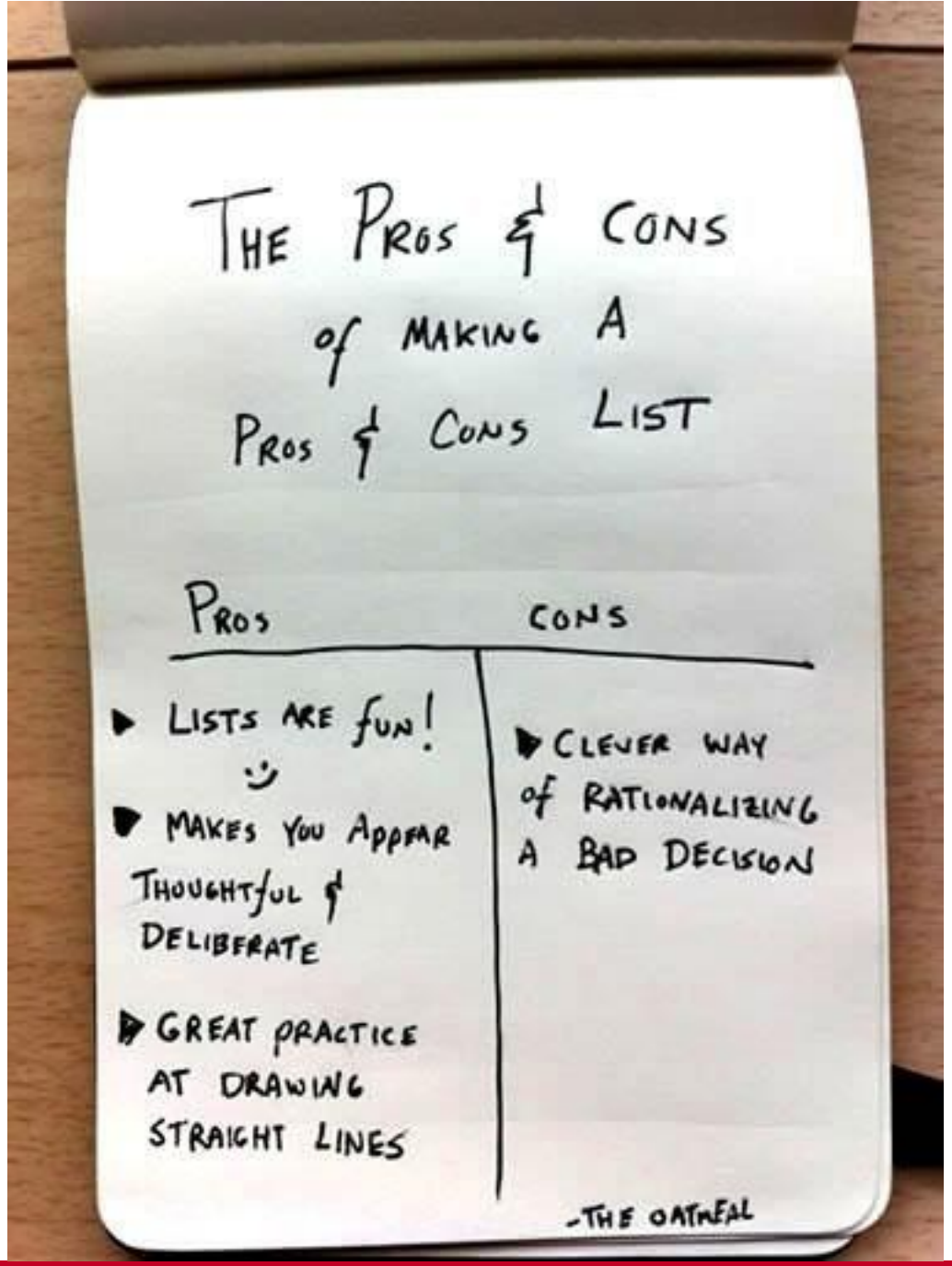
Tools for Reaching Consensus

- 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


THE PROS & CONS of MAKING A PROS & CONS LIST
PROS
CONS
▶ LISTS ARE FUN! ☺
▶ MAKES YOU APPEAR THOUGHTFUL & DELIBERATE
▶ GREAT PRACTICE AT DRAWING STRAIGHT LINES
▶ CLEVER WAY of RATIONALIZING A BAD DECISION
-THE OATMEAL

List Reduction

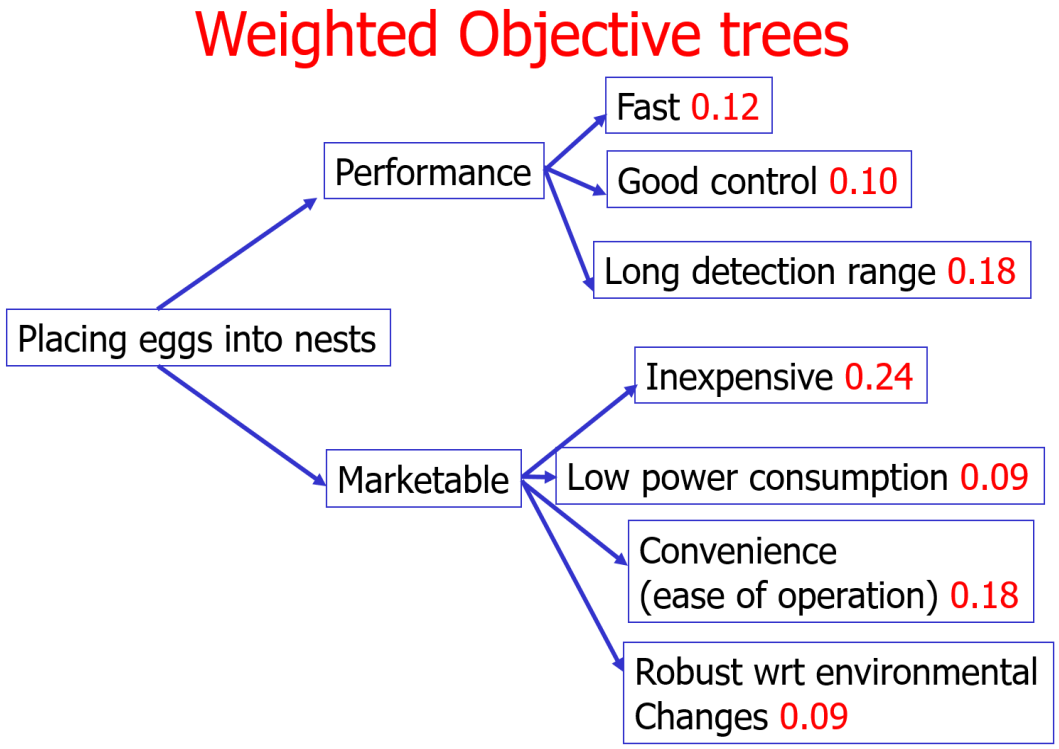
- A way of processing the output of a brainstorming session
- Used to reduce a large list of items to a manageable few
- **Method:**
  - Display the list of items to be reduced
  - Vote for the items on the list
    - As each item is called out by the meeting leader
    - Anyone wants to keep the item 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 kept.
    - Continue 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

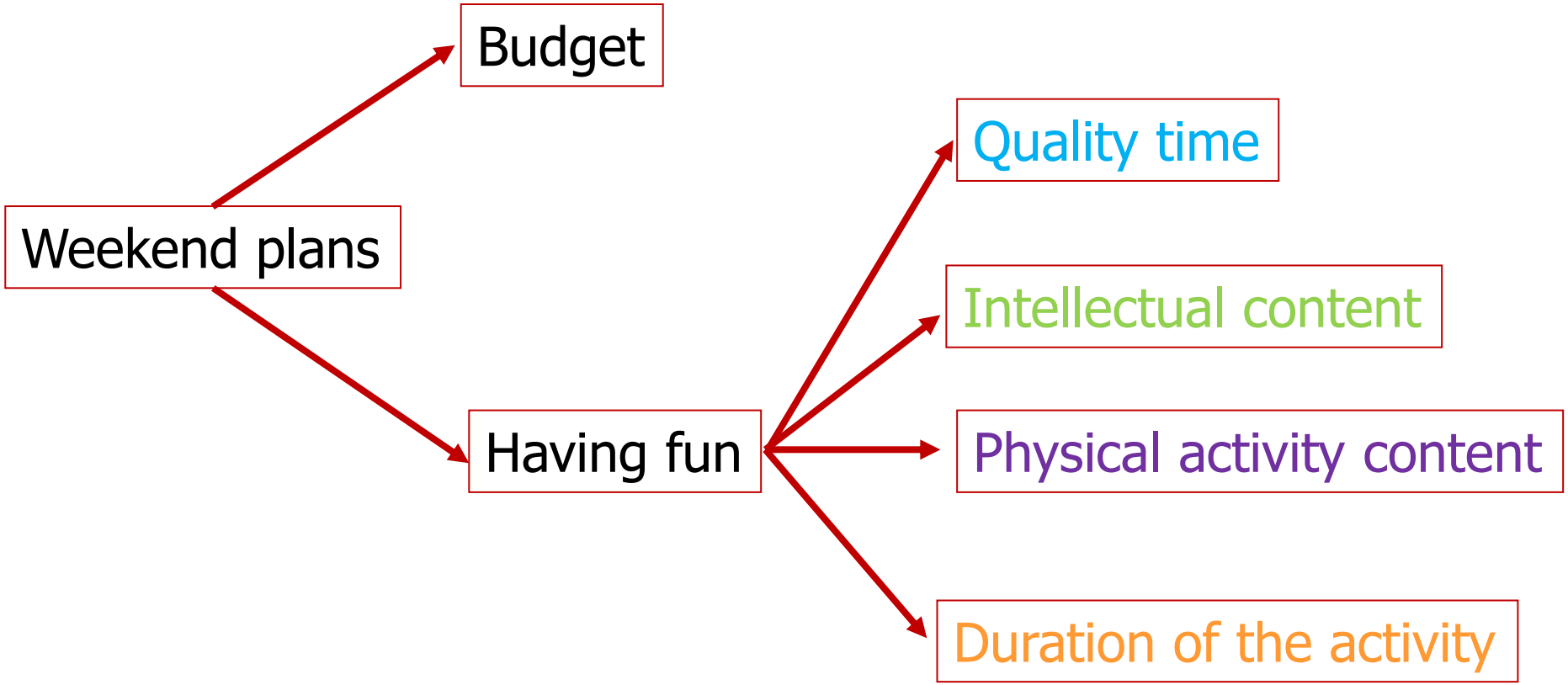
- One can use pairwise comparisons technique to assess objectives.



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

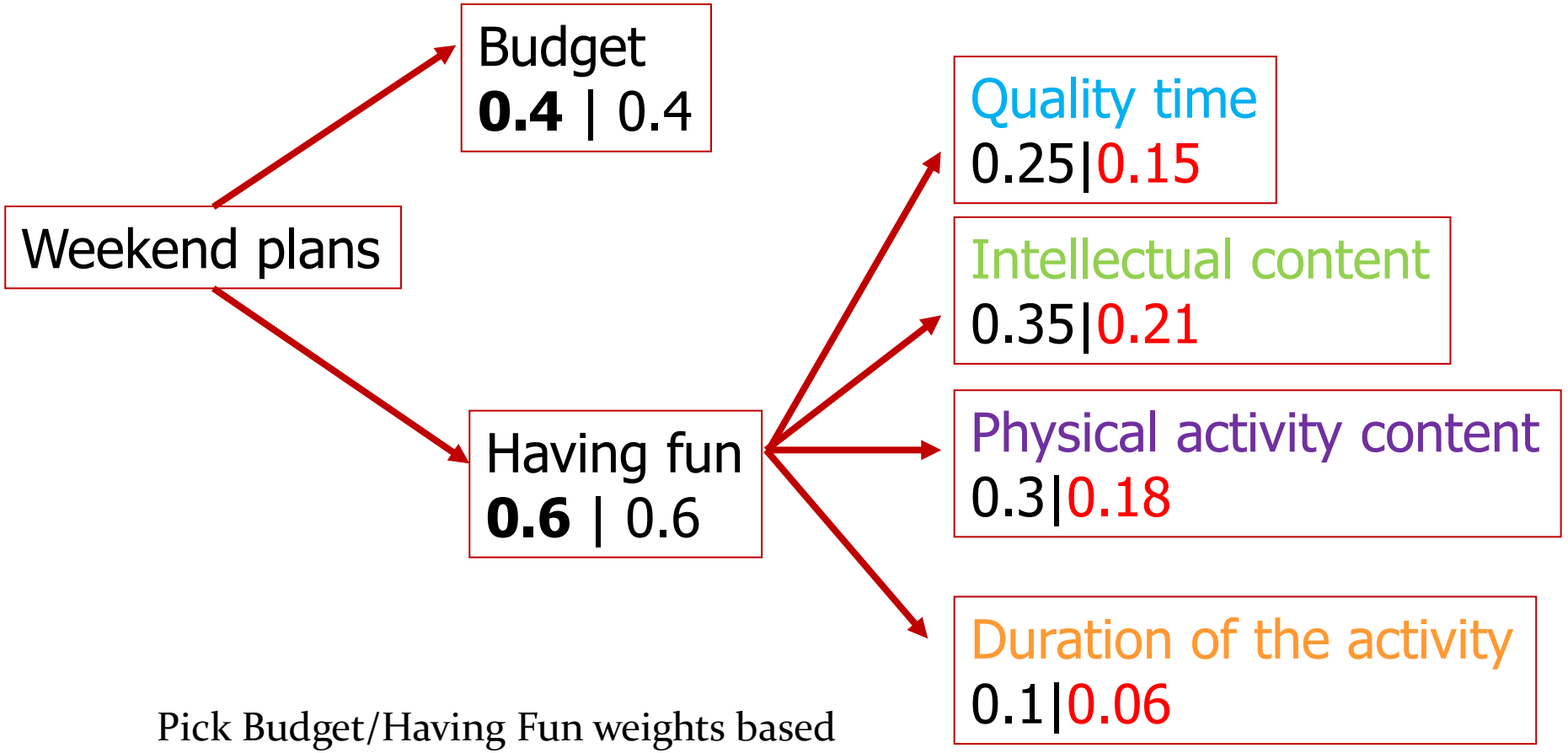
Pairwise comparison charts

	QT Quality Time	IC Intellectual content	PA Physical activity	D Duration	
QT					
IC					
PA					
D					

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

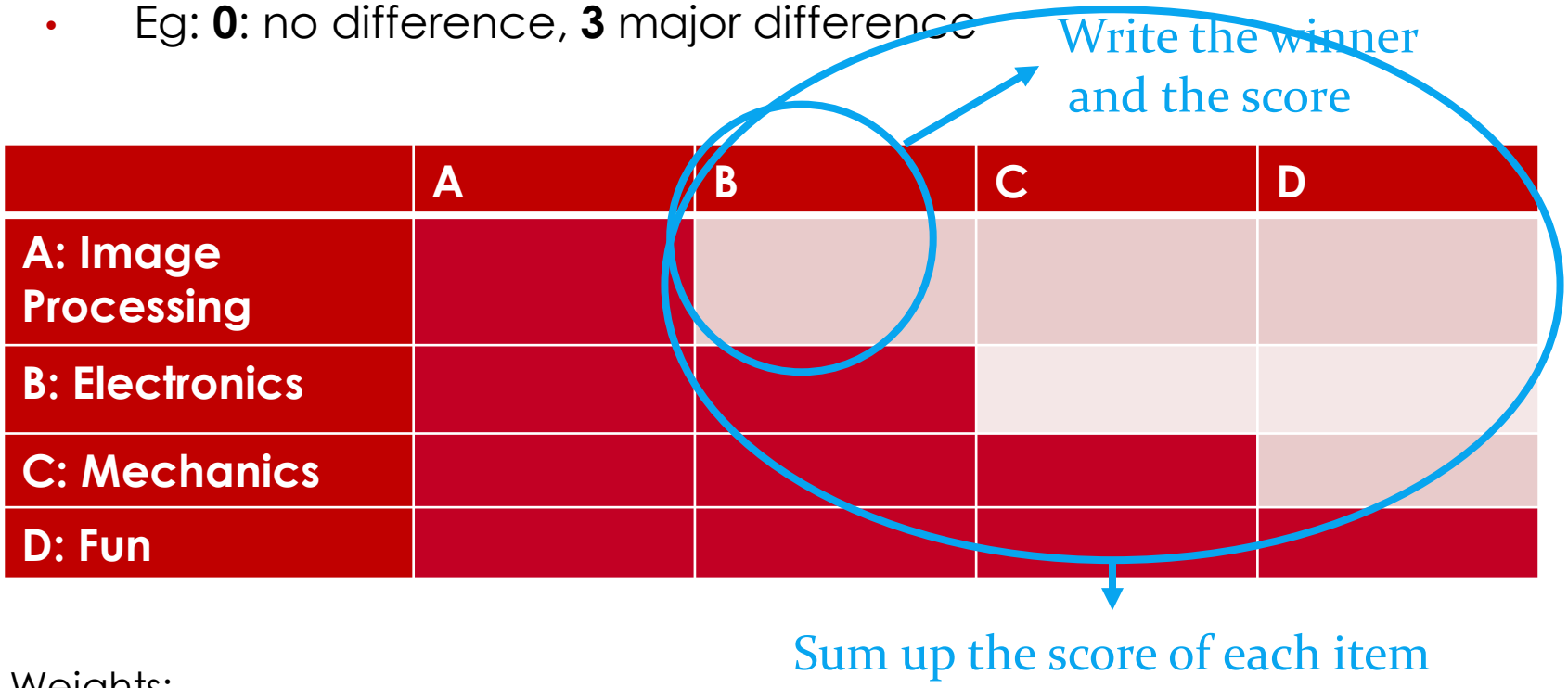


Pick Budget/Having Fun weights based on your judgement

Evaluation

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: Electronics				
C: Mechanics				
D: Fun				

Weights:

A=1 (9.1 %) B= 3 (27.3 %) C=2 (18.2 %) D=5 (45.5 %)

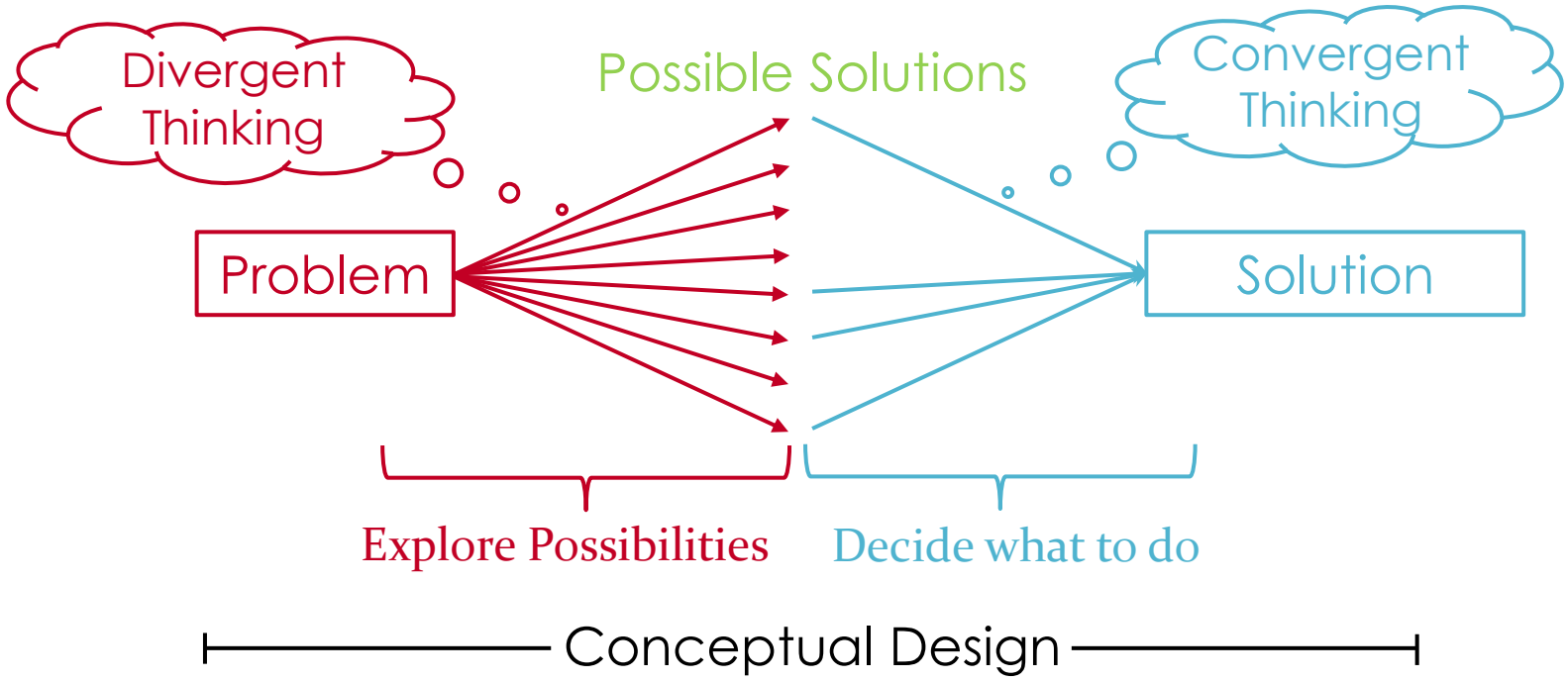
Generating Ideas

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.



Creative Thinking Methods - Brainstorming

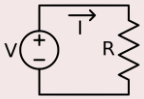
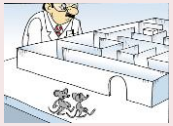
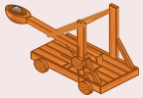
- Short and effective session for obtaining solutions
- Widely accepted method
- Groups of 4-8 people are the most successful
- A session may last half an hour or so
- **Free expression** is essential. Criticism of the ideas must be avoided. Nothing should be said to **discourage** a group member from 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

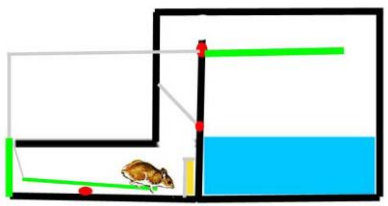
- Mousetrap
- Generate as many ideas for each of four sub-blocks in a mousetrap

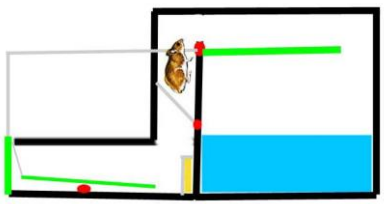
Attract mouse
Stop mouse
Store mouse
Export mouse

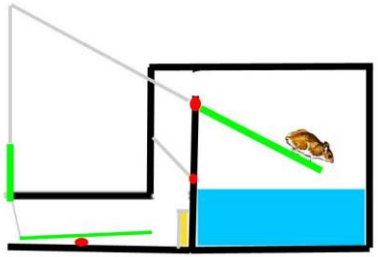
Mousetrap

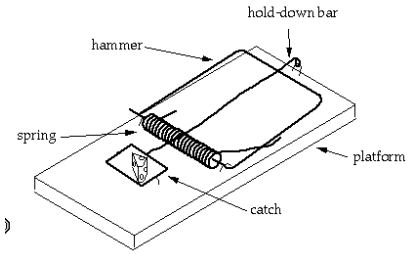
	Solution Idea		
Attract mouse	Cheese tunnel 	Squeaks 	Pheromones 
Stop mouse	Exterminate 	Block Exit 	High Voltage 
Keep mouse	Box 	Cage 	Maze 
Export mouse	Release 	Find a job 	Catapult 

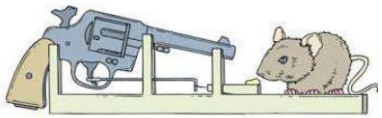
Mouse Trap – Propose Alternatives



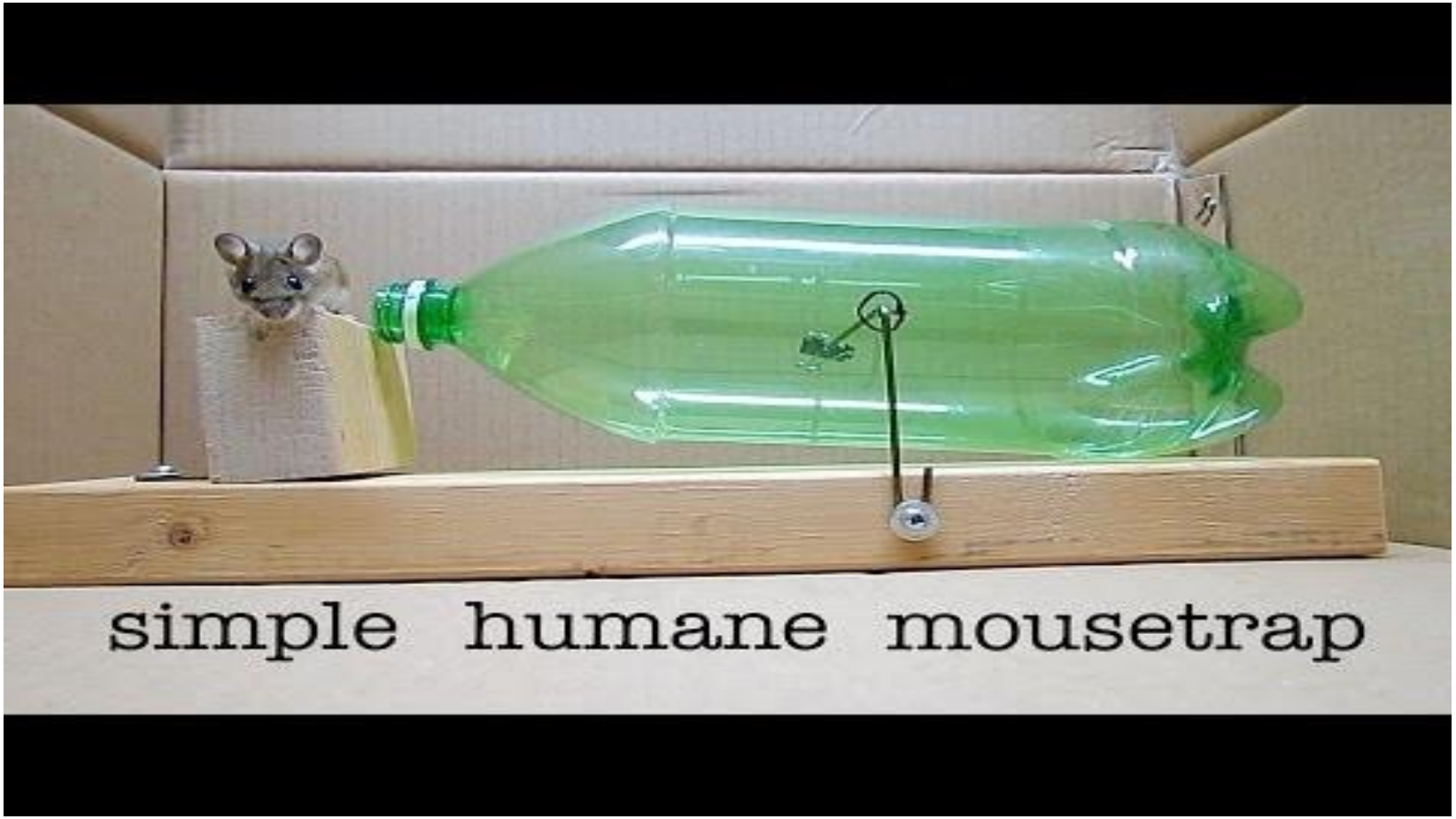








Mousetrap



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: Water filter

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 we 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

Murphy's & 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.

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· K · (N-1)*