EE493
ENGİNEERİNG DESİGN-1

Concept Generation
Problem Solving Tools and Techniques

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Adapted from Dr. Afşar Saranlı's Lecture

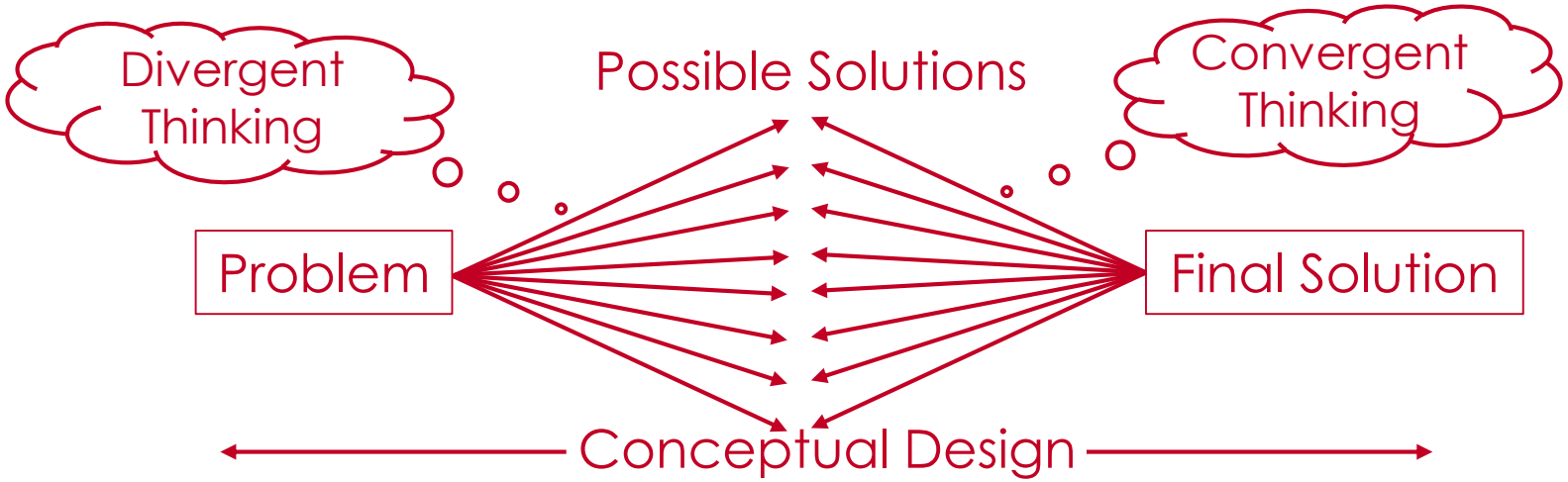
Outline

- Generating ideas
- Reaching consensus
- Displaying and analyzing data
- Planning and scheduling actions and tasks
- Words of wisdom and lessons learned

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 and egg from breaking
  - Convergent Thinking: Solving a well-defined, straightforward answer to a problem.
    - Example: What is the capital of Norway?
- Divergent and convergent thinking is 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
    - …

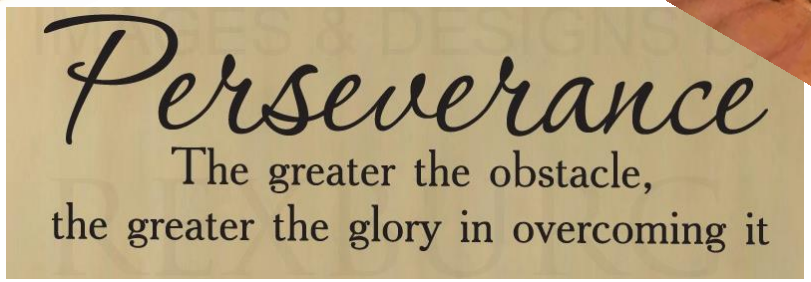
Creative Thinking: Requirements

- Generate and work on a large number of alternatives

  "It is easy to obtain 100 patents if you also have 5000 unsuccessful inventions." T. Edison

- Perseverance

  "I am convinced that about half of what separates the successful entrepreneurs from the non-successful ones is pure perseverance." Steve Jobs.

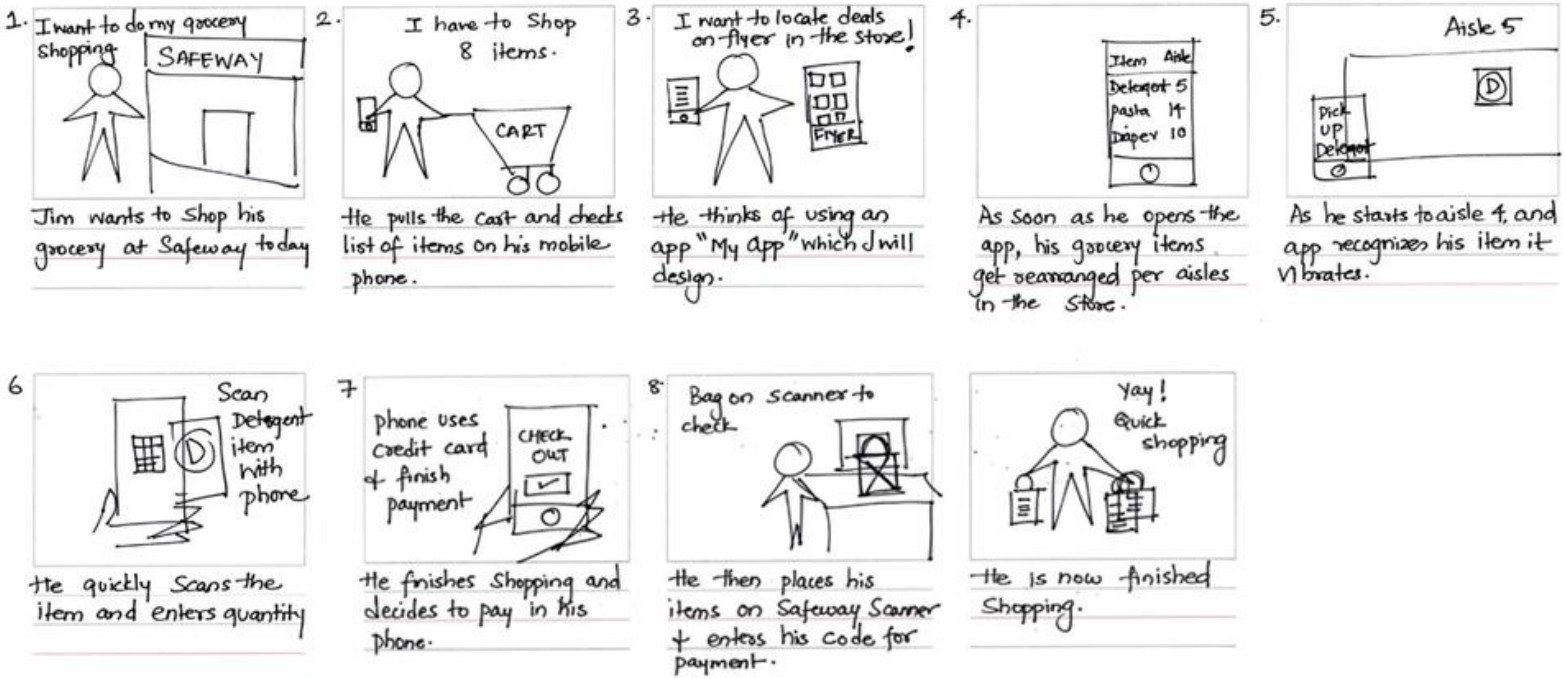


Creative Thinking: Methods-1

- Have a strong mind: Mental Exercises
  - Making lists
    - Example: Write down 20 different uses of pencil
  - Word games
    - Example: Scrabble
  - Puzzles
  - Many online resources
    - Example: www.brainhq.com
- Brainstorming
  - Generate and list as many ideas as possible
  - No critizing or rewarding ideas
  - No negative reaction
- Brainwriting
  - Brainstorming may lead to key players do the talking and leading
  - To avoid: Each member writes down their ideas, papers are circulated

Creative Thinking: Methods-2

- Reverse Brainstorming and Brainwriting:
  - 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.
- Storyboard technique



Creative Thinking: Methods-3

- Random stimulation
  - Pick a word from the newspaper, and use it to suggest an idea
    - Example: Reducing car pollution
    - You are stuck with clean fuels, making cars more efficient etc.
    - Pick a word from a newspaper: Plants
      - Plant trees on the road sides
      - Pass exhaust gasses from a soup of algae
      - Plant means factory; may be collect exhaust gasses and use it for something else? You can dump collected exhaust gas when you fill up gas?
    - Remember: No critism!
- Many more methods
  - Good reference: www. mindtools.com

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

Tools for Reaching Consensus

- List reduction
- Balance sheets
- Weighted voting
- Pairwise comparisons
- And many more, check www.mindtools.com

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

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

Weighted Voting-1

- Assigns different weights to voters
- Weights (number of votes of each voter) may also be the same, but each voter is free to assign as many votes as s/he wants on a single item.

Holiday Plan

	Beach	Trecking	Foreign country	Visit Grand parents
Mother	1	0	2	3
Father	2	1	2	1
Zeynep	3	0	1	0
Ali	1	2	0	1

Pairwise Comparison-1

- People are good at comparing two items at a time
- List the criterion and compare a pair one at a time

	Strength	Manufacturability	Cost	Weight	Compat. W/ Chassis	Maintenence	Simplicity	Crash Survivability	Aesthetics	Compatible W/ Sway Bar	Dummy	Absolute Total	Normalized Total	Weight
Strength		1	1	1	0	1	1	0	1	0	1	7	0.8	8
Manufacturability	0		1	1	0	1	1	0	1	0	1	6	0.7	7
Cost	0	0		0	0	0	0	0	1	0	1	2	0.2	2
Weight	0	0	1		0	1	1	0	1	0	1	5	0.6	6
Compat. W/ Chassis	1	1	1	1		1	1	1	1	1	1	10	1.1	11
Maintenence	0	0	1	0	0		1	0	1	0	1	4	0.4	4
Simplicity	0	0	1	0	0	0		0	1	0	1	3	0.3	3
Crash Survivability	1	1	1	1	0	1	1		1	1	1	9	1.0	10
Aesthetics	0	0	0	0	0	0	0	0		0	1	1	0.1	1
Compatible W/ Sway Bar	1	1	1	1	0	1	1	0	1		1	8	0.9	9

Pairwise Comparison-2

- Pairs can also be weighted
  - Compare each item and score the difference (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: Robotics				D, 0
D: Fun				

Weights:

A=1 (9.1 %)

B= 3 (27.3 %)

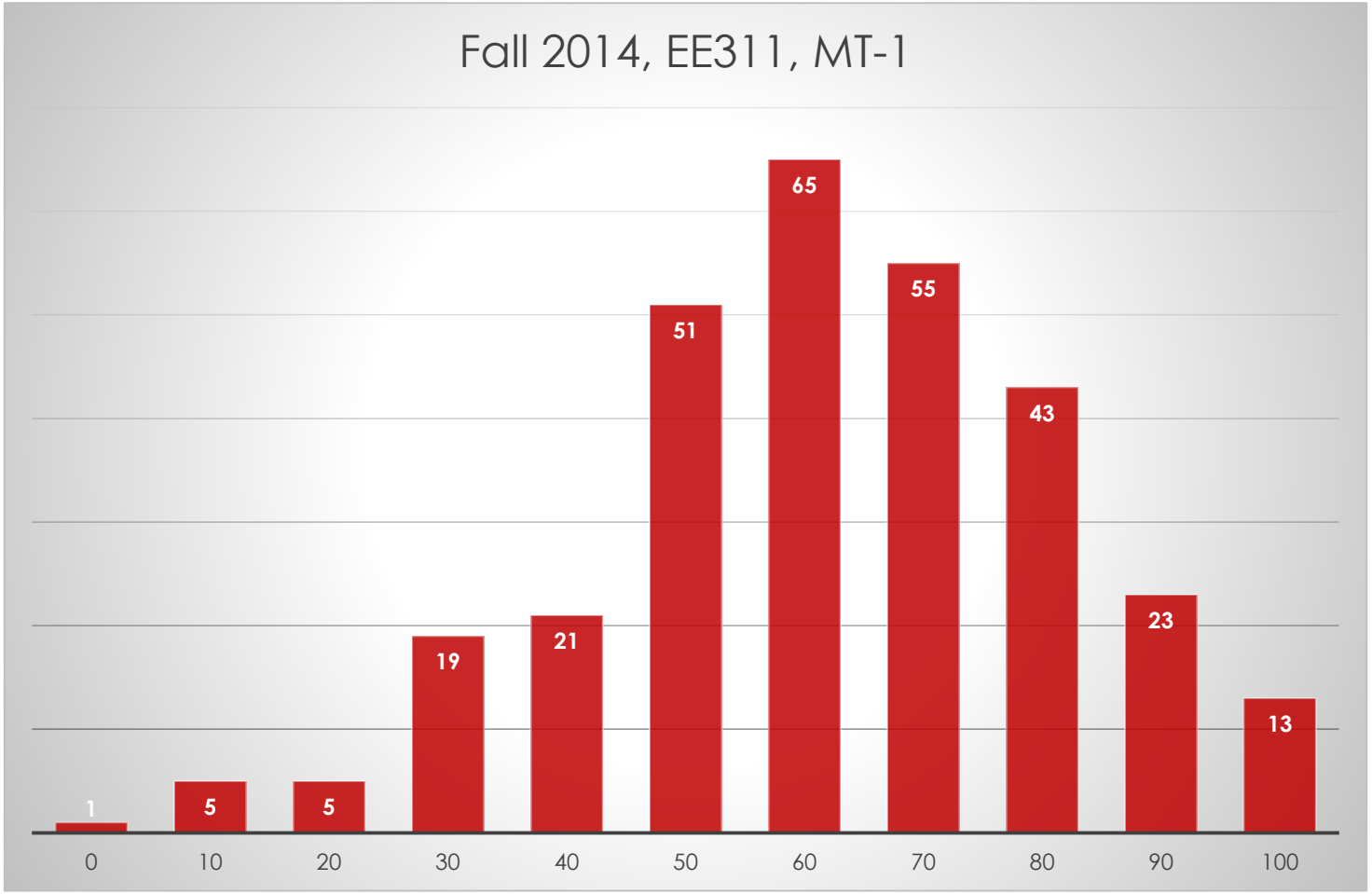
C=2 (18.2 %)

D=5 (45.5 %)

Displaying and analyzing data

Histogram-1

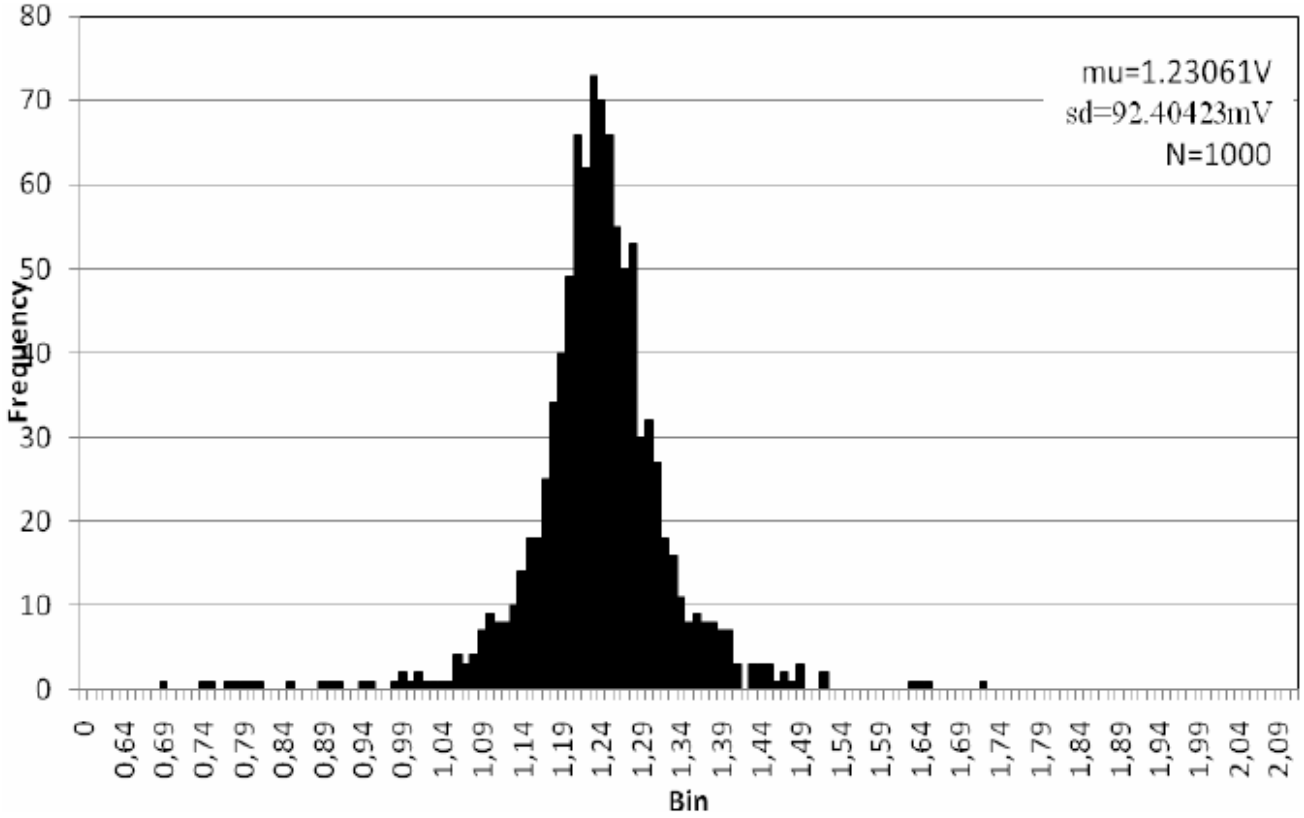
- Used to display distribution



Histogram-2

- Easy method to see average, standard deviation

Output Voltage Variation of a commercial Voltage Reference Circuit

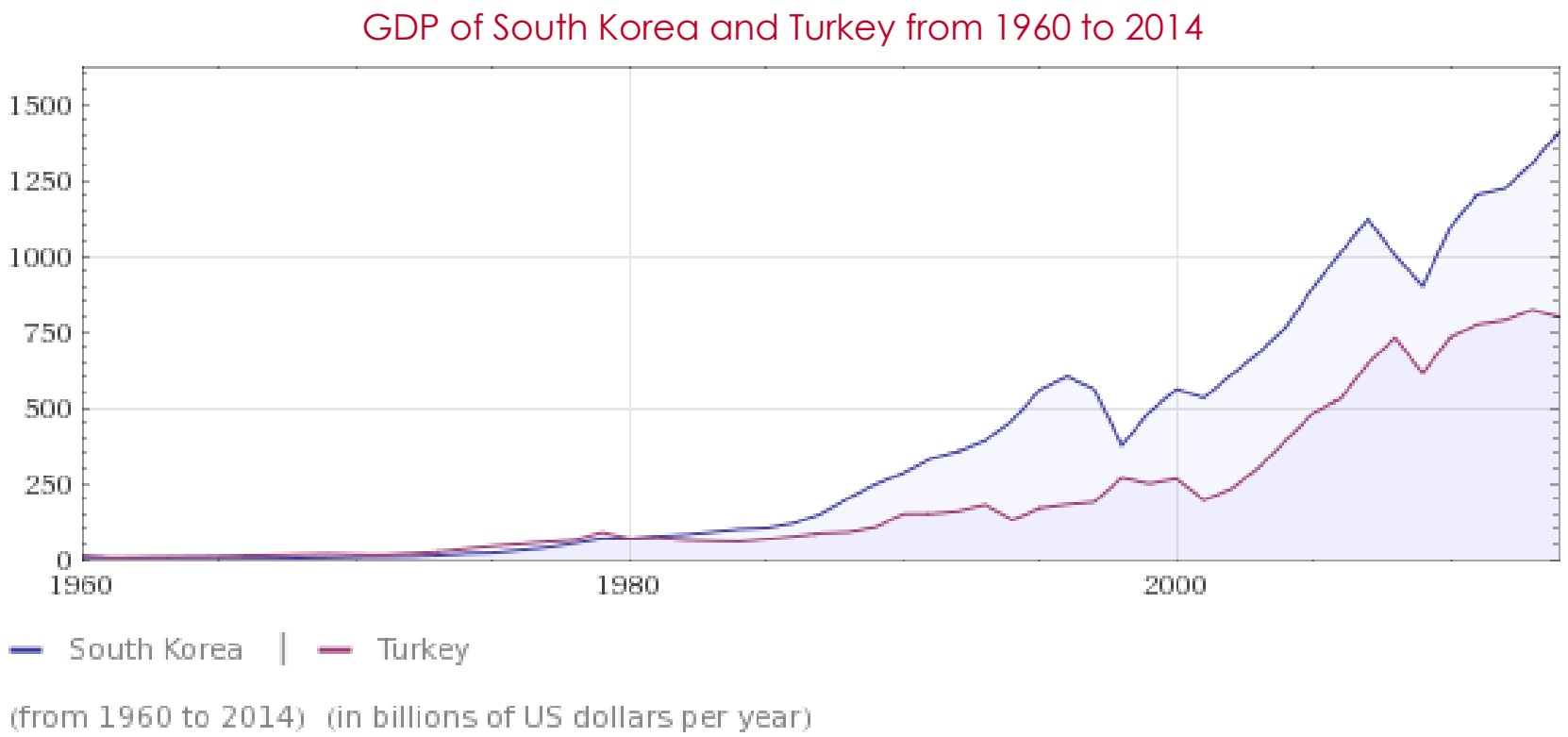


Pie Charts

- Used to show the relation of each part to the whole

Time Charts

- Display change of a data over a period of time.



Cost-Benefit Analysis

- Enables the group to estimate the real cost and benefits for a solution under consideration
- Usually used based on financial data
- Can be used for other data as well
  - Example: Designing an overdamped system
    - Benefit: Stable
    - Cost: Longer settling time
  - Example: Designing an underdamped system
    - Benefit: Speed
    - Cost: Ringing and possible oscillation
- Can be used to:
  - Help choose a solution by making comparisons
  - Uncover benefits and costs that are not trivial or evident

Cost-Benefit Analysis Example

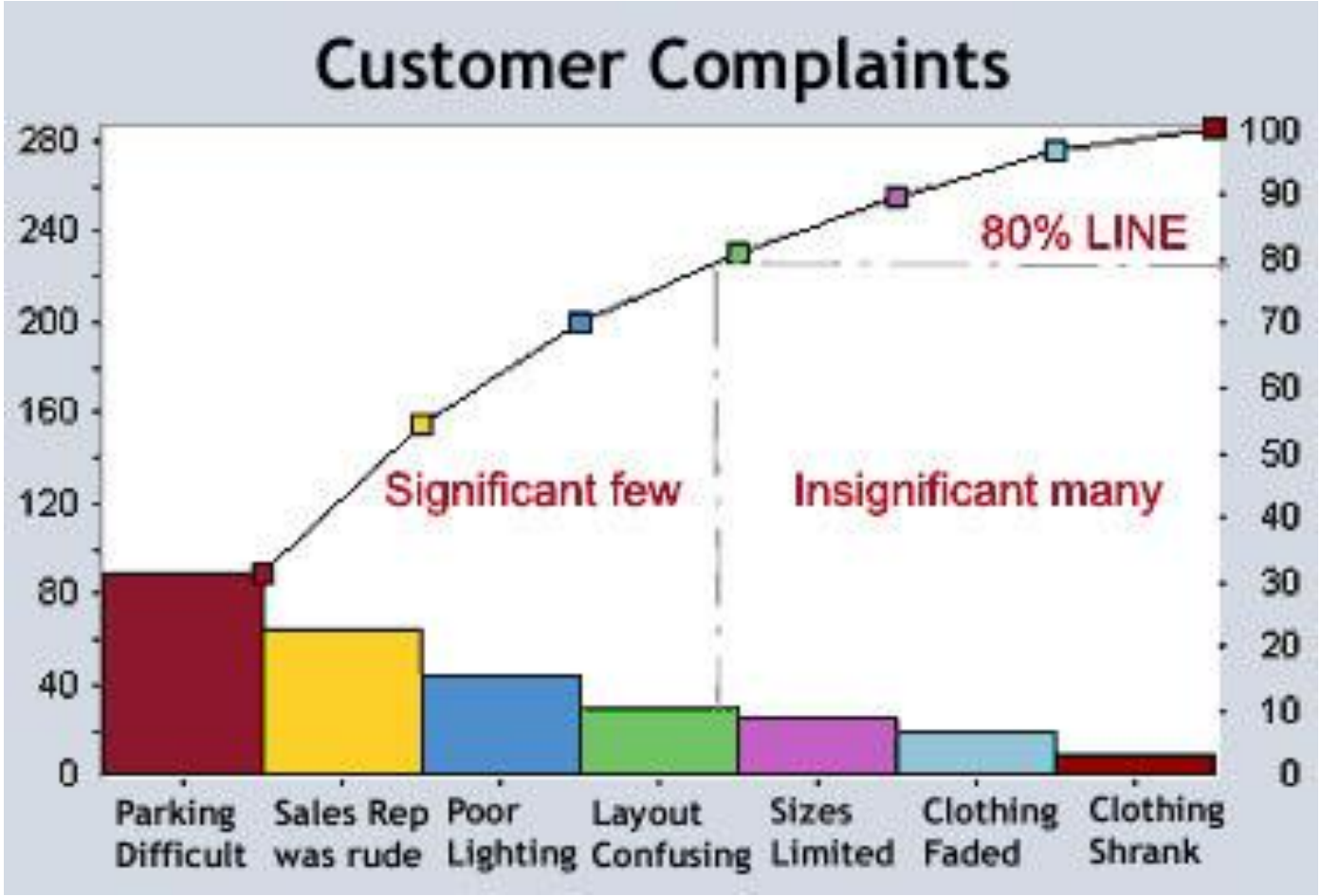
- Costs:
  - Machine $1000
  - Rewiring and installation $500
  - Cost of lost production $500
  - Cost of retraining operator $250

- Benefit (annual)
  - Reduce rejects by 10% $750
  - Reduce man-hours for the job $500
  - Reduce start-up time $250

- Verdict

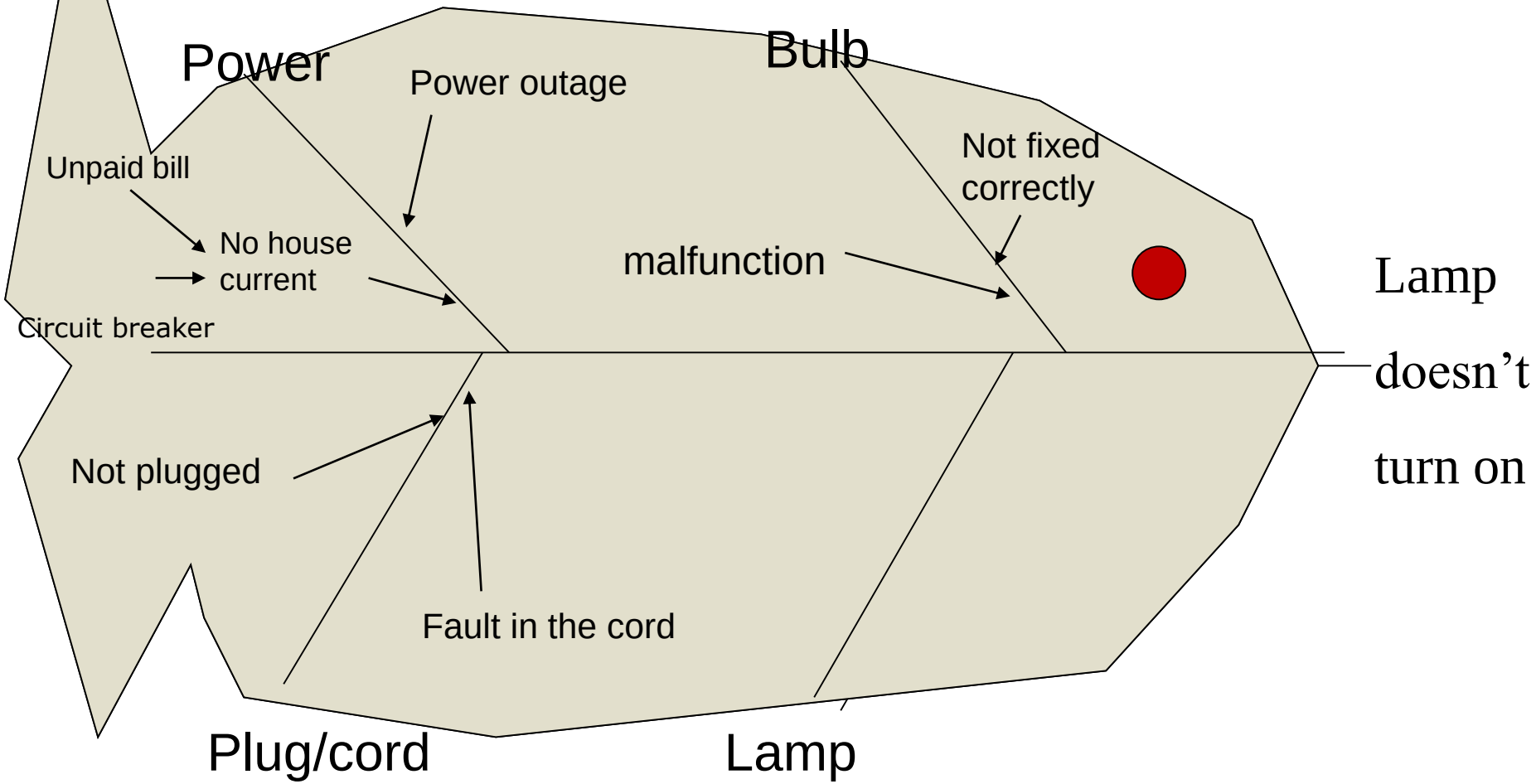
Pareto Analysis

- A resorted histogram to gather focus on important problems



Fishbone Diagram

- Systematic and hierarchic way of looking at the effects and their causes



Mind Mapping

- Diagram used to visually organize information.
- Could be vital for minute details not get lost during crunch time.

Planning and scheduling actions and tasks

Tools for planning actions

- Specify and clarify tasks that must be done
- Sequence those tasks
  - See which one depends on the completion of the other
- Assess the requirements
  - Material, pre-requisites, man power
- Make sure everyone knows who is responsible of what
- Specify the results you expect, when you expect them and how to monitor them.

Scheduling Techniques

- Flow Charts
- Gantt Charts
- Pert Charts
- Networks
  - Critical Path Method (CPM)
  - Program Evaluation and Review Technique (PERT)

Gantt Charts-1

- Bar chart with a calendar scale
- Clearly shows timing aspect
- Useful in scheduling and tracking activities
- Drawn against time (x-axis)
- List of axis are the values (y-axis)
- Many software alternatives
  - Microsoft Project
  - OpenProj
  - Excel, or any other worksheet software

Gantt Charts-2

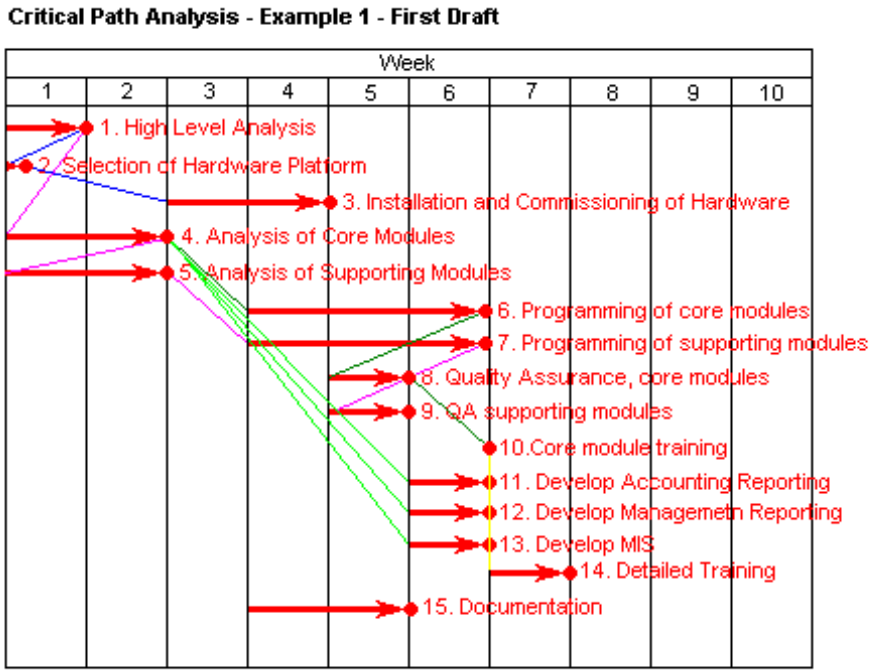
ID	Task Name
1	**Robot Platformu Prototip Geliştirilmesi**
2	**Deneysel amaçlı bacaklı robot tasarımı ve üretimi**
3	Temel işlemci mimarisinin, motor sürücü ve güç devreleri tasarımı
4	İşlemci ve elektronik birimlerin tümleştirilmesi ve testleri
5	Seçilen algılayıcı birimlerinin entegrasyonu ve testleri
6	Mekanik tasarımın yenilenmesi, üretimi ve testleri
7	Sistem entegrasyonu ve temel işlerlik testleri
8	İkinci prototipin üretilmesi
9	Mekanik revizyonlar ve tasarım değişiklikleri
10	**Moduler Kontrol Yazılım Mimarisinin Tasarımı ve Gerçeklemesi**
11	Alt seviye algılayıcı-kumanda yazılım tasarımı ve gerçeklemesi
12	Ara seviye davranış yazılım mimarisinin tasarımı ve gerçeklemesi
13	Üst seviye kullanıcı kumanda arabirimi yazılımı tasarımı ve gerçeklemesi
14	Yazılım mimarisinin yeni platform üzerinde uygulanması
15	Platform Prototipi İlk Demonstrasyonu
16	**Platformun Matematiksel Modellemesi ve Simülasyonlar**
17	Bacaklı platformun istenen davranışlara uygun modelinin oluşturulması
18	Simülasyon yazılımının geliştirilmesi
19	Simülasyonun fiziksel gerçekliğinin doğrulanması
20	Davranışa özel modeller ve simülasyon değişiklikleri
21	**Algılayıcı Algoritmaları Geliştirme**
22	Literatür taraması ve algılayıcı yelpazesinin seçimi
23	**Öz Durum algılama algoritmaları**
24	Bacaklı davranış altında gyro, pusula ve GPS ile öz durum kestirimi
25	Bacak boy, kuvvet ve darbe verilerinin algılanması ve yorumlanması
26	Çeşitli öz durum algılayıcıl bilgilerinin tümleştirilmesi
27	Algılayıcı algoritmalarının değişik dinamik davranışlar için özelleştirilmesi
28	Bacaklı davranış altında platform enerji sarfiyatının karakterizasyonu
29	**Çevre algılama algoritmaları**
30	Lazer, sonar ve IR algılayıcılar yardımıyla engel tanıma ve sınıflama
31	Kamera verileri kullanılarak çevre algılama ve tanıma
32	Mesafe ve kamera verilerinin tümleştirilmesi
33	Çevre nitelikleri tanıma ve öz konum belirleme
34	**Algılayıcı geri beslemeli dinamik davranış algoritmaları**
35	Algılayıcı geri beslemeli kontrol ile düz yürüme ve koşma
36	Uzun mesafeli koşma için çeşitli yüzeylerde güç tüketim optimizasyonu
37	Algılayıcı geri beslemeli kontrol ile engebeli zeminde düz yürüme ve koşma
38	Algılayıcı geri beslemeli kontrol ile eğik zeminde tırmanma ve yan geçiş
39	Algılayıcı geri beslemeli kontrol ile hendek atlama
40	Platformun Arazi Demonstrasyonu

Requirements

- Common to all planning techniques
  - The objectives of the project must be defined and understood
  - The project is broken down into major work areas (sub-projects)
  - Tasks needed to complete each sub-project are defined
  - The time needed is estimated along with the resources
    - People
    - Equipment
    - etc.

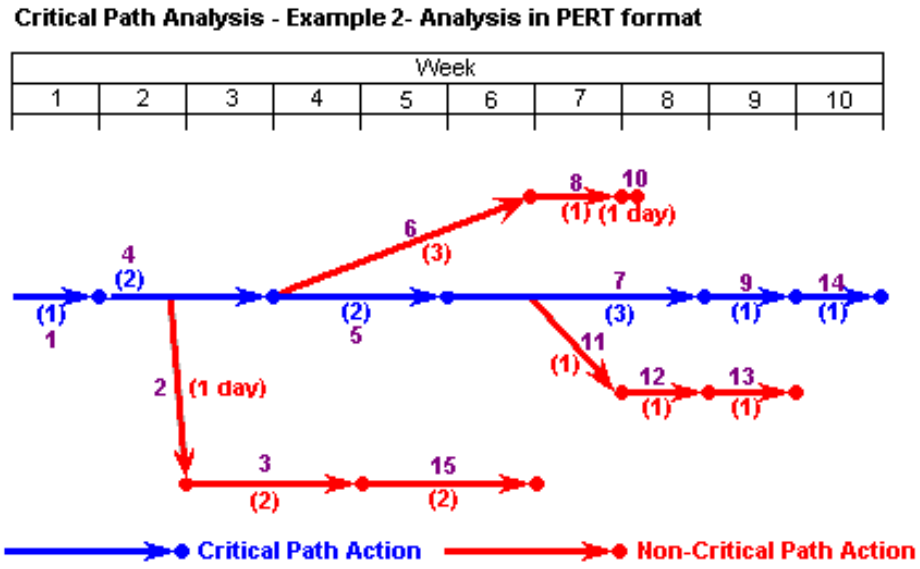
Critical Path Analysis-1

- Critical Path Analysis is very effective in analyzing a complex project time frame
- Helps you to calculate
  - The minimum time in which the project can be completed,
  - Which activities should be prioritized



Critical Path Analysis-1

- The final stage is to prepare a clean final copy of the analysis showing the critical path and non-critical paths



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.
  - It does not matter how well you plan it, last 2-3 weeks will always work overtime to complete a project.

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

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.