Engineering Design Process

Systematic Design

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Objectives of this lecture

Systematic Design

Requirements

Specifications

Function Tree

QFD

1) Systematic Design process.
2) Understand Requirements and Specifications
3) Introduction to Function Tree.
4) Introduction to Quality Function Deployment (QFD).
5) Ethics at the Requirements, Specifications and QFD stages.

Outcomes

Systematic Design

Requirements

Specifications

Function Tree

QFD

By the end of this lecture, you will be able to:

- **Apply the design process using systematic design methods to develop engineering components [c, k].**
- **Identify customer requirements.**
- **Identify engineering specifications and constraints.**
- **Create Function Tree and a stage 1 'QFD' Chart**

Review of Last Lecture

Systematic Design

Requirements

Specifications

Function Tree

QFD

- **Why Design is important?**
- **Why Design is difficult?**
- **What are the Design Schools of thoughts?**
- **What are the pitfalls(traps, mistakes) of classical Brainstorming?**

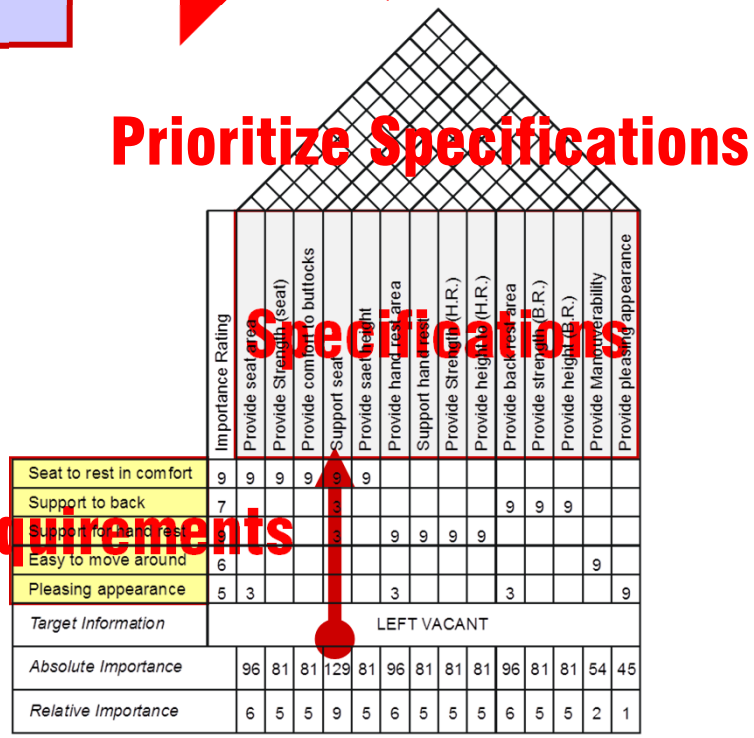
- **Answer by True or False:**
  - **[ ] The customers of a product are only the end-users.**
  - **[ ] Conventional design has more opportunities for weakness Identification.**

Systematic Design Process - Steps

1) Requirements
2) Specifications
3) Conceptual Design
4) Embodiment Design
5) Detailed Design

QFD

QFD: Quality function deployment



(1) Requirements

- Requirements are a 'wish list' that the product needs to do (EXPECTED).
- This is usually given by the customers or sponsors or even as a list of requirements in the designer's mind.
- They are not usually technical.
- E.g. for a coffee cup … 'something that will hold coffee' etc…
- Let us find requirement for a "kettle".

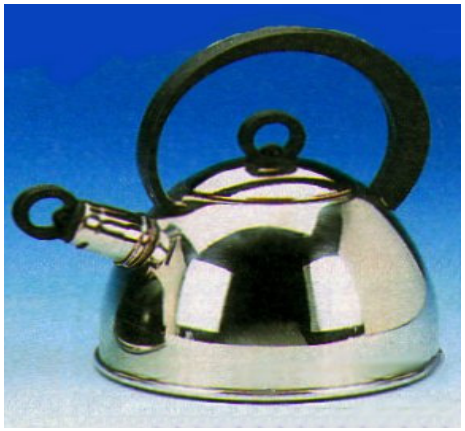
e.g. The Need for a Kettle

The need of the society was a vessel that will transfer heat from an energy source to water, keep the temperature close to the boiling point and safely transfer the boiled water into the coffee mug or tea cup.

Resources of Requirements:

- ***Market Segments***
- ***Economical/Political***
- ***Research & Development***

e.g. The Need for a Kettle
Market Segments



- **Gas fire kettles.**
- **Electric kettles for *travel and small users.***
- **Electric kettles for *large and small number of cups* with energy efficiency.**
- **Electric kettles with *aesthetically pleasing appearance* for the affluent users.**

e.g. The Need for a Kettle
Requirements for a Kettle

Systematic Design

Requirements

Specifications

Function Tree

QFD

List some requirements for a Kettle?!!

3 ➢ **Heat varied amounts of water**

5 ➢ **Energy efficient**

1 ➢ **Easy to move around**

9 ➢ **Safe handling during pouring**

7 ➢ **Aesthetically (beauty) pleasing surface**

8 ➢ **Boil water fast**

9 ➢ **Automatic switching off from the energy source or alert user when water is boiling**

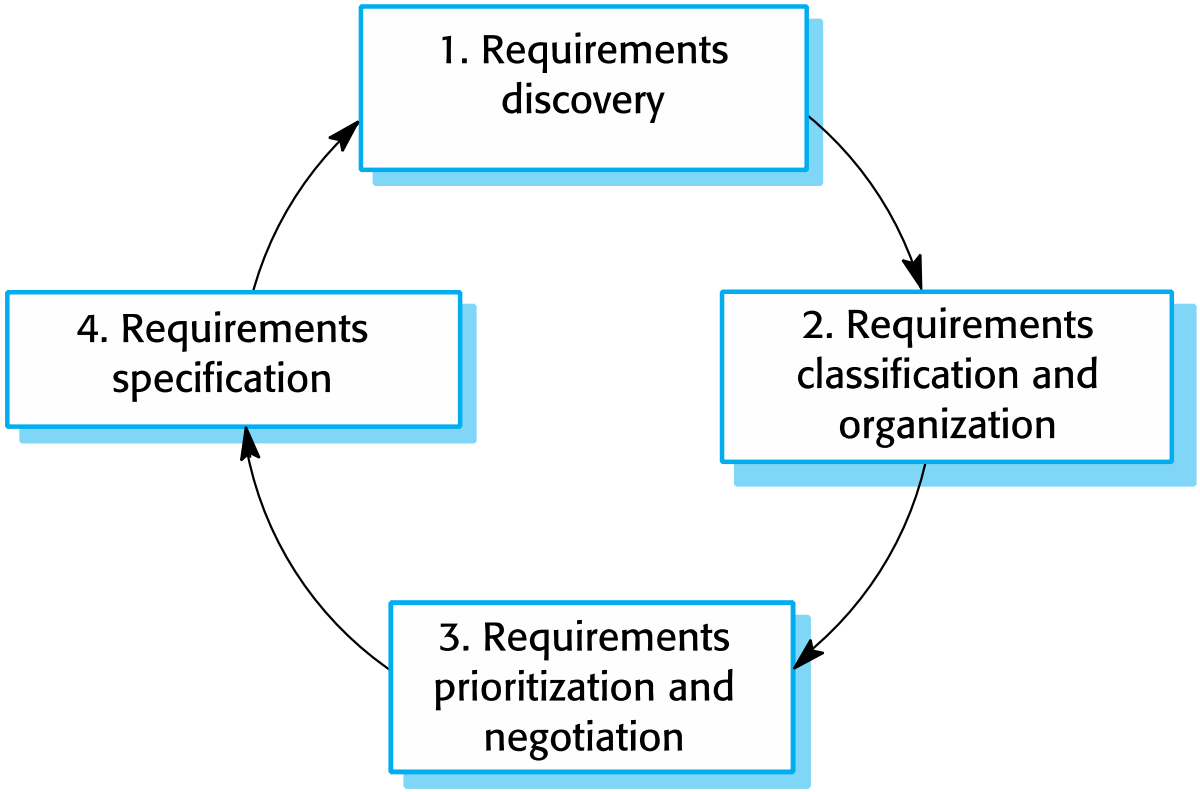
➢ **- - - - - -**

Importance Rating to rank the requirements

Problems of requirements analysis

- Stakeholders don't know what they really want.
- Stakeholders express requirements in their own terms.
- Different stakeholders may have conflicting requirements.
- Organizational and political factors may influence the system requirements.
- The requirements change during the analysis process. New stakeholders may emerge and the business environment may change.

Requirements elicitation(clarification)



Requirements elicitation

- **Requirements discovery**
  - Interacting with stakeholders to discover their requirements. Domain requirements are also discovered at this stage.
- **Requirements classification and organisation**
  - Groups related requirements and organises them into coherent clusters.
- **Prioritisation and negotiation**
  - Prioritising requirements and resolving requirements conflicts.
- **Requirements specification**
  - Requirements are documented and input into the next round of the spiral.

(2) Specifications

- A **specification** is a description of the product that is generated beforehand to guide the development of the product.
- It lays down the requirements in technical terms for the product to be designed.
- It usually converts the 'requirements' into Engineering terms.
- **Specifications** are what the product SHOULD DO.
- **Constraints** are the opposite of specifications and describe what the product CANNOT OR SHOULD NOT DO.
- They are usually defined in terms of **functions.**

Invest on the **most important specifications**

How to determine the most important one? QFD

Coffee Cup Example

Systematic Design

Requirements

Specifications

Function Tree

QFD

The requirements of a Coffee cup

- **Reasonable size for sufficient quantity of hot coffee with minimum possibility of accidental spilling.**
- **Carried by hand without burning the hand.**
- **Aesthetically pleasing.**

Specifications of a Coffee Cup (without measure)

•	**Provide**	**Storage for hot coffee**
•	**Provide**	**Stability when placed on the tray or table**
•	**Allow**	**Minimum heat loss**
•	**Allow**	**For easy holding and tipping**
•	**Protect**	**Hands from burning**
•	**Provide**	**Easily washable surfaces (smooth, non-sticky)**
•	**Provide**	**Aesthetically pleasing appearance**

e.g. Khalifa Tower
Specifications and Constraints!!!

Systematic Design

Requirements

Specifications

Function Tree

QFD

Requirements vs. Specifications

Requirements	Specifications
Wish list for the product EXPECT to do	What the product SHOULD DD What the product SHOULD NOT DO
From stakeholder (Customer, Designer, R&D, Political-Economical conditions)	From Designer
Not technical terms	Usually technical terms

There is many specifications. **How to itemize them?**

Function Tree

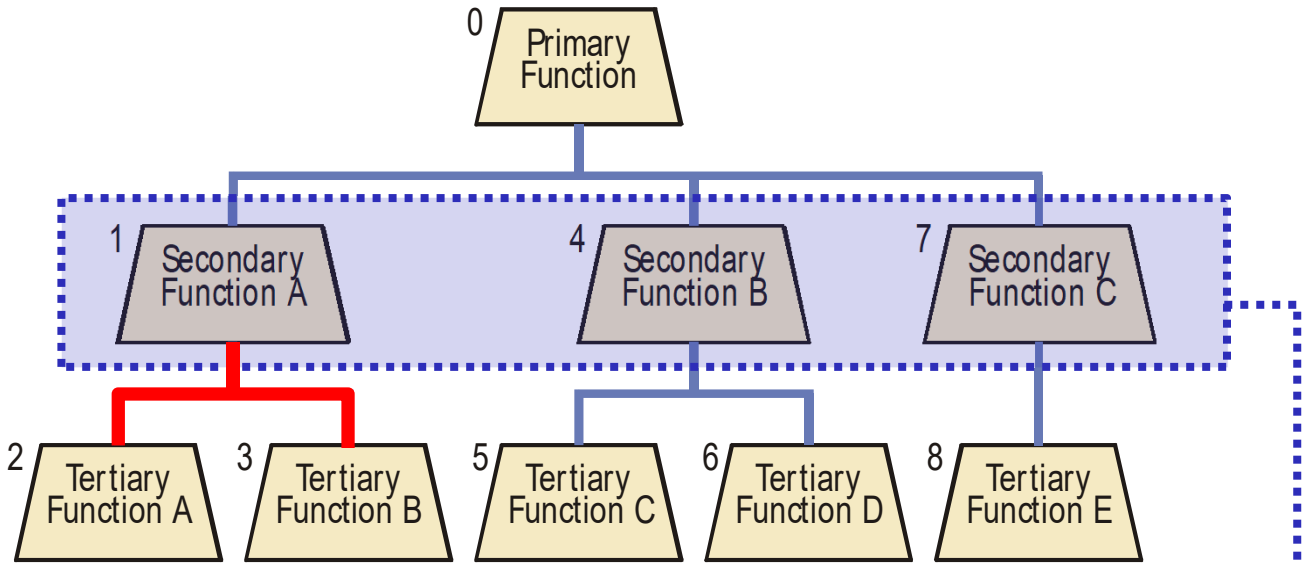
Systematising Functions To Function Tree

- **Specifications describe the functions performed by the product in order to meet the requirements of the customer. They usually have a measure attached to them. e.g. power source should last more than 36 hours of continuous use.**

- **Functions often have underlying law of physics or engineering.**

- **Systematising Functions means drawing relationships between individual functions that need to be performed by the object of analysis, and then showing those relationships on a chart (Function Tree).**

Function Tree



- ***Why we need Function Tree. To helps the designer:***
  1) ***To identify the high order functions (Level One).....***
  2) ***To identify the links among functions of the product.***
  3) ***To create alternatives to be designed or improved.***

Components of Function Description

- **Involves asking the question What is its action?**
- **Example of Functions**
  - **Glue A and B**
  - **Separate C and D**
- **Advantages:**
  - **Makes it possible to identify each function clearly.**
  - **Makes functions understandable to anyone.**
  - **Makes it easier to come up with ideas.**

Function Tree
e.g. Light Bulb

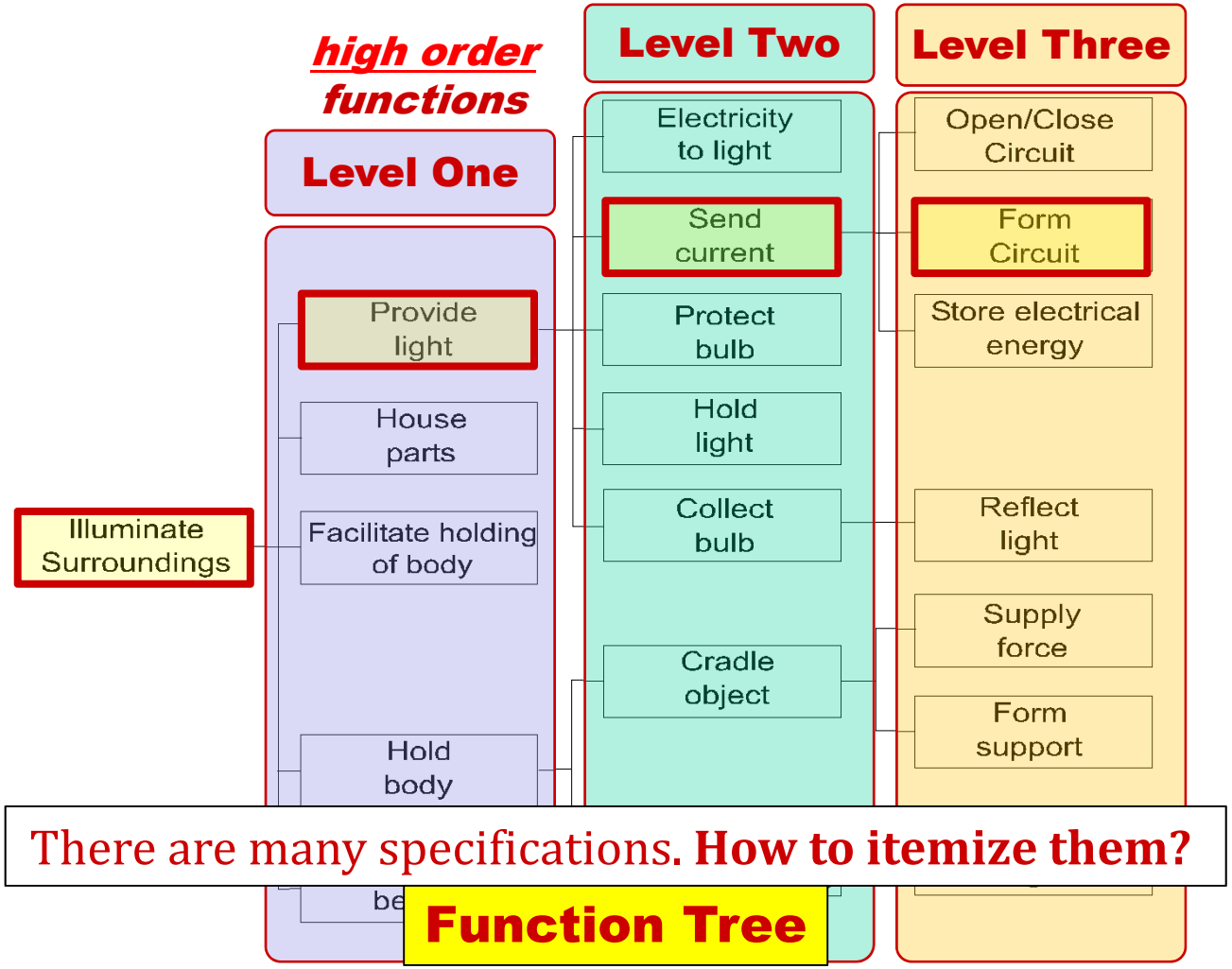
Systematic Design

Requirements

Specifications

Function Tree

QFD



Systematic Design Process - Steps

1) Requirements
2) Specifications
3) Conceptual Design
4) Embodiment Design
5) Detailed Design

QFD

What is a QFD?

QFD - Quality Function Deployment

Systematic Design

Requirements

Specifications

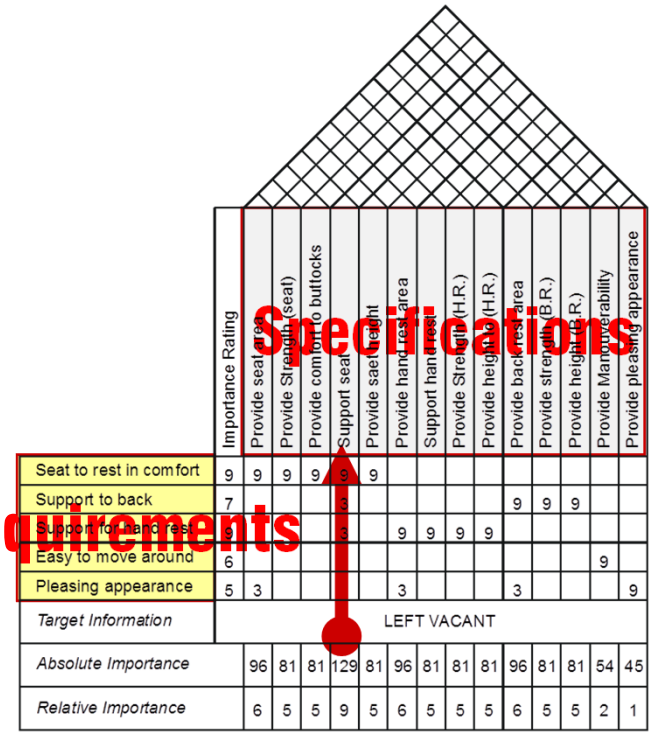
Function Tree

QFD

- Know as a house of quality which is drawn to measure requirements against specifications.

- This method allows each stage of the design process to be measured quantitatively on how well it is achieving the previous stage and hence how good the design is.

Prioritize Specifications



QFD - Quality Function Deployment

- QFD Around for Nearly 50 Years.
- Japanese professors Yoji Akao and Shigeru Mizuno developed it in the late 1960s.
- First implemented at Mitsubishi Heavy Industries, Kobe Shipyard in 1972
- QFD was first introduced to America and Europe in 1983.
- Toyota strongly influenced adoption of QFD in North America
  - Between 1977-1984 achieved a 61% reduction in product development cost, a 33% reduction in product development cycle, and virtual elimination of rust related warranty problems.
- American automotive manufacturers, Ford and GMC soon adopted it. Later, other American companies such as General Electric, IBM and AT&T.

QFD Chart 1 (House of Quality)

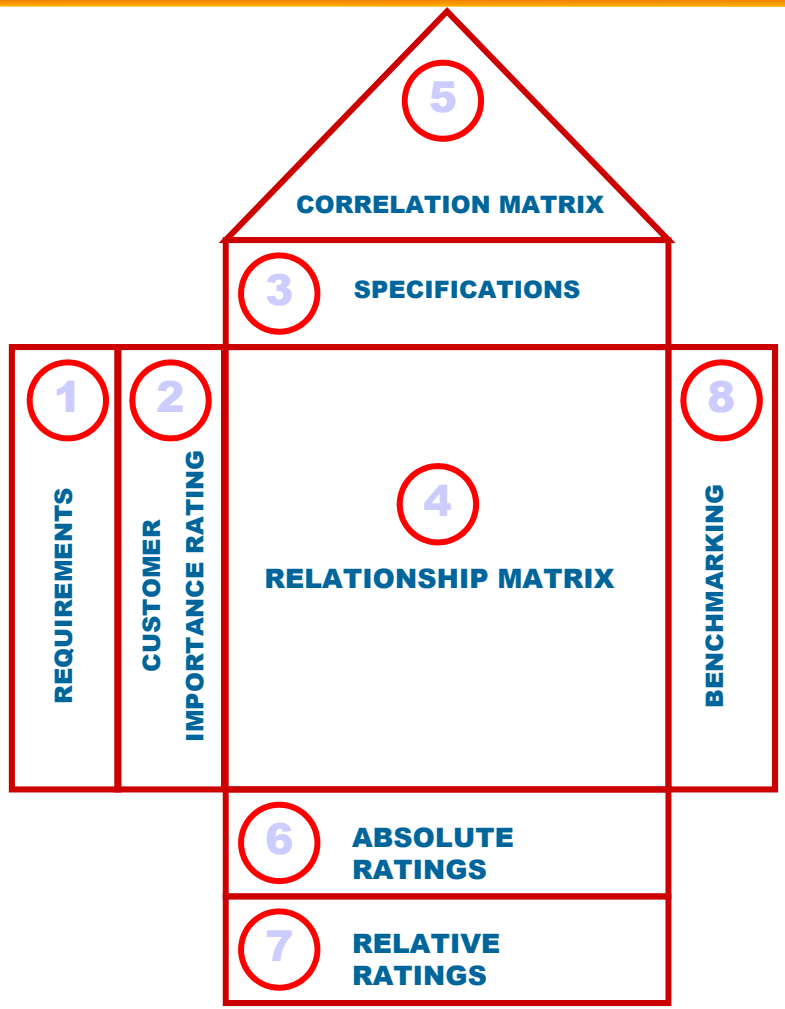
Systematic Design

Requirements

Specifications

Function Tree

QFD



Let us build the HOUSE

QFD Chart 1 (House of Quality)

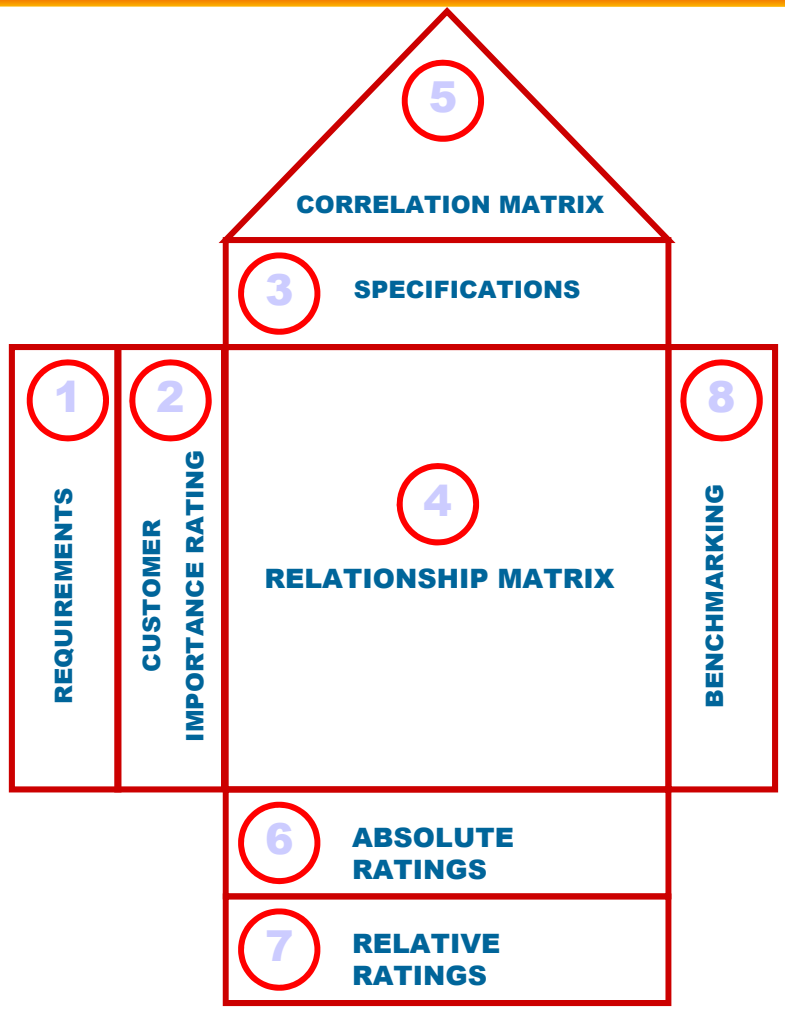
Systematic Design

Requirements

Specifications

Function Tree

QFD



Stage 1 Chart – Requirements & Specifications

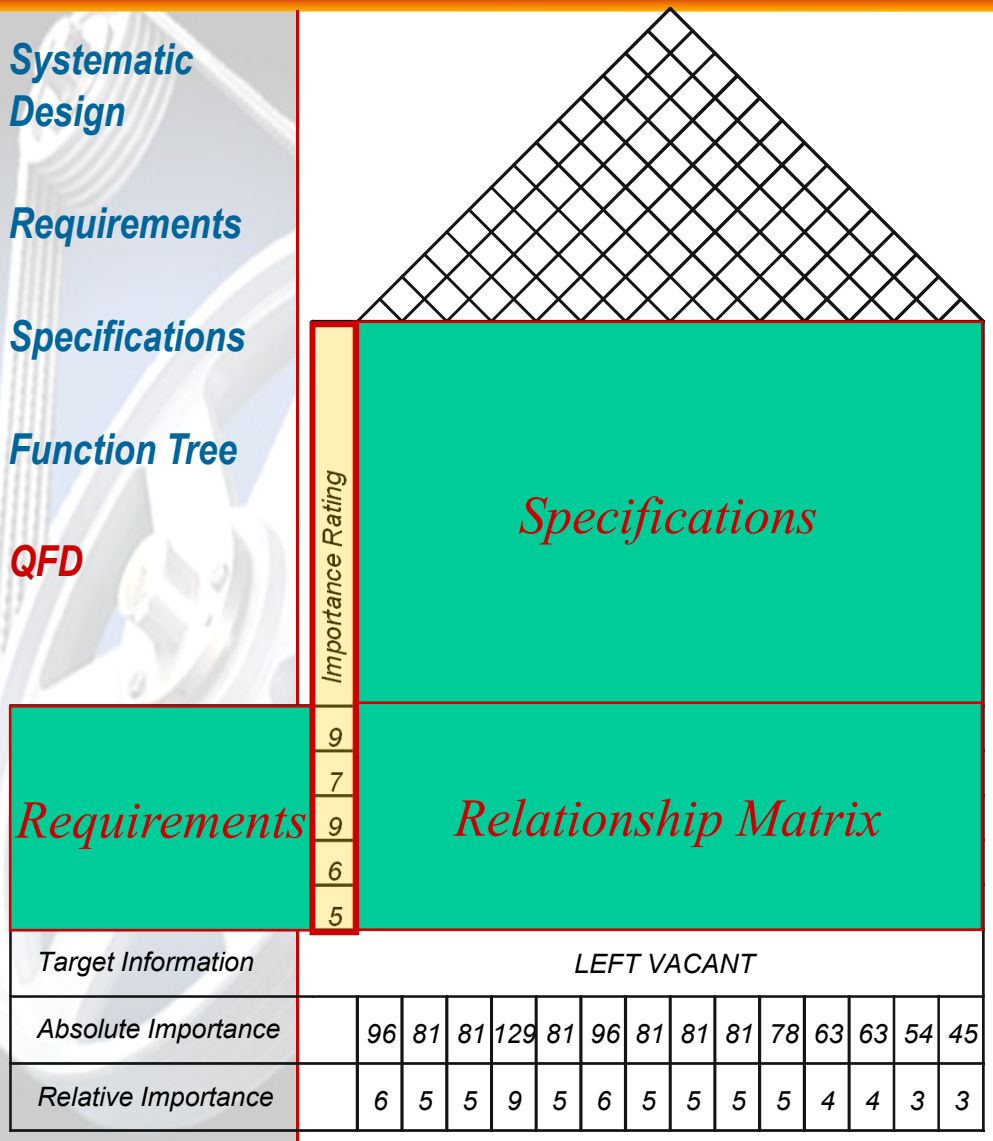
Systematic Design

Requirements

Specifications

Function Tree

QFD



- Each requirement is given a rating from 1 – 9 (9 is the most important)
- e.g. if safety is very important it can be rated 9 etc.
- Each specification is then rated in relationship to each requirement. This is to find out how well each specification addresses each requirement.
- If there is NO relationship, leave the grid space blank
- If there is a slight or weak correlation, rate as 1
- If there is medium correlation, rate as 3
- If there is high/strong correlation, rate as 9

Stage 1 Chart – Requirements & Specifications

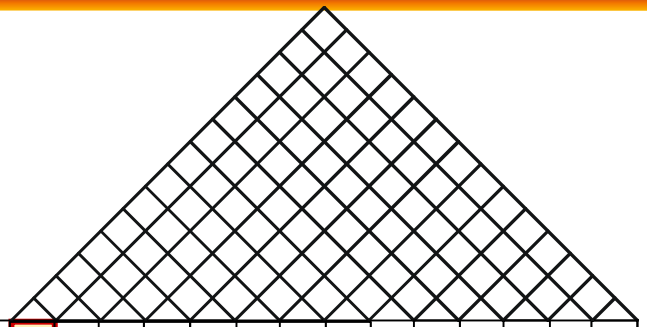
Systematic Design

Requirements

Specifications

Function Tree

QFD



	Importance Rating	Provide seat area	Provide Strength (seat)	Provide comfort to buttocks	Support seat	Provide saet height	Provide hand rest area	Support hand rest	Provide Strength (H.R.)	Provide height to (H.R.)	Provide back rest area	Provide strength (B.R.)	Provide height (B.R.)	Provide Manouverability	Provide pleasing appearance
Seat to rest in comfort	9	9	9	9	9	9									
Support to back	7				3						9	9	9		
Support for hand rest	9				3		9	9	9	9					
Easy to move around	6													9	
Pleasing appearance	5	3					3				3				9
Target Information	LEFT VACANT														
Absolute Importance		96	81	81	129	81	96	81	81	81	78	63	63	54	45
Relative Importance		6	5	5	9	5	6	5	5	5	5	4	4	3	3

- Multiply each specification rating by it's corresponding requirement importance rating and add up the column to get the absolute importance rating.
- Eg for the first specification (Provide seat area):
- (9 x 9) + (3 x 5) = 96
- The highest absolute rating becomes the benchmark value and is given a relative importance of 9. All other specifications are then weighted to this value.
- E.g. 129 is the maximum value - becomes 9
- For 1st specification 96/129 x 9 = 6 rounded down

9x45/129=3.14=3

Desk Chair QFD

194 is the max value and becomes 9

Specifications

Requirements	Importance rating (weight 1 to 9)	Provide support to seating area	Use of cushion	Allow changing elevation	Use leather cover	Provide arm support	Allow arm location modification	Provide back support
Comfortable seat	9	3	9	9	3	3	3	9
Support to back	7		3	3	3			9
Change hight	9	3		9		1		
Pleasant look	6			1	9	3	1	3
Arm support	5			1		9	9	
Absolute rating		54	102	194	102	99	78	162
Relative rating		2	4	9	4	4	3	7

162x9/194=7.5=7

Desk Chair QFD

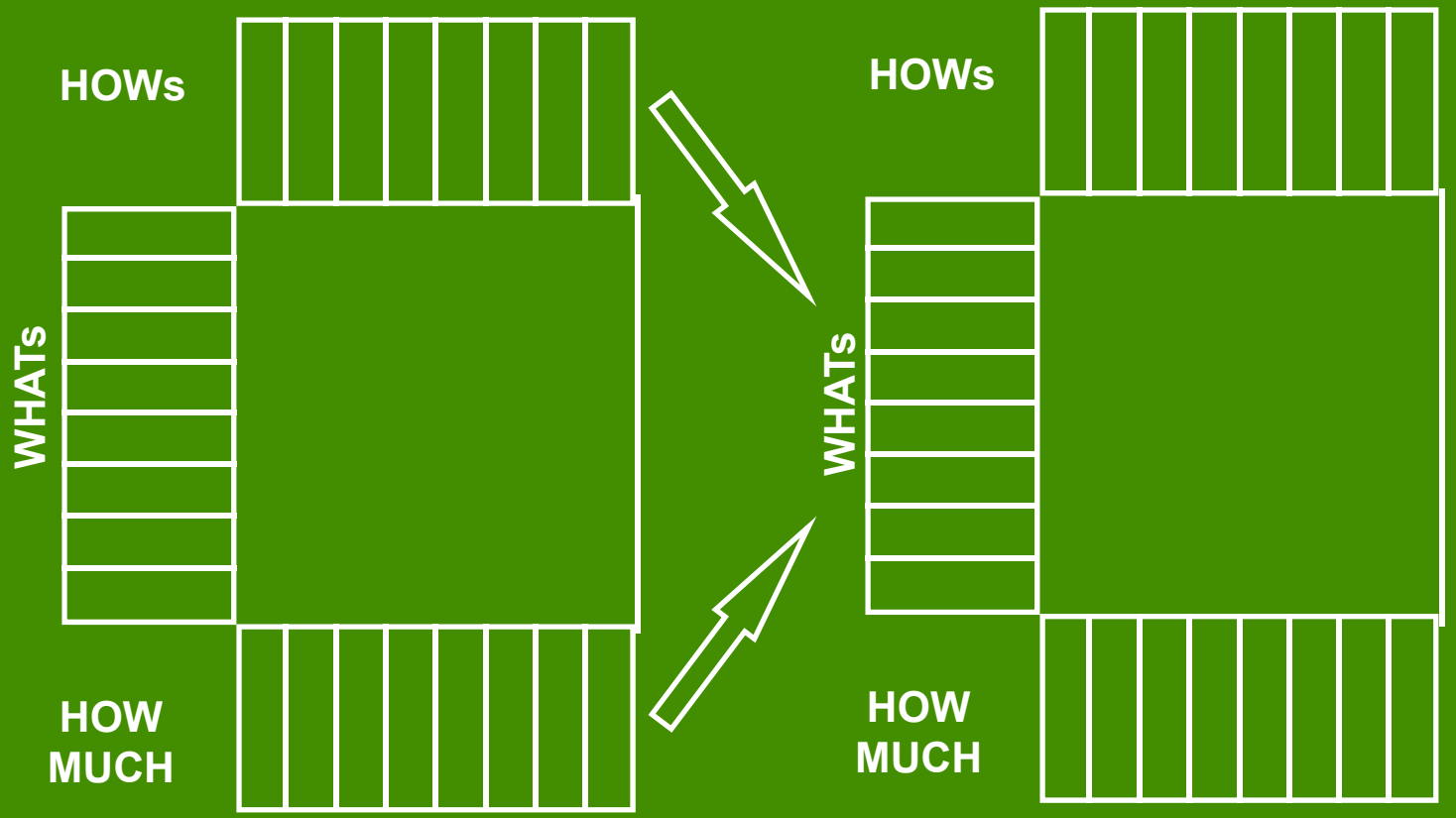
Specifications

Requirements

	Importance rating(weight 1 to 9)	Block UV radiation	Use none scratchable surfaces	Allow different color & shapes	Use nose pads	Provide strong support frame	Allow foldable frame	Provide ears sleeve support
Safe	9	9	9		3	9	1	1
Easy to clean	5		3	1			1	
Convenient & easy to store	8		1		9	1	9	3
Pleasant look	9		3	9	3		3	3
Easy to ware	6			1			3	9
Durable	6	3	9		1	9	9	
Absolute rating		99	185	92	132	143	185	114
Relative rating		4	9	4	6	6	9	5

114x9/185=5.4=5

QFD Process



QFD Charts

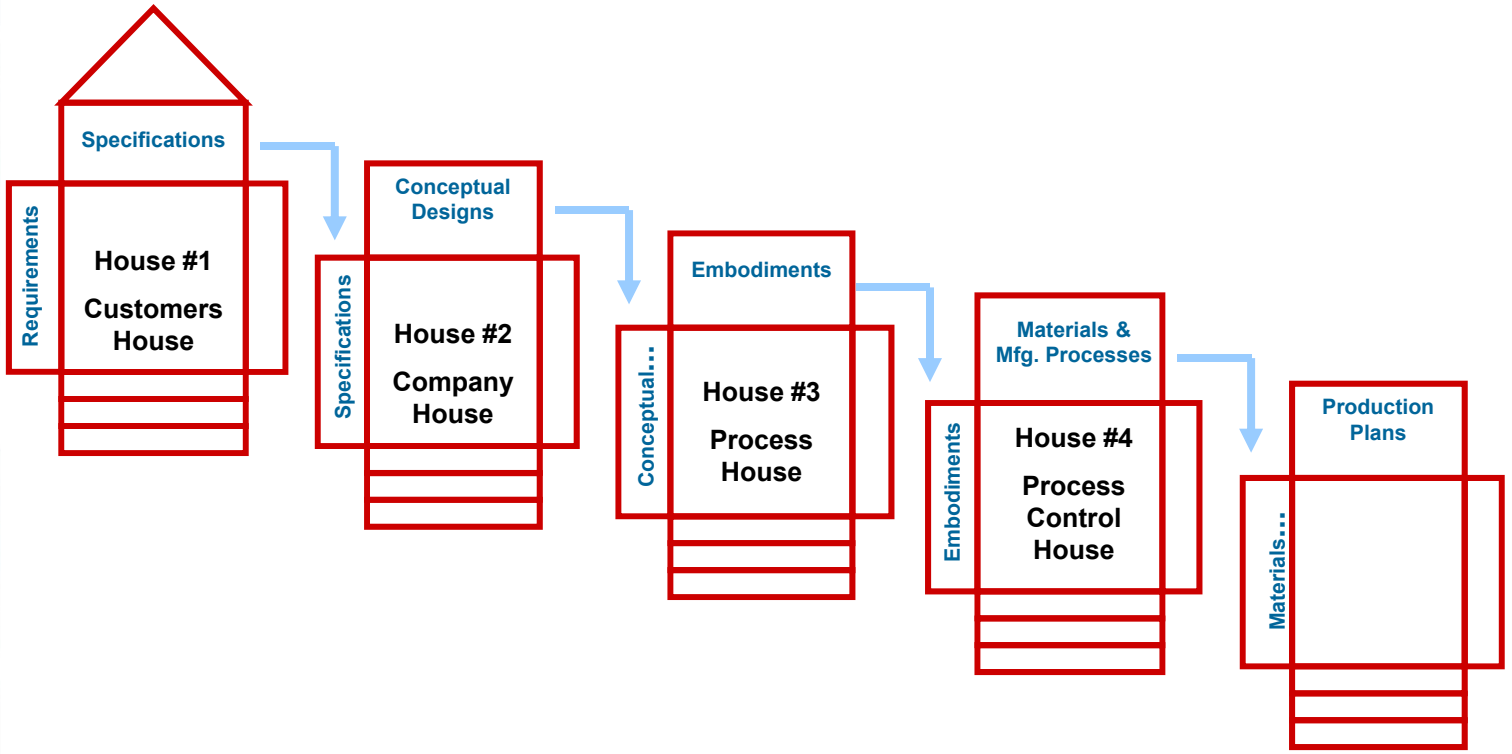
Systematic Design

Requirements

Specifications

Function Tree

QFD



Benefits Of Adopting QFD

- **Reduced time to market**
- **Reduction in design changes**
- **Decreased design and manufacturing costs**
- **Improved quality**
- **Increased customer satisfaction**

Ethics & the early stages of design

- Try to identify what ethical issues could arise during the requirements and specifications stage of the design process.
- Discuss ethical issues related to the QFD.
- In your groups, identify and list these down.

Ethics & the early stages of design

Ethics Case Study: An engineering working on designing an automobile. The engineer used QFD method to evaluate the product and come up with the most important specification in design. He found out that "providing robust engine" ranked 1st , and "Allow smooth transmission" ranked 2nd during QFD study. The engineer works for transmission department and have been asked by the CEO (chief executive officer)of the company to modify the numbers so the QFD lead to redesign of the of transmission.

1) **What is the ethical dilemma to the engineer and the CEO?**
2) **What the claim should be for the engineer and the CEO?**
3) **What moral frameworks and NSPE code that support your answer.**

Further Reading and References

- http://www.clemson.edu/ces/cedar/images/6/6e/Systematic_Design_Process.pdf
- http://www.sciencebuddies.org/engineering-design-process/engineering-design-process-steps.shtml#theengineeringdesignprocess
- **For QFD:** http://www.isixsigma.com/tools-templates/qfd-house-of-quality/quality-function-deployment-competitive-advantage/
- http://en.wikipedia.org/wiki/Engineering_design_process

Conclusions

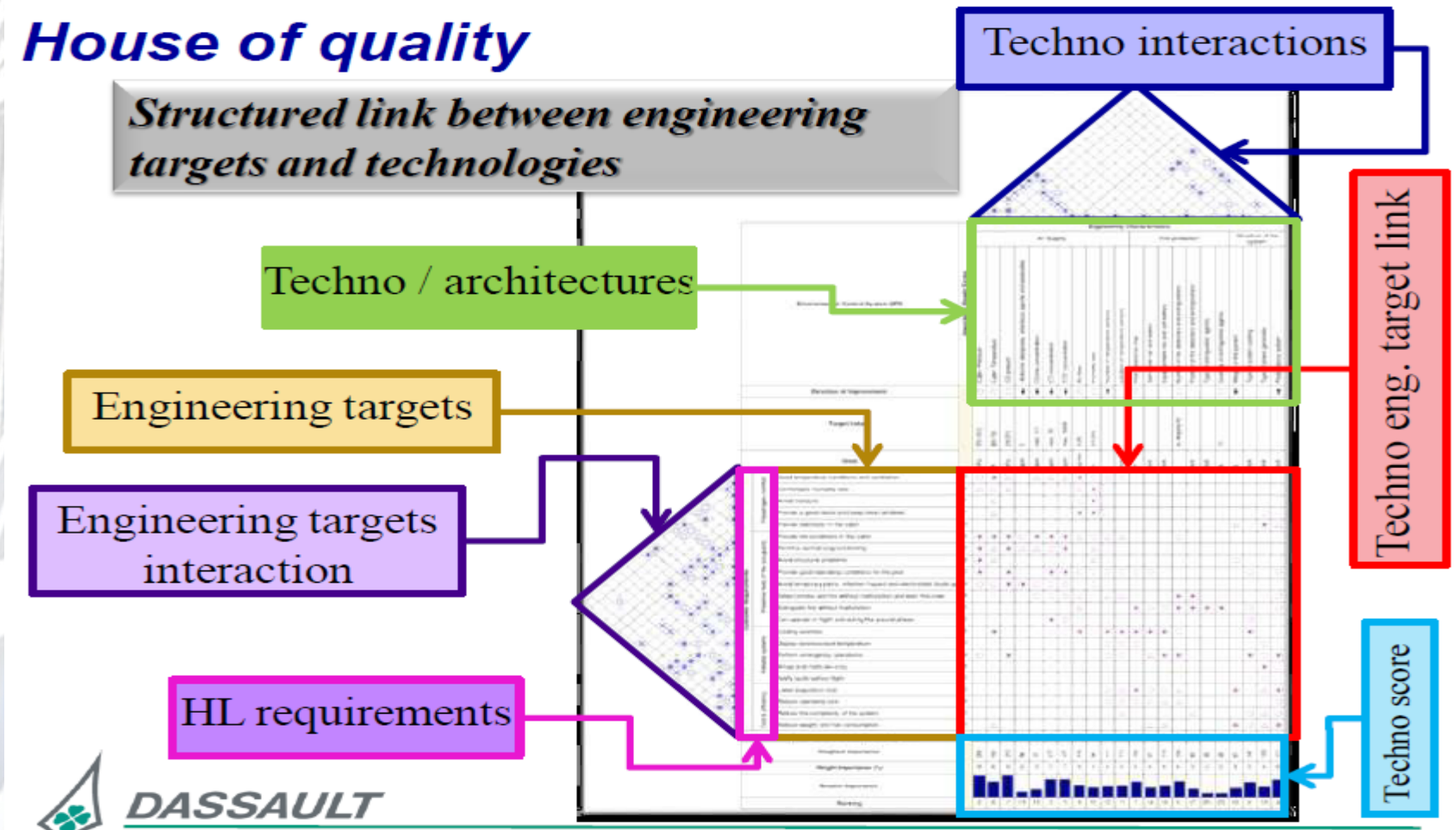
You should now be able to:

- **Understand the importance and challenges of design**
- **Appreciate the difference between conventional and systematic design**
- **Describe the systematic design process**
- **Identify all types of Customers and their requirements**
- **Identify engineering specifications and constraints**
- **Create a stage 1 'QFD' Chart and calculate the importance ratings**
- **Understand that the design process is there to help you but it will not make the design for you.**
- **Your problem solving skills and creativity are STILL NEEDED!**

QFD Summary

- Orderly Way Of Obtaining Information & Presenting It
- Shorter Product Development Cycle
- Considerably Reduced Start-Up Costs
- Fewer Engineering Changes
- Reduced Chance Of Oversights During Design Process
- Environment Of Teamwork
- Consensus Decisions
- Preserves Everything In Writing

Advanced Example



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