Formulating Design Problems

- Designing a high-performance motorcycle
- What is a “design problem?”
- What is the “solution” to a design problem?
- How do we solve a design problem?
- Steps in formulating
- Customer & company requirements
- Engineering Design Specifications
- Gaining consensus
- Quality products
- QFD/House of Quality
- Summary

What is a design problem?

- An opportunity to make and sell a new product
- Need to fix an existing product
- Make and sell a variant of an older design

Customer or company requirements-------”Function”

Example: Improve an existing motorcycle

What info would help us understand this design problem?

How quickly should the cycle accelerate to 60 mph?

What should the top speed be?

Is fuel consumption less important than acceleration?

What riding comforts are expected?

Is an electric starter desired?

Will the customer tolerate a liquid cooling system?

Will customer care about aesthetics?

High-Performance Motorcycle Design

Other information?

What is the target cost of manufacture?

Which is more preferred: low-end torque or high-end speed?

What is the anticipated production run quantity?

What types of instruments are preferred, digital and or analog?

What are the desired service intervals?

What is the solution to a design problem?

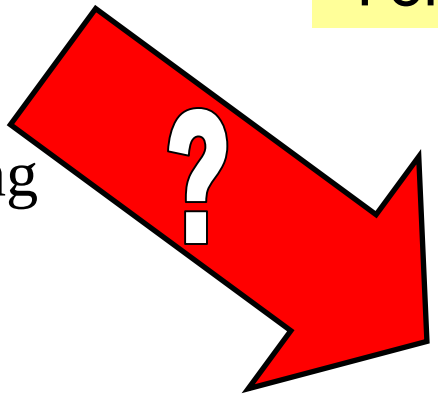
- Set of drawings
- Package of predicted performance calculations
- Test reports on prototypes
- Manufacturing specifications
- Bill of materials
- Estimates of sales revenues, costs and profit

i.e.… A “design” ready for manufacture ------- “Form”

How do we solve a design problem?

Design problem
(function, customer need)

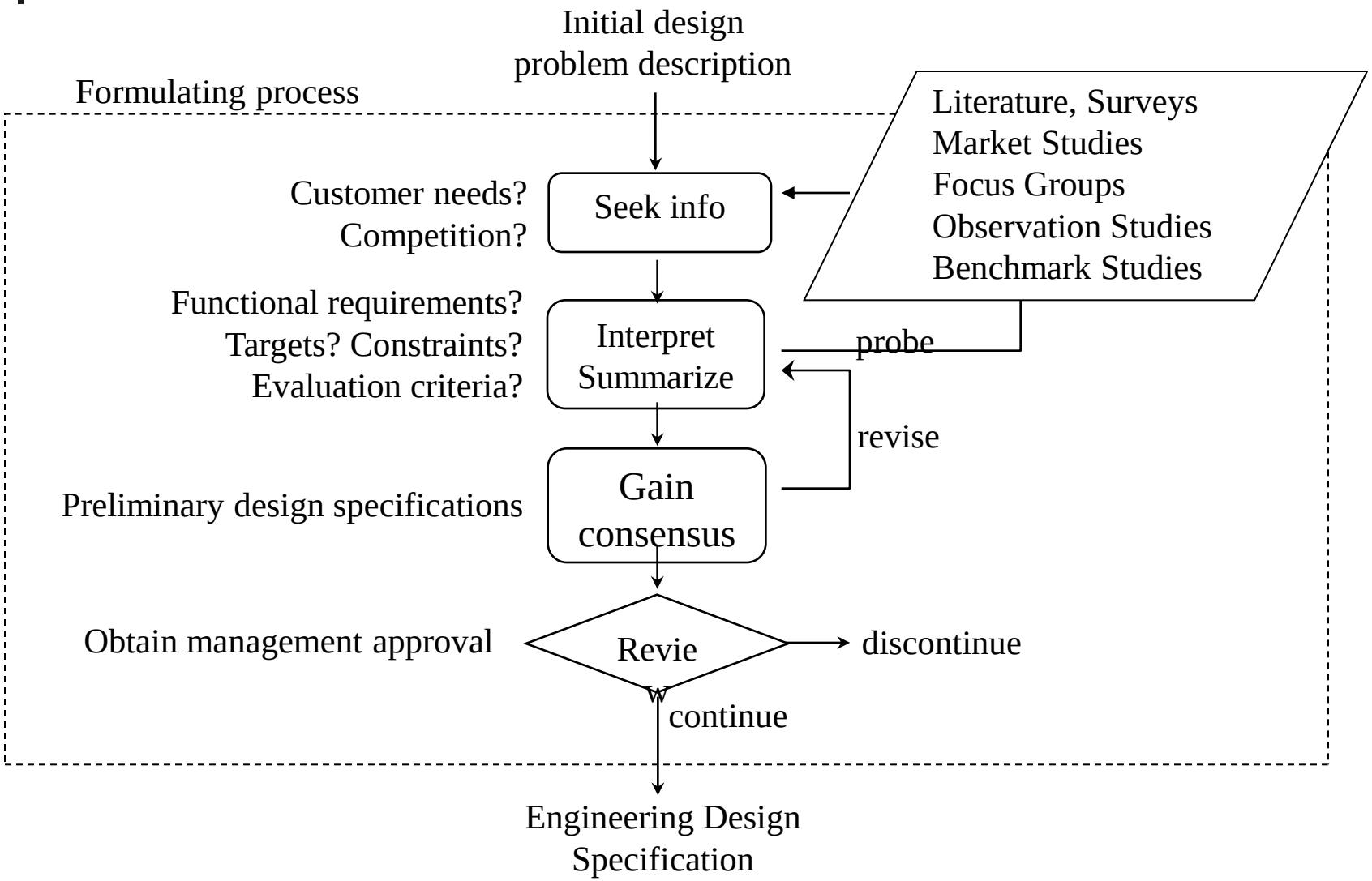
"Formulate" first!



Decision making processes and activities

Solution
(form, manufacturable product design)

Decisions & info. flow during formulation



Steps in formulating a design problem

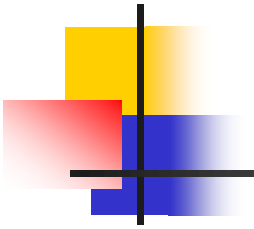
1. obtain a detailed understanding of the design problem

2. document our understanding in an EDS

3. choose a solution strategy

4. develop a project plan (scope of work, budget and schedule)

5. establish a consensus among team members & management

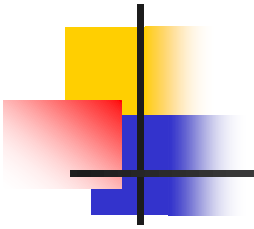


Step 1. Obtain a detailed understanding

Initially, we search for information relating to ….

Customer Requirements

Company Requirements



Motorcycle design: Customer requirements

Function / performance:

- start engine quickly,
- support rider(s) comfortably, …

Operating

- road shock
- wet, cold, high altitude

Other

- maintenance intervals
- fuel economy

Information sources

- Surveys
- Market Studies
- Literature
- Focus Groups
- Observation Studies
- Benchmark Studies

Motorcycle design: Company requirements

Marketing:

need product in 24 months,

sale price competitive

Manufacturing

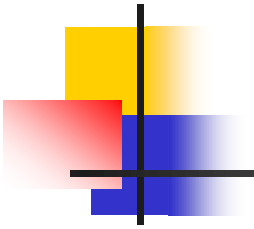
5,000 units per year

use existing manufacturing plant

Financial

$300,000 R&D budget

minimum 20% ROI 20% B/T



Must all requirements be satisfied?

Requirements can be separated into:

"must haves," and

"desirable."

"must have" requirements = become design constraints

"desirable" requirements = weighted by importance

Motorcycle – Importance of each requirement

Customer importance weights by sub-function

Sub-function	Weight
start engine quickly	15 %
support rider(s) comfortably	10 %
transport rider(s) fast	50 %
steer bike easy	20 %
absorb road shocks	5 %
total	100 %

Translating customer/company requirements

How will we know when we have designed a product that satisfies the customer?

e.g.

Customer says, "I want a fast motorcycle."

What does "fast" mean?

120 mph top speed?

32 ft/sec/sec acceleration?

4000 Hz engine frequency?

Engineers need objective … i.e. quantitative targets.

Engineering characteristics, units, and limits

Sub-function	**Engineering Characteristic**	**Units**	**Limits**
start engine quickly	cranking time	seconds	$\leq$ 6 secs
support rider(s) comfortably	cushion compression	inches	
transport rider(s) fast	acceleration top speed 0-60 mph	feet/ sec^2 mph/kph seconds	$\geq$ 32 ft/s^2 $\geq$ 90 mph $\leq$ 6 secs
steer bike easy	steering torque turning radius	pound-ft feet	
Absorb road shocks	suspension travel	inches	> 5 in.

Engineering characteristics

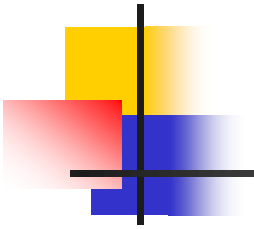
…are quantities that measure the "performance" of a candidate design with respect to specific customer required functions.

Satisfaction values based on the amount of customer satisfaction

Amount of satisfaction	**Value**
Most satisfied	1.0
Very satisfied	0.9
Moderately satisfied	0.8
Somewhat satisfied	0.6
Hardly satisfied	0.3
Not satisfied	0.0

qualitative

quantitative



Step 2. Document our understanding

1. obtain a detailed understanding of the design problem,

2. document our understanding in an EDS

3. choose a solution strategy

4. develop a project plan (scope of work, budget and schedule)

5. establish a consensus among team members & management

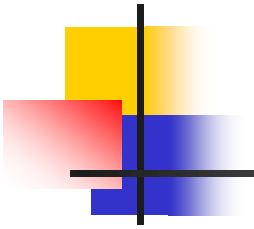
Engineering Design Specification template

Cover page (title, stakeholders, and date)
Introduction
- Simple description of design problem
- (Un)intended purpose(s) or use(s) of the product
- Special features

Customer and Company requirements
- Engineering characteristics, units, limits
- Customer satisfaction

Constraints
Appendices

(See coffee maker example)



Step 3. Choose a strategy

Formulating a design problem

1. obtain a detailed understanding of the design problem,
2. document our understanding in an EDS
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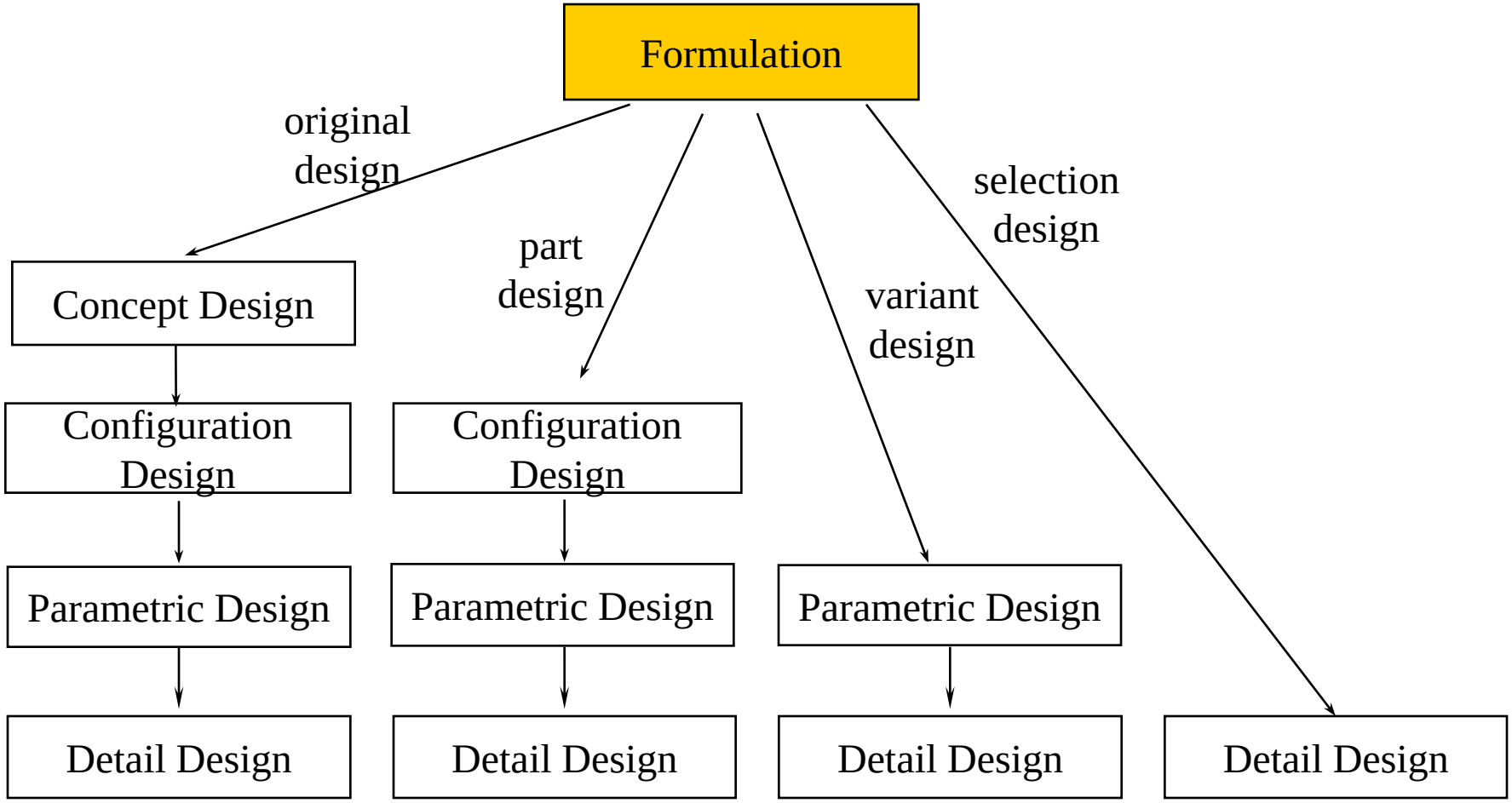
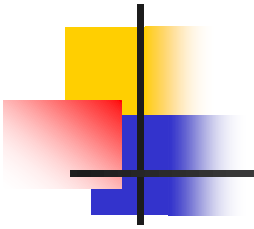
5. establish a consensus among team members & management

Choosing a strategy

1. list possible alternative solution strategies, for example:
   discontinue product, variant design, original design, etc
2. estimate the expected benefits and the costs of each alternative
3. assess the risk of each alternative strategy
4. establish criteria to evaluate alternatives
   (e.g. benefits/costs, risk, Return on investment)
5. evaluate the alternatives
6. select the best alternative

Formulation initiates all solution strategies.





Step 4. Project Planning

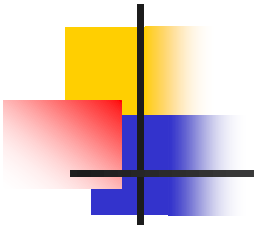
1. obtain a detailed understanding of the design problem,

2. document our understanding in an EDS

3. choose a solution strategy

4. develop a project plan (chapter 14)

5. establish a consensus among team members & management



Step 5. Establish a consensus of opinion

Formulating a design problem

1. obtain a detailed understanding of the design problem,

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3. choose a solution strategy

4. develop a project plan

5. establish a consensus among team members & management

Getting consensus is "built-in"

If your team members follow the previous five steps to a sound formulation, they will:

1. Have a common understanding of the "problem,"
2. Understand WHY,
3. Know WHAT has to be done and WHEN, and
4. Commit to WHO & HOW MUCH

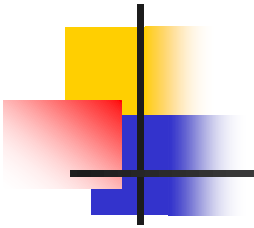
Other (advanced) formulation methods?

Yes, the best one being…

The house of quality for product planning

… part of Quality Function Deployment (QFD)

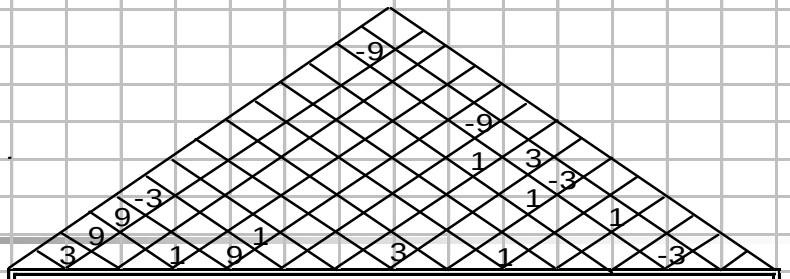
1. What is the house of quality?
2. How does it help us to formulate a design problem?



How can ensure that we'll design… a quality product?

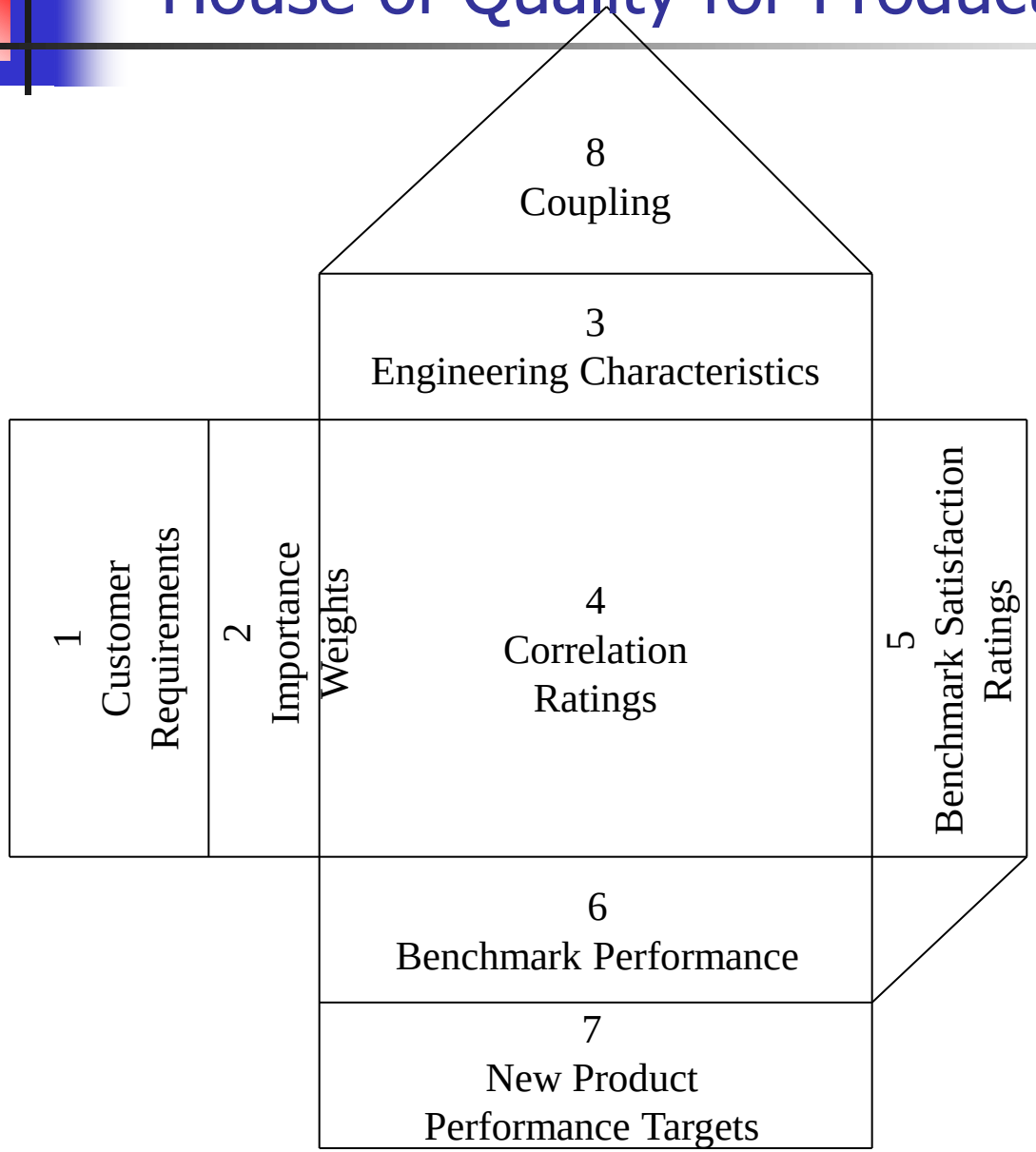
What is a quality product?

Example HoQ



	Customer Requirements	Importance wt.	Engineering Characteristics (units)													Customer Satisfaction Rating (0.00 - 1.00)		
			slides (yes/no)	friction factor	start switch force (lbf)	force to sharpen (lbf)	hold force required (lbf)	grasp torque (in-lbf)	shavings storeage (cu.in.)	no. steps to empty	120 VAC (yes/no)	cord length (ft)	point cone angle (degrees)	no. hands to operate	weight (oz)	point roughness (micro in.)			
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	CP	A	B
1	doesn't slide when using	0.10	9	3	3	3	9	1						3	3			0.9	
2	needs little insertion force	0.05			9	9												0.8	
3	requires little insertion torque	0.05						9										0.9	
4	operates when pencil is inserted	0.15			9									9				1.0	
5	collects pencils shavings well	0.05							9	1								1.0	
6	empties shavings easily	0.20							3	9		1		3	-3			0.6	
7	plugs into wall socket easily	0.05									9							0.9	
8	cord is long enough	0.05										9						0.8	
9	grinds pencil to sharp point	0.20											9			3		0.7	
10	needs only one hand two operat	0.10		3										9	3			0.8	
	Total Importance	1.00																	
	Performance current product(CP)																		
	competitior A: Model #25		N	1	0	0	0	0	2	6	Y	6	20	1	20	6			
	competitor B																		
	New Product Targets		N	1	0	0	0	0	3	4	Y	6	18	1	18	5			

House of Quality for Product Planning



Group method

Encourages discussion

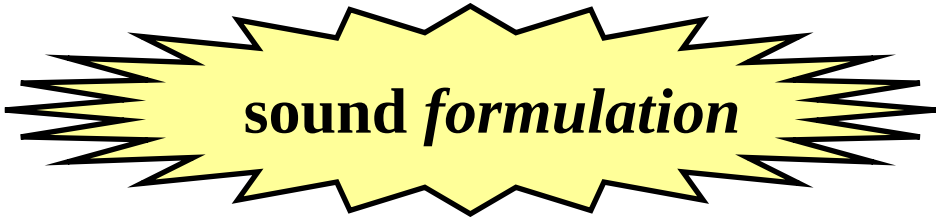
Forces agreement between team members

Structures information

Summary

- Necessary decisions and information flow during formulation
- Five steps to formulate a design problem
- Customer & company requirements
- Engineering Design Specifications
- Gaining consensus
- House of Quality for product planning
- Quality Function Deployment

Secret for a successful solution is a …



Summary

- Products and process plants have an anatomy of components
- Components include parts & subassemblies
- Process plant components include systems and equipments
- Components can be standard or special purpose
- Component decomposition diagrams are very useful
- Types of design include: original, variant, selection, adaptive, redesign
- Tinkering is really not engineering design