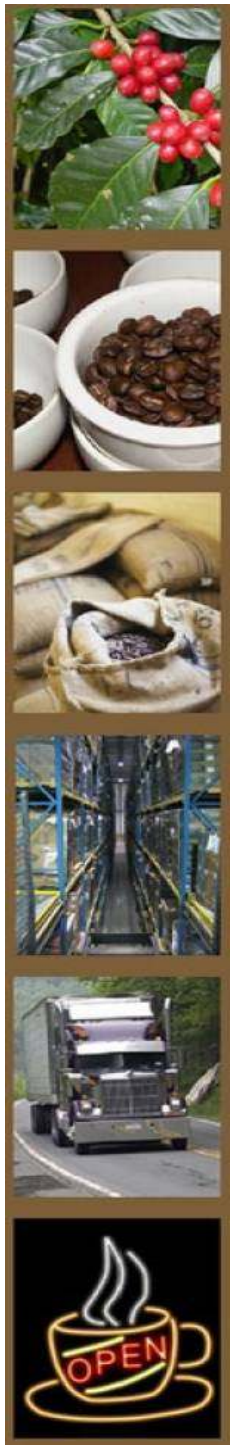
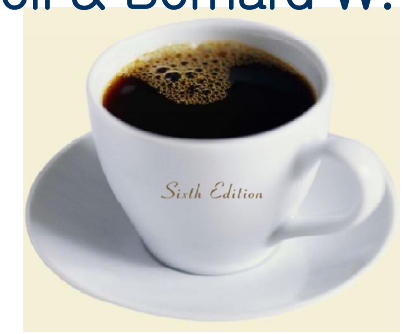


Chapter 4

Product Design

Operations Management - 6th Edition

Roberta Russell & Bernard W. Taylor, III



Beni Asllani
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Lecture Outline

- Design Process
- Concurrent Design
- Technology in Design
- Design Reviews
- Design for Environment
- Design for Robustness
- Quality Function Deployment

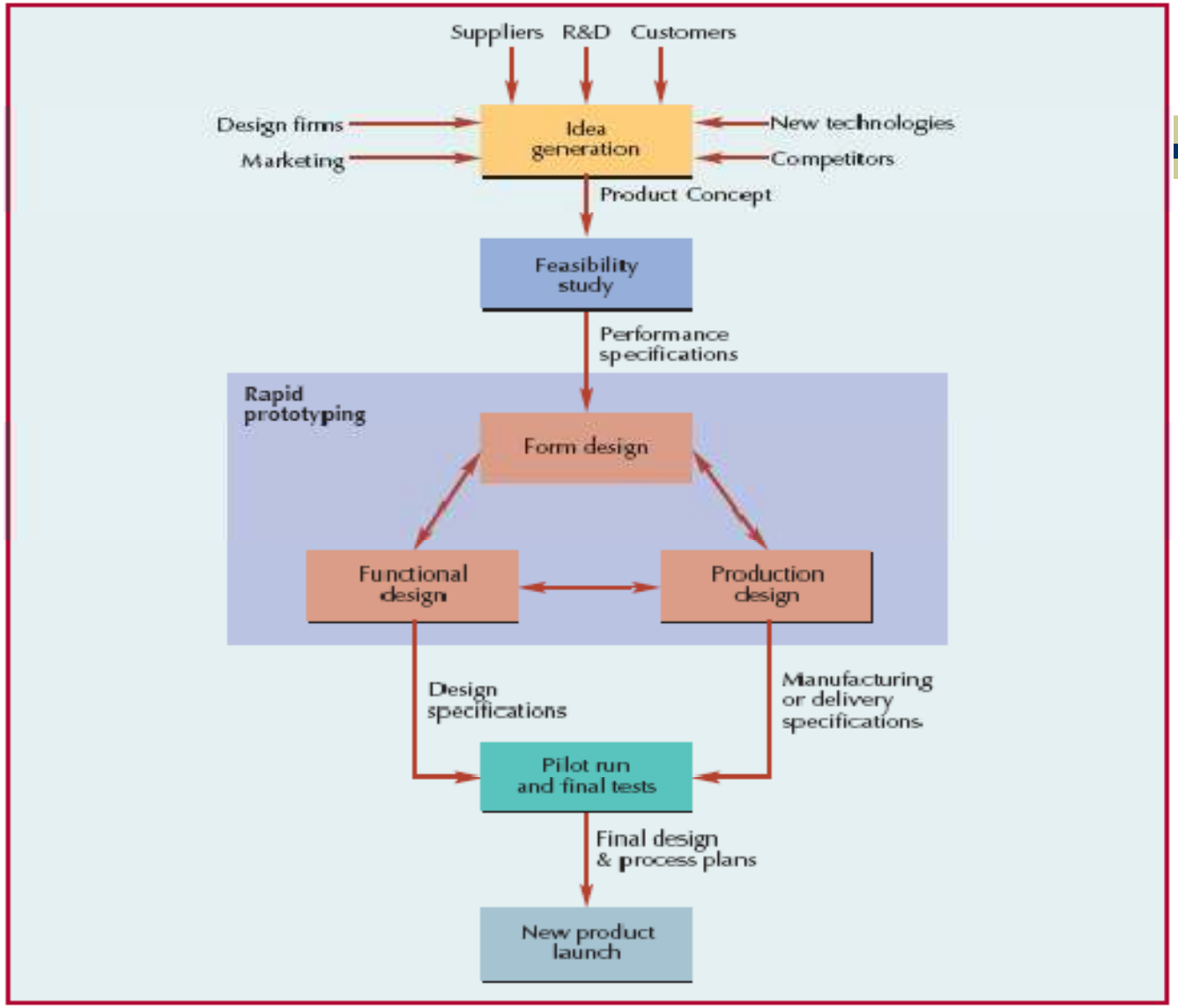
Design Process

- Effective design can provide a competitive edge
  - matches product or service characteristics with customer requirements
  - ensures that customer requirements are met in the simplest and least costly manner
  - reduces time required to design a new product or service
  - minimizes revisions necessary to make a design workable

Design Process (cont.)

- Product design
  - defines appearance of product
  - sets standards for performance
  - specifies which materials are to be used
  - determines dimensions and tolerances

Design Process (cont.)



Idea Generation

- Company's own R&D department
- Customer complaints or suggestions
- Marketing research
- Suppliers
- Salespersons in the field
- Factory workers
- New technological developments
- Competitors

Idea Generation (cont.)

- Perceptual Maps
  - Visual comparison of customer perceptions
- Benchmarking
  - Comparing product/process against best-in-class
- Reverse engineering
  - Dismantling competitor's product to improve your own product

Perceptual Map of Breakfast Cereals

Feasibility Study

- Market analysis
- Economic analysis
- Technical/strategic analyses
- Performance specifications

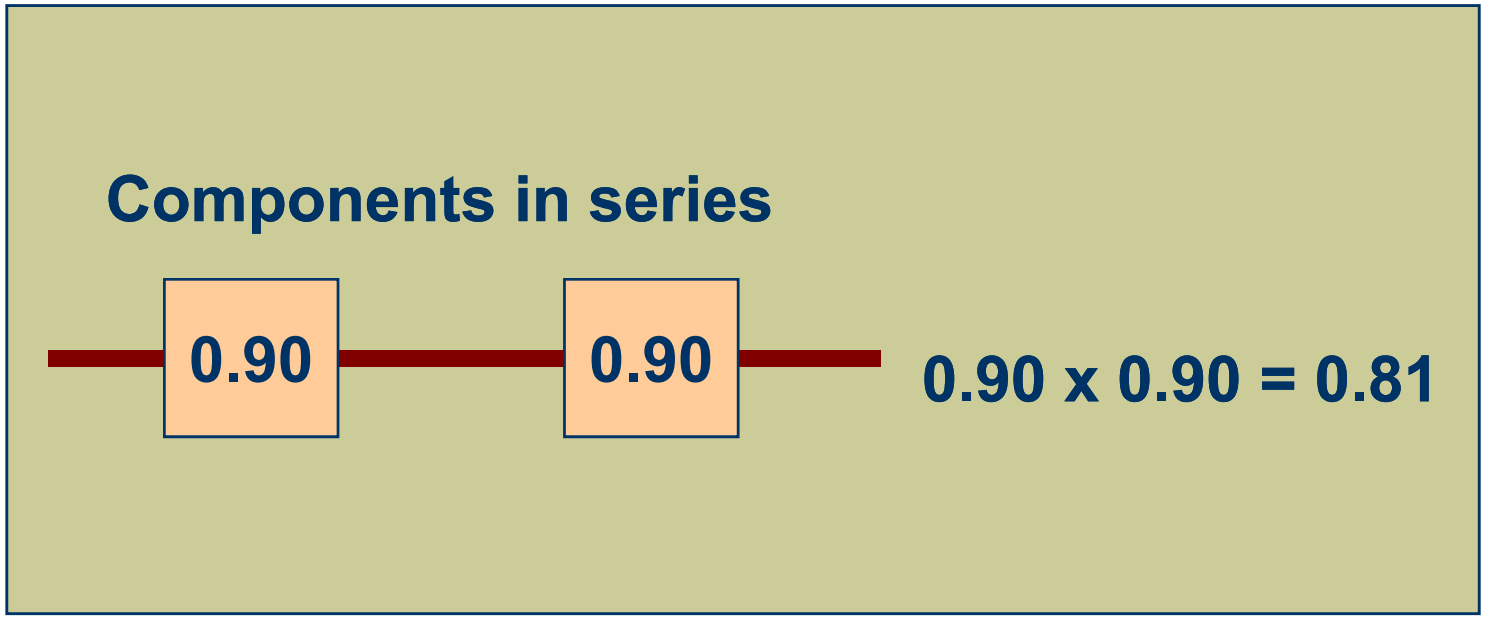
Rapid Prototyping

- testing and revising a preliminary design model
- Build a prototype
  - form design
  - functional design
  - production design
- Test prototype
- Revise design
- Retest

Form and Functional Design

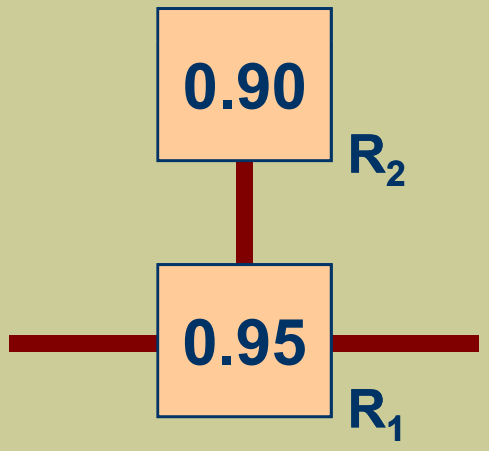
- Form Design
  - how product will look?
- Functional Design
  - how product will perform?
    - reliability
    - maintainability
    - usability

Computing Reliability



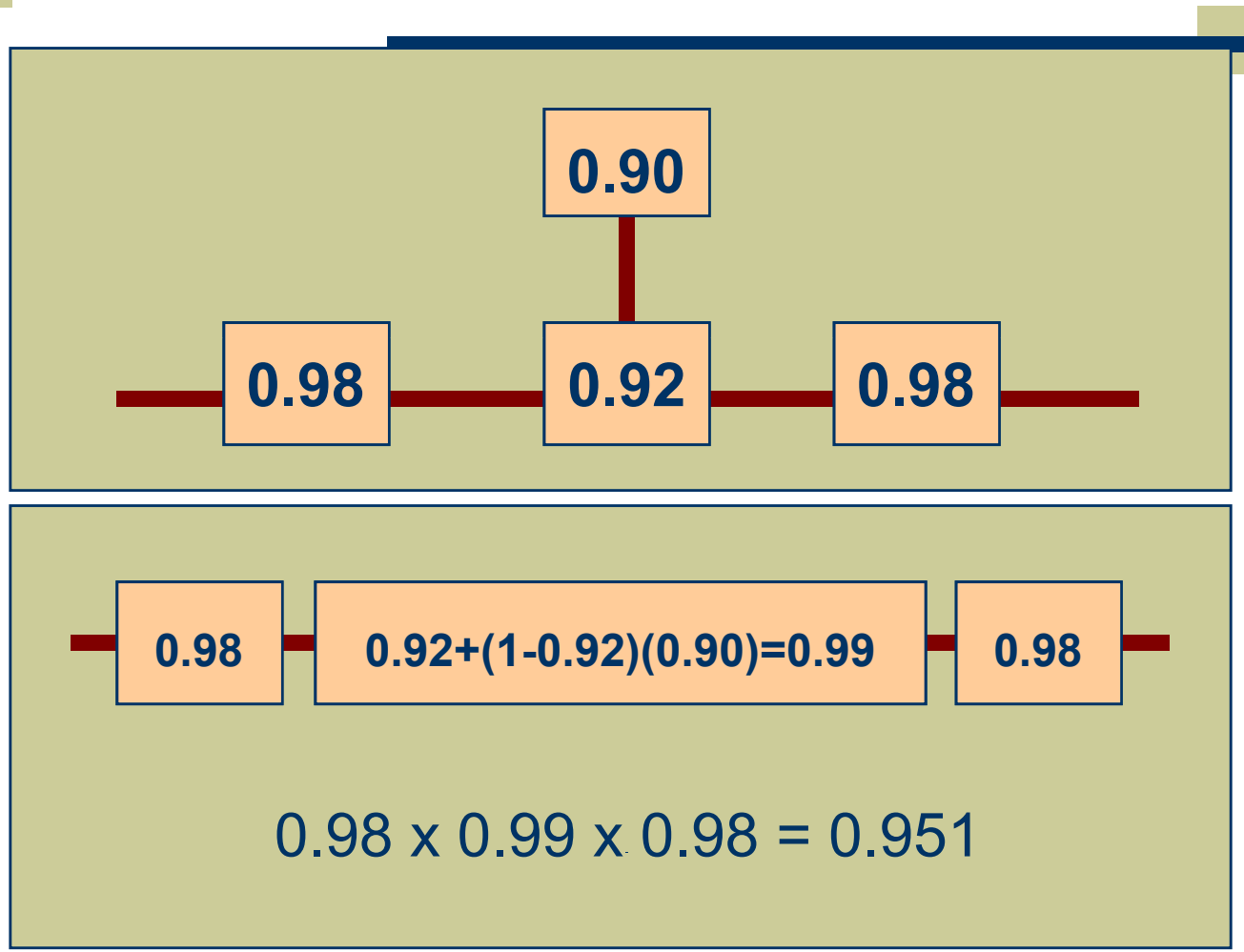
Computing Reliability (cont.)

Components in parallel



$$0.95 + 0.90(1-0.95) = 0.995$$

System Reliability



System Availability (SA)

$$SA = \frac{MTBF}{MTBF + MTTR}$$

where:
MTBF = mean time between failures
MTTR = mean time to repair

System Availability (cont.)

PROVIDER	MTBF (HR)	MTTR (HR)
A	60	4.0
B	36	2.0
C	24	1.0

$SA_A = 60 / (60 + 4) = .9375$ or 94%

$SA_B = 36 / (36 + 2) = .9473$ or 95%

$SA_C = 24 / (24 + 1) = .96$ or 96%

Usability

- Ease of use of a product or service
  - ease of learning
  - ease of use
  - ease of remembering how to use
  - frequency and severity of errors
  - user satisfaction with experience

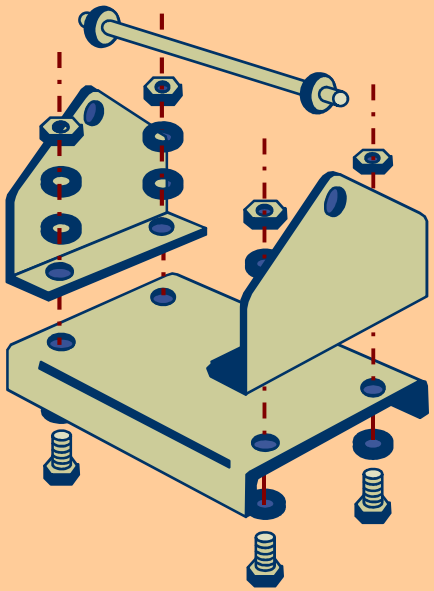
Production Design

- How the product will be made
  - Simplification
    - reducing number of parts, assemblies, or options in a product
  - Standardization
    - using commonly available and interchangeable parts
  - Modular Design
    - combining standardized building blocks, or modules, to create unique finished products
  - Design for Manufacture (DFM)
    - Designing a product so that it can be produced easily and economically

Design Simplification

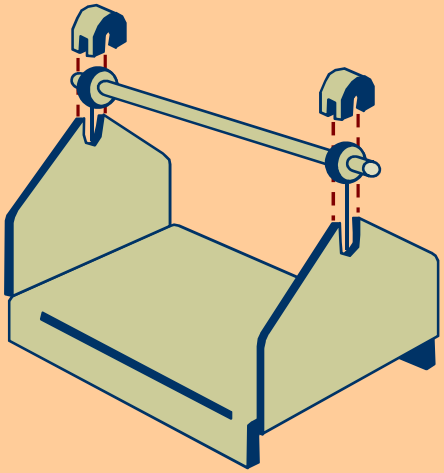
Source: Adapted from G. Boothroyd and P. Dewhurst, "Product Design…. Key to Successful Robotic Assembly." *Assembly Engineering* (September 1986), pp. 90-93.

(a) Original design



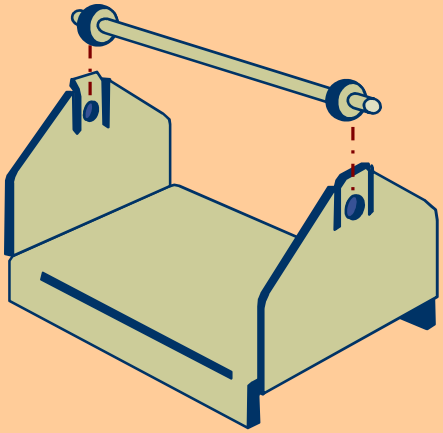
Assembly using common fasteners

(b) Revised design



One-piece base & elimination of fasteners

(c) Final design

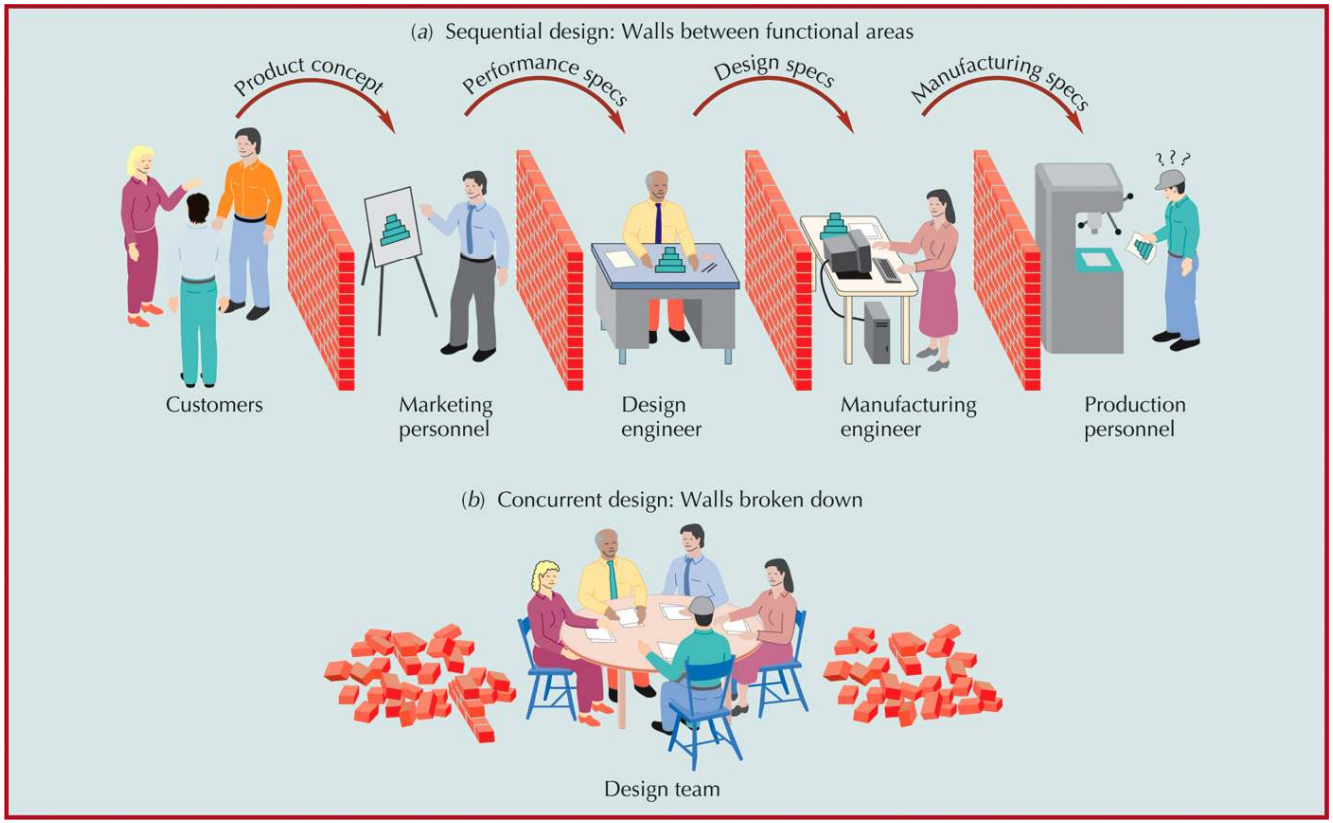


Design for push-and-snap assembly

Final Design and Process Plans

- Final design
  - detailed drawings and specifications for new product or service
- Process plans
  - workable instructions
    - necessary equipment and tooling
    - component sourcing recommendations
    - job descriptions and procedures
    - computer programs for automated machines

Design Team



Concurrent Design

- A new approach to design that involves simultaneous design of products and processes by design teams
- Improves quality of early design decisions
- Involves suppliers
- Incorporates production process
- Uses a price–minus system
- Scheduling and management can be complex as tasks are done in parallel
- Uses technology to aid design

Technology in Design

- Computer Aided Design (CAD)
  - assists in creation, modification, and analysis of a design
  - computer-aided engineering (CAE)
    - tests and analyzes designs on computer screen
  - computer-aided manufacturing (CAD/CAM)
    - ultimate design-to-manufacture connection
  - product life cycle management (PLM)
    - managing entire lifecycle of a product
  - collaborative product design (CPD)

Collaborative Product Design (CPD)

- A software system for collaborative design and development among trading partners
- With PML, manages product data, sets up project workspaces, and follows life cycle of the product
- Accelerates product development, helps to resolve product launch issues, and improves quality of design
- Designers can
  - conduct virtual review sessions
  - test “what if” scenarios
  - assign and track design issues
  - communicate with multiple tiers of suppliers
  - create, store, and manage project documents

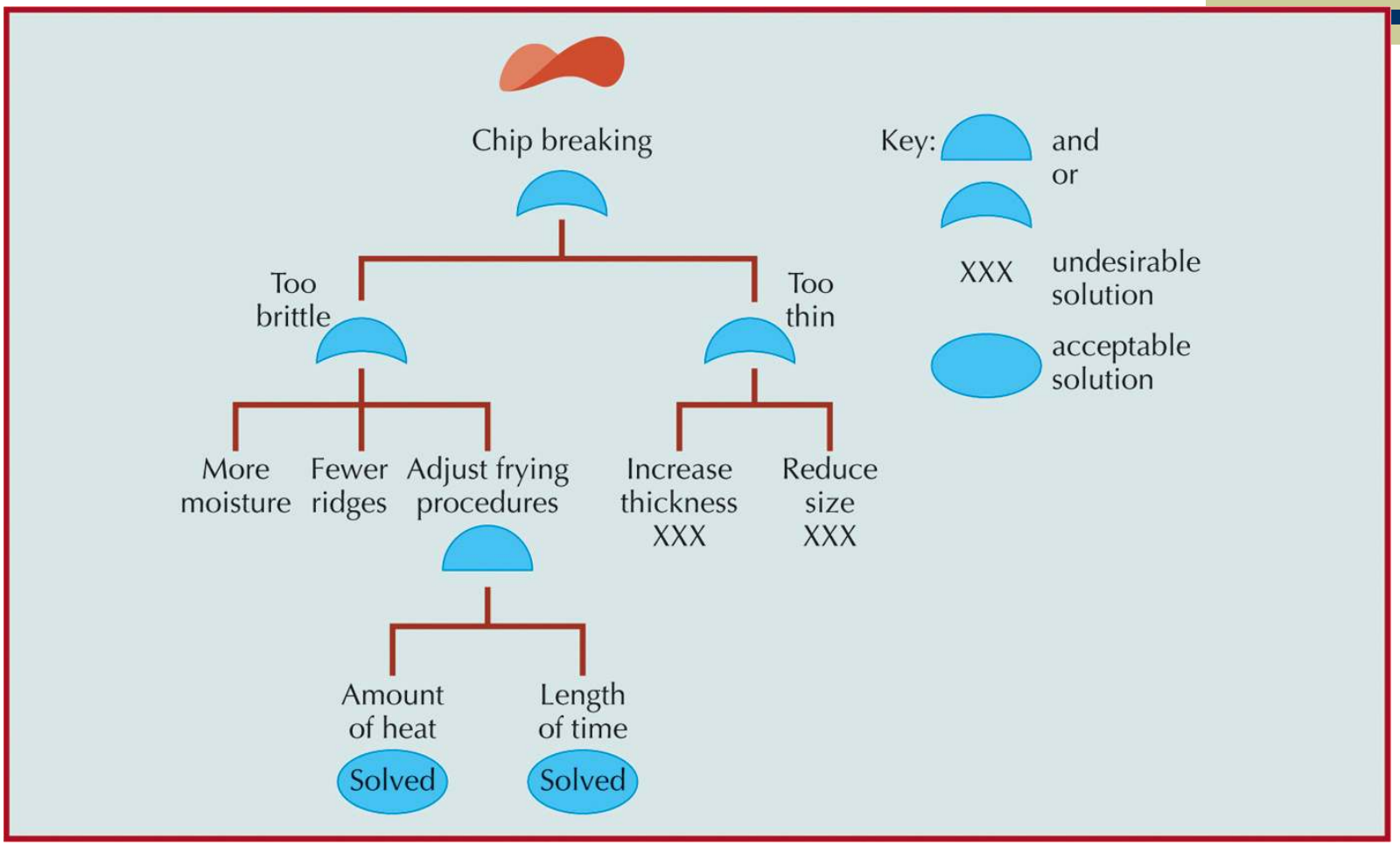
Design Review

- Review designs to prevent *failures* and ensure *value*
  - Failure mode and effects analysis (FMEA)
    - a systematic method of analyzing product failures
  - Fault tree analysis (FTA)
    - a visual method for analyzing interrelationships among failures
  - Value analysis (VA)
    - helps eliminate unnecessary features and functions

FMEA for Potato Chips

Failure Mode	Cause of Failure	Effect of Failure	Corrective Action
Stale	◆low moisture content ◆expired shelf life ◆poor packaging	◆tastes bad ◆won't crunch ◆thrown out ◆lost sales	◆add moisture ◆ cure longer ◆better package seal ◆shorter shelf life
Broken	◆too thin ◆too brittle ◆rough handling ◆rough use ◆poor packaging	◆can't dip ◆poor display ◆injures mouth ◆chocking ◆perceived as old ◆lost sales	◆change recipe ◆change process ◆change packaging
Too Salty	◆outdated receipt ◆process not in control ◆uneven distribution of salt	◆eat less ◆drink more ◆health hazard ◆lost sales	◆experiment with recipe ◆experiment with process ◆introduce low salt version

Fault tree analysis (FTA)



Value analysis (VA)

- Can we do without it?
- Does it do more than is required?
- Does it cost more than it is worth?
- Can something else do a better job?
- Can it be made by
  - a less costly method?
  - with less costly tooling?
  - with less costly material?
- Can it be made cheaper, better, or faster by someone else?

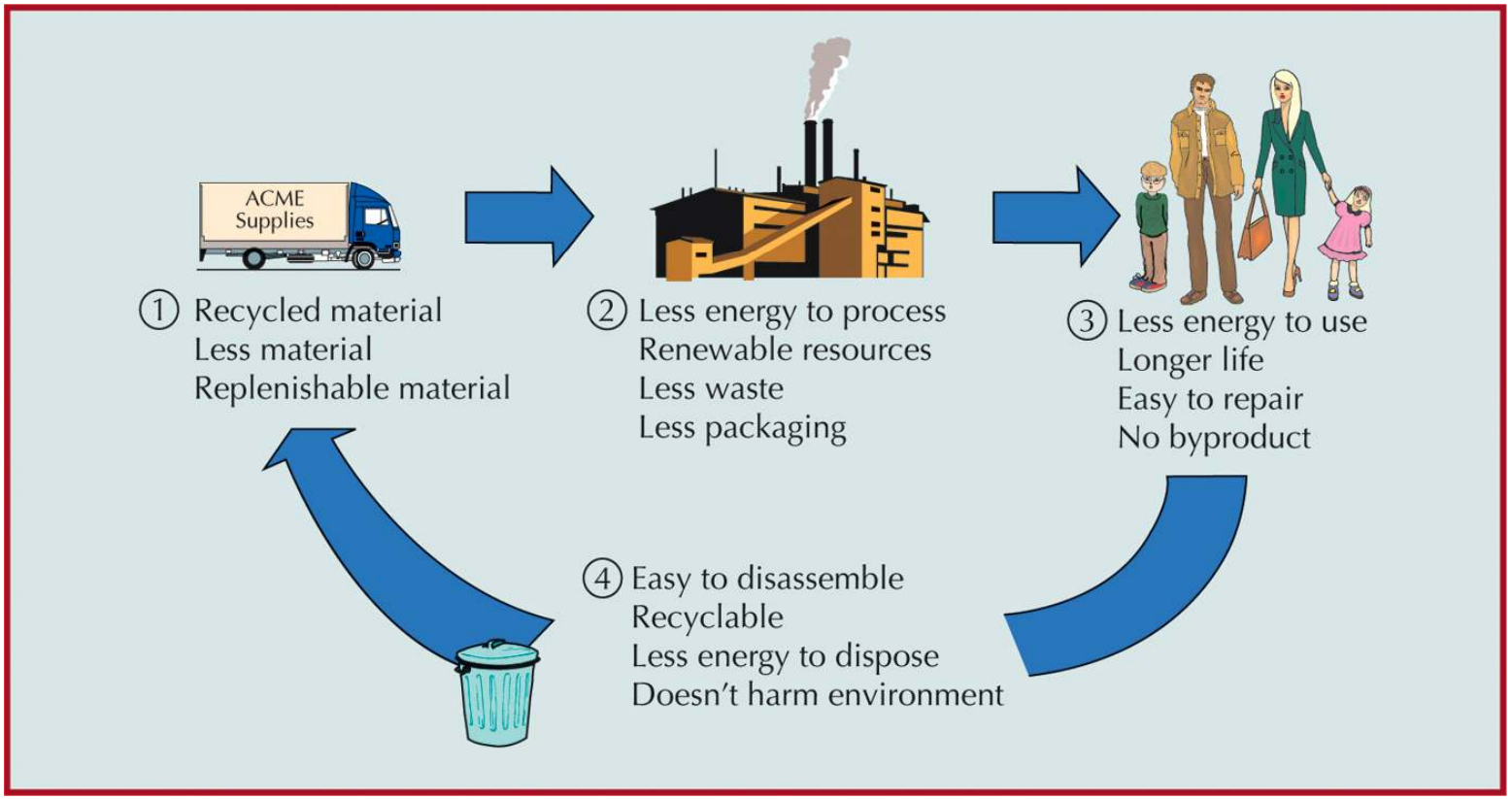
Value analysis (VA) (cont.)

- Updated versions also include:
  - Is it recyclable or biodegradable?
  - Is the process sustainable?
  - Will it use more energy than it is worth?
  - Does the item or its by-product harm the environment?

Design for Environment and Extended Producer Responsibility

- Design for environment
  - designing a product from material that can be recycled
  - design from recycled material
  - design for ease of repair
  - minimize packaging
  - minimize material and energy used during manufacture, consumption and disposal
- Extended producer responsibility
  - holds companies responsible for their product even after its useful life

Design for Environment



Sustainability

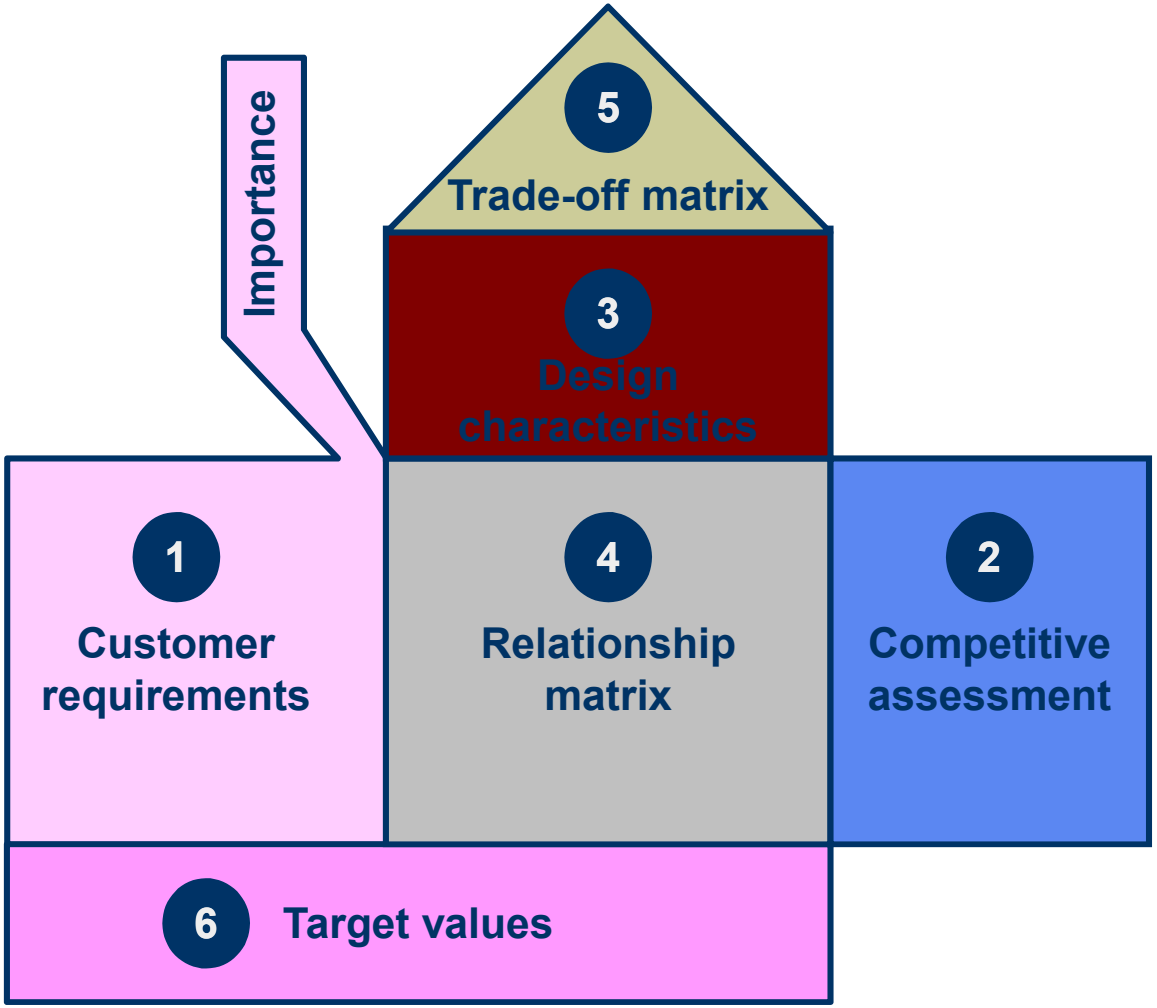
- Ability to meet present needs without compromising those of future generations
- Green product design
  - Use fewer materials
  - Use recycled materials or recovered components
  - Don’t assume natural materials are always better
  - Don’t forget energy consumption
  - Extend useful life of product
  - Involve entire supply chain
  - Change paradigm of design

Source: Adapted from the Business Social Responsibility Web site, www.bsr.org, accessed April 1, 2007.

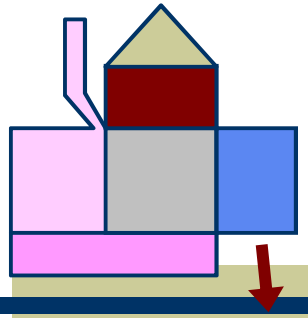
Quality Function Deployment (QFD)

- Translates voice of customer into technical design requirements
- Displays requirements in matrix diagrams
  - first matrix called “house of quality”
  - series of connected houses

House of Quality

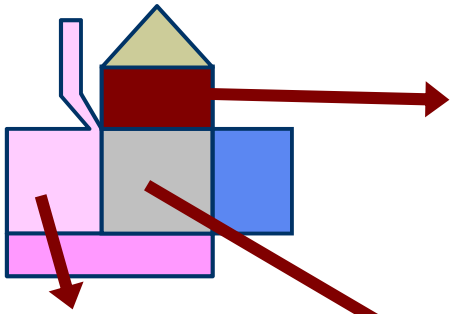


Competitive Assessment of Customer Requirements



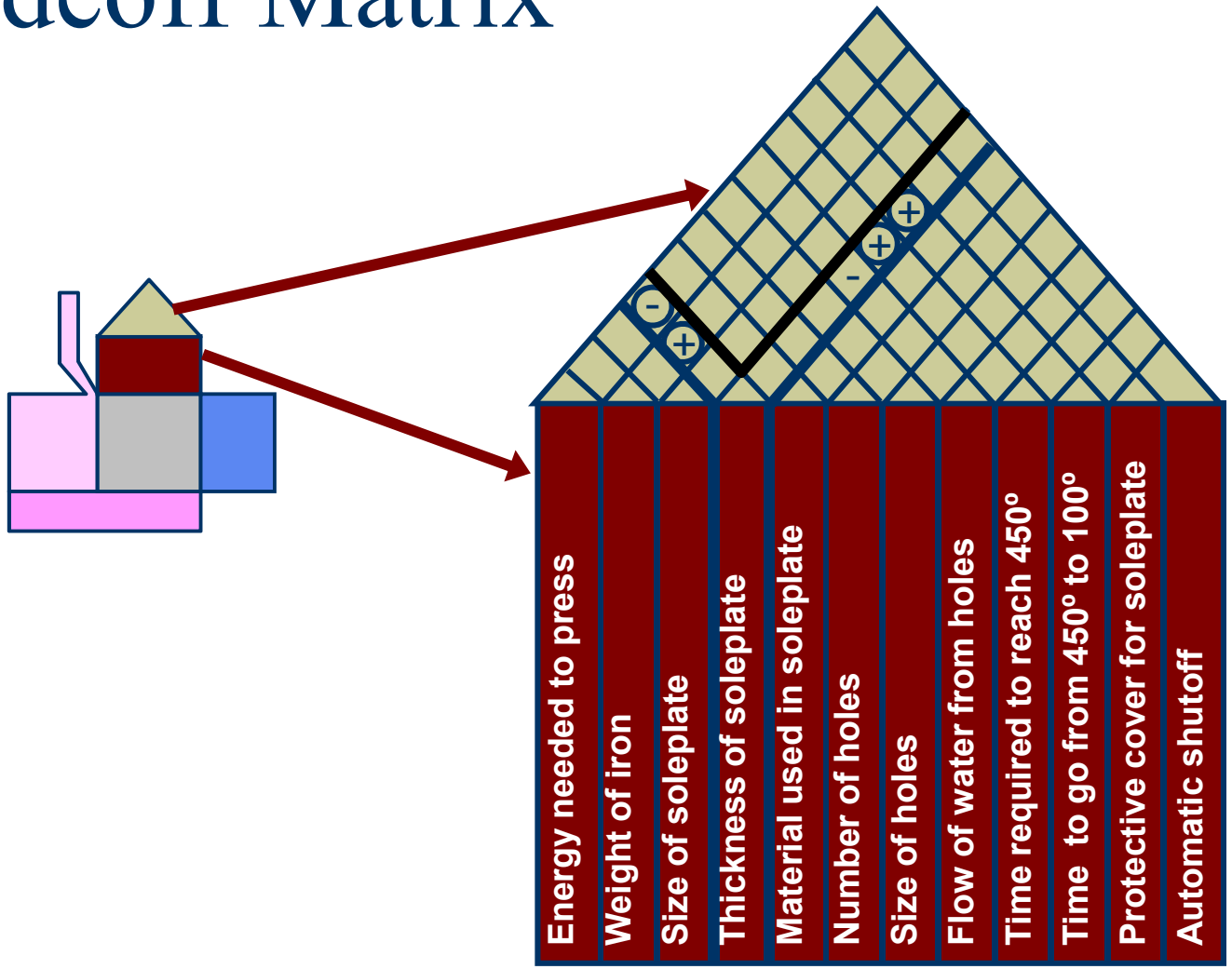
	Customer Requirements		Competitive Assessment 1 2 3 4 5
Irons well	Presses quickly	9	B A X
	Removes wrinkles	8	AB X
	Doesn't stick to fabric	6	X BA
	Provides enough steam	8	AB X
	Doesn't spot fabric	6	X AB
	Doesn't scorch fabric	9	A XB
Easy and safe to use	Heats quickly	6	X B A
	Automatic shut-off	3	ABX
	Quick cool-down	3	X A B
	Doesn't break when dropped	5	AB X
	Doesn't burn when touched	5	AB X
	Not too heavy	8	X A B

From Customer Requirements to Design Characteristics

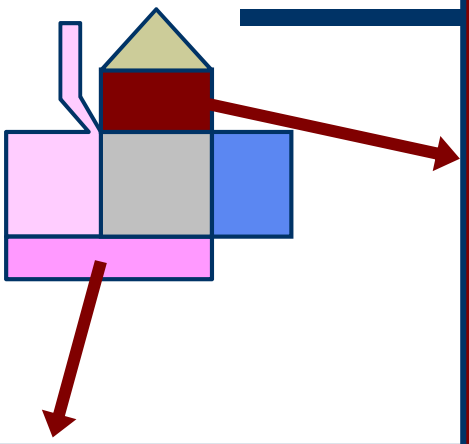


	Customer Requirements	Energy needed to press	Weight of iron	Size of soleplate	Thickness of soleplate	Material used in soleplate	Number of holes	Size of holes	Flow of water from holes	Time required to reach 450° F	Time to go from 450° to 100°	Protective cover for soleplate	Automatic shutoff
Irons well	Presses quickly	-	⊖	+	+	+				-			
	Removes wrinkles		⊕		+		+	+	+				
	Doesn't stick to fabric		-			⊕			+		⊕	+	
	Provides enough steam			+			+	+	+				
	Doesn't spot fabric					+	-	-	⊖				
	Doesn't scorch fabric				+	⊕			+	-	⊕		
Easy and safe to use	Heats quickly			-	-					⊕		-	
	Automatic shut-off												⊕
	Quick cool-down			-	⊖	+					⊕		
	Doesn't break when dropped		+	+	⊕							+	
	Doesn't burn when touched				+						+	⊕	+
	Not too heavy	+	⊖	-	-	⊕						-	

Tradeoff Matrix

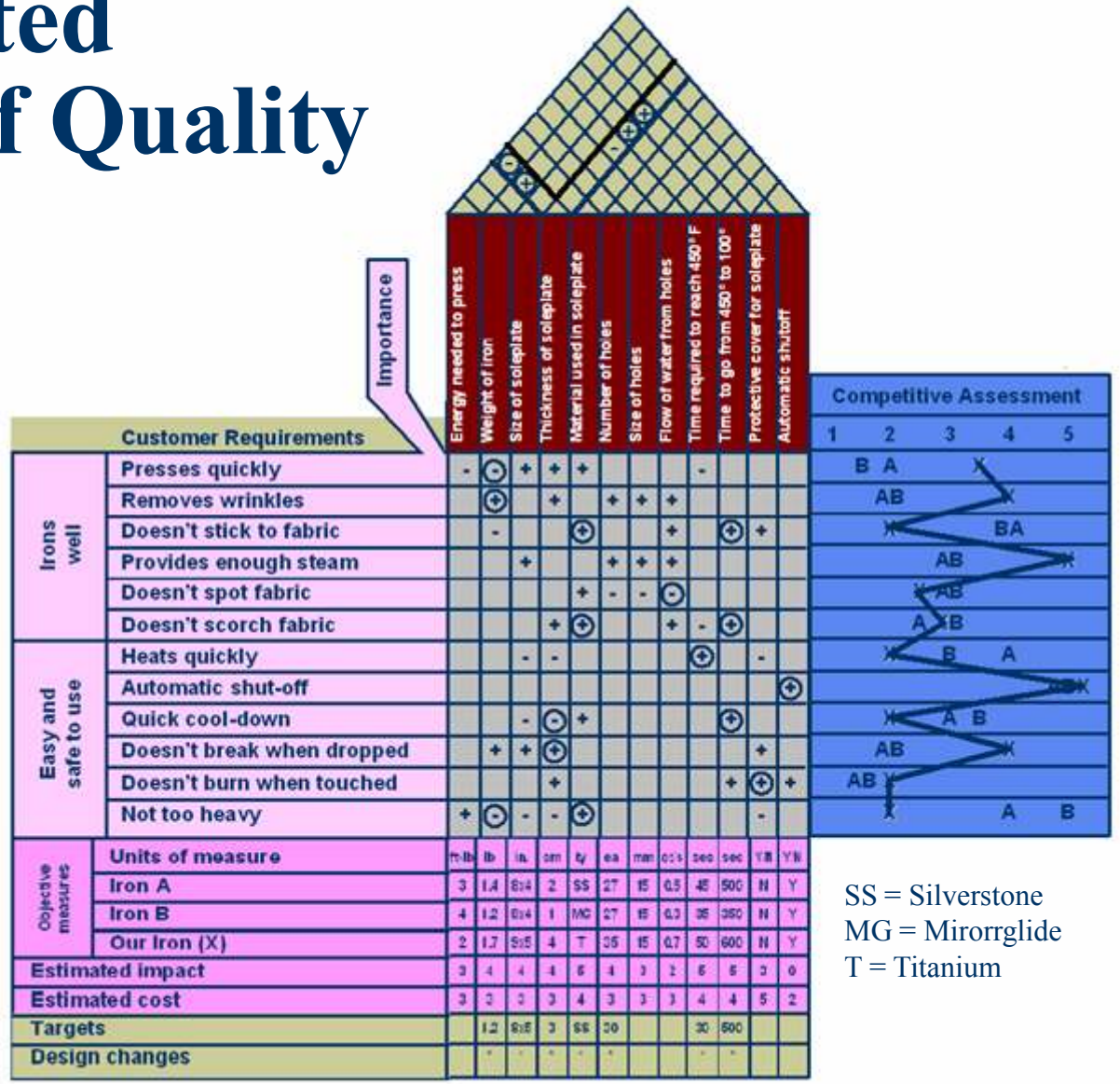


Targeted Changes in Design



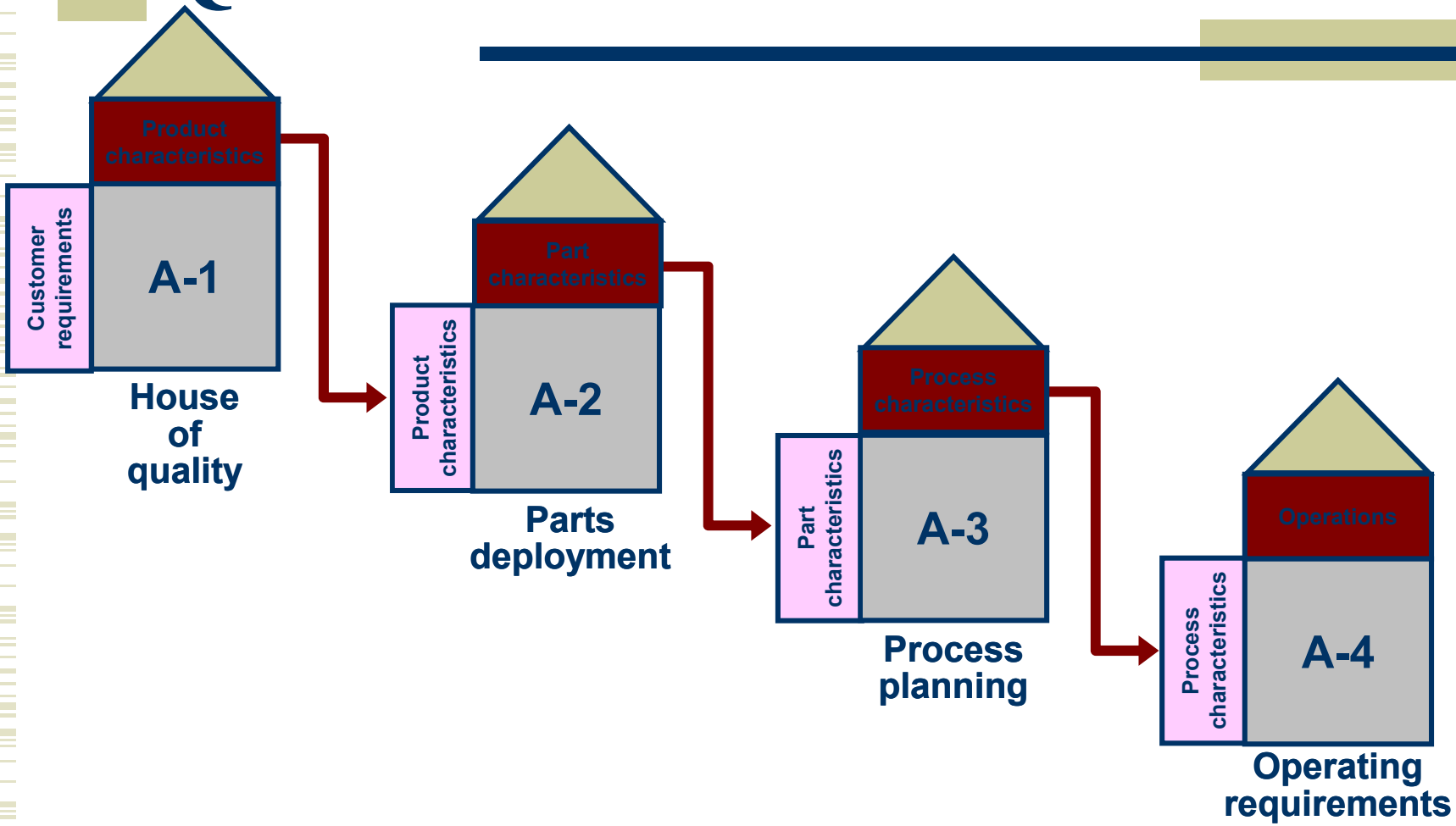
		Energy needed to press	Weight of iron	Size of soleplate	Thickness of soleplate	Material used in soleplate	Number of holes	Size of holes	Flow of water from holes	Time required to reach 450°	Time to go from 450° to 100°	Protective cover for soleplate	Automatic shutoff
Objective measures	Units of measure	ft-lb	lb	in.	cm	ty	ea	mm	oz/s	sec	sec	Y/N	Y/N
	Iron A	3	1.4	8x4	2	SS	27	15	0.5	45	500	N	Y
	Iron B	4	1.2	8x4	1	MG	27	15	0.3	35	350	N	Y
	Our Iron (X)	2	1.7	9x5	4	T	35	15	0.7	50	600	N	Y
Estimated impact		3	4	4	4	5	4	3	2	5	5	3	0
Estimated cost		3	3	3	3	4	3	3	3	4	4	5	2
Targets			1.2	8x5	3	SS	30			30	500		
Design changes			*	*	*	*	*			*	*		

Completed House of Quality



SS = Silverstone
MG = Mirorrglide
T = Titanium

A Series of Connected QFD Houses



Benefits of QFD

- Promotes better understanding of customer demands
- Promotes better understanding of design interactions
- Involves manufacturing in design process
- Provides documentation of design process

Design for Robustness

- Robust product
  - designed to withstand variations in environmental and operating conditions
- Robust design
  - yields a product or service designed to withstand variations
- Controllable factors
  - design parameters such as material used, dimensions, and form of processing
- Uncontrollable factors
  - user's control (length of use, maintenance, settings, etc.)

Design for Robustness (cont.)

- Tolerance
  - allowable ranges of variation in the dimension of a part
- Consistency
  - consistent errors are easier to correct than random errors
  - *parts* within tolerances may yield *assemblies* that are not within limits
  - consumers prefer product characteristics near their ideal values

Taguchi's Quality Loss Function

- Quantifies customer preferences toward quality
- Emphasizes that customer preferences are strongly oriented toward consistently
- Design for Six Sigma (DFSS)