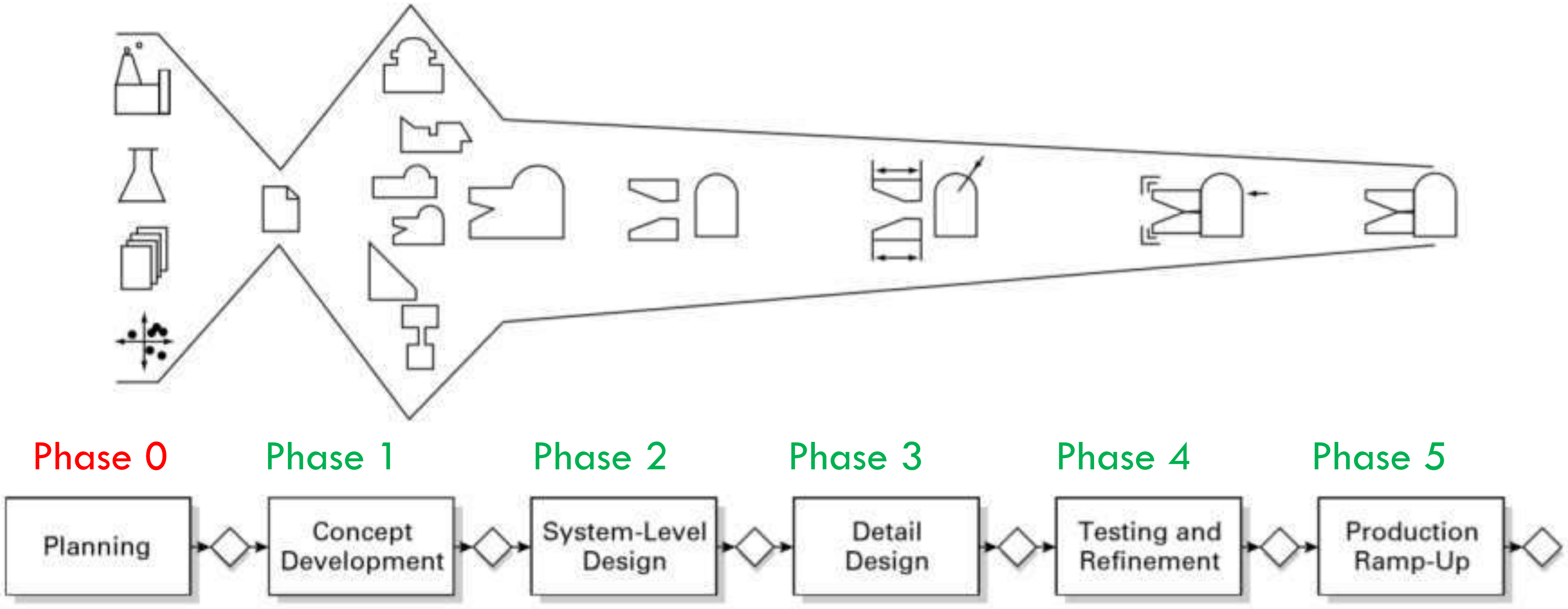
PRODUCT DEVELOPMENT

The Product Development Process

- A product development process is the sequence of steps or activities that an enterprise employs to conceive, design, and commercialize a product.
- A well-defined development process is useful for quality assurance, coordination, planning, management, and improvement.
- The generic product development process consists of six phases.



Phases of Product Development

Phase 0: Planning

- The planning activity comes before the project approval and launch of the actual product development process.
- This phase begins with opportunity identification guided by corporate strategy and includes assessment of technology developments and market objectives.
- The output of the planning phase is the project mission statement, which specifies the target market for the product, business goals, key assumptions, and constraints.
- Opportunity Identification is a process of gathering, evaluating, and choosing from a broad range of product opportunities.

Phase 0: Planning

- Before beginning the development project, the firm typically specifies a particular market opportunity and lays out the broad constraints and objectives for the project.
- This information is frequently formalized as a mission statement (also sometimes called a charter or a design brief).
- The mission statement specifies which direction to go in but generally does not specify a precise destination or a particular way to proceed.

Product Description
Benefit Proposition
Key Business Goals
Primary Market
Secondary Markets
Assumptions
Stakeholders

Phase 0: Planning mission statement example

Mission Statement: Screwdriver Project	
Product Description	
Benefit Proposition	
Key Business Goals	
Primary Market	
Secondary Markets	
Assumptions	
Stakeholders	

Phases of Product Development

Phase 1: Concept development

- In the concept development phase, the needs of the target market are identified, alternative product concepts are generated and evaluated, and one or more concepts are selected for further development and testing.
- A concept is a description of the form, function, and features of a product and is usually accompanied by high level specifications/requirements, an analysis of competitive products, and an economic justification of the project.

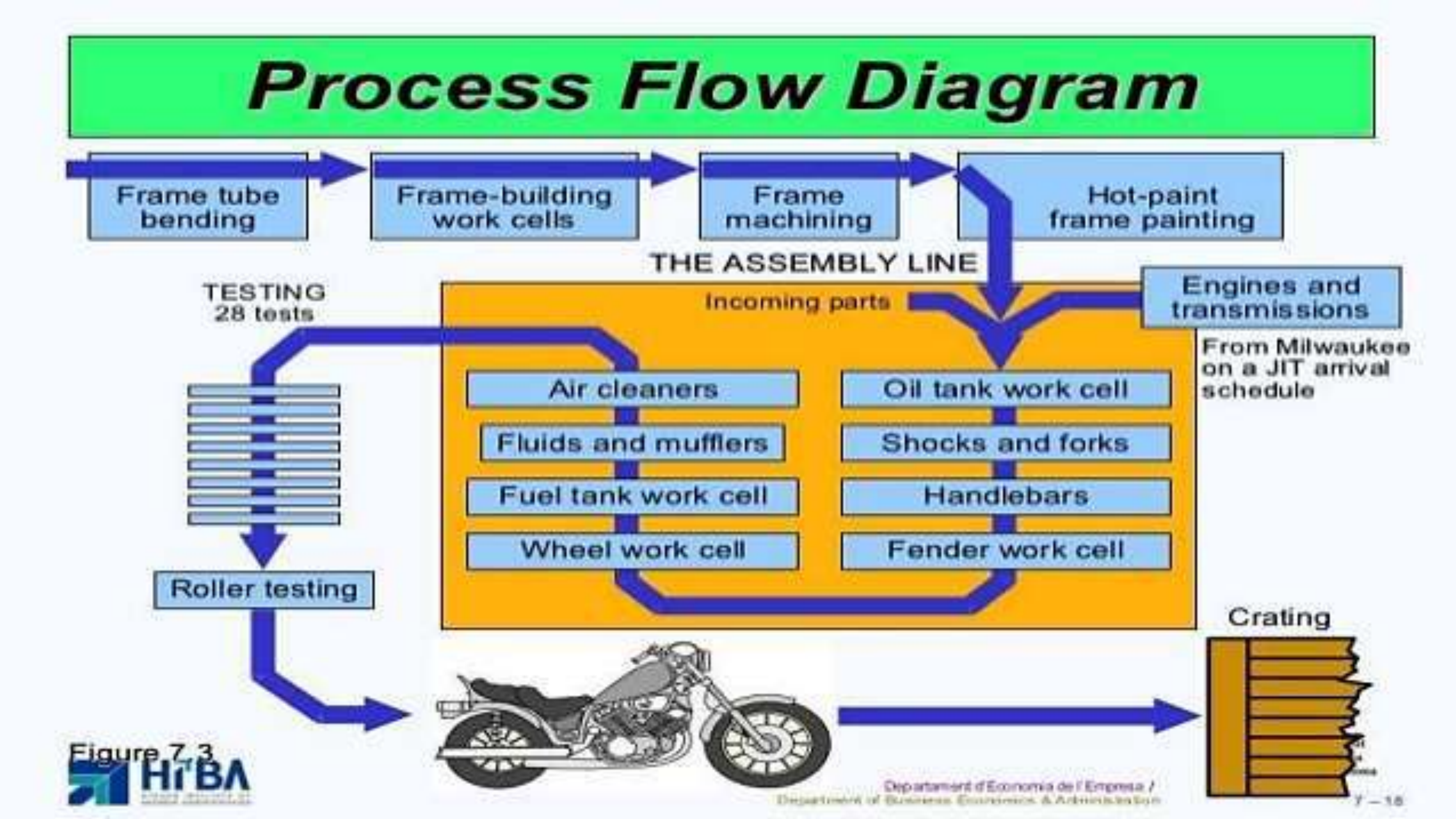
Phases of Product Development

Phase 2: System-level design

- The system-level design phase includes the definition of the product architecture, decomposition of the product into subsystems and components, and preliminary design of key components.
- Initial plans for the production system and final assembly are usually defined during this phase as well.
- The output of this phase usually includes a geometric layout of the product, a functional specification of each of the product's subsystems, and a preliminary process flow diagram for the final assembly process.

EX. Motorcycle: Define Subsystems

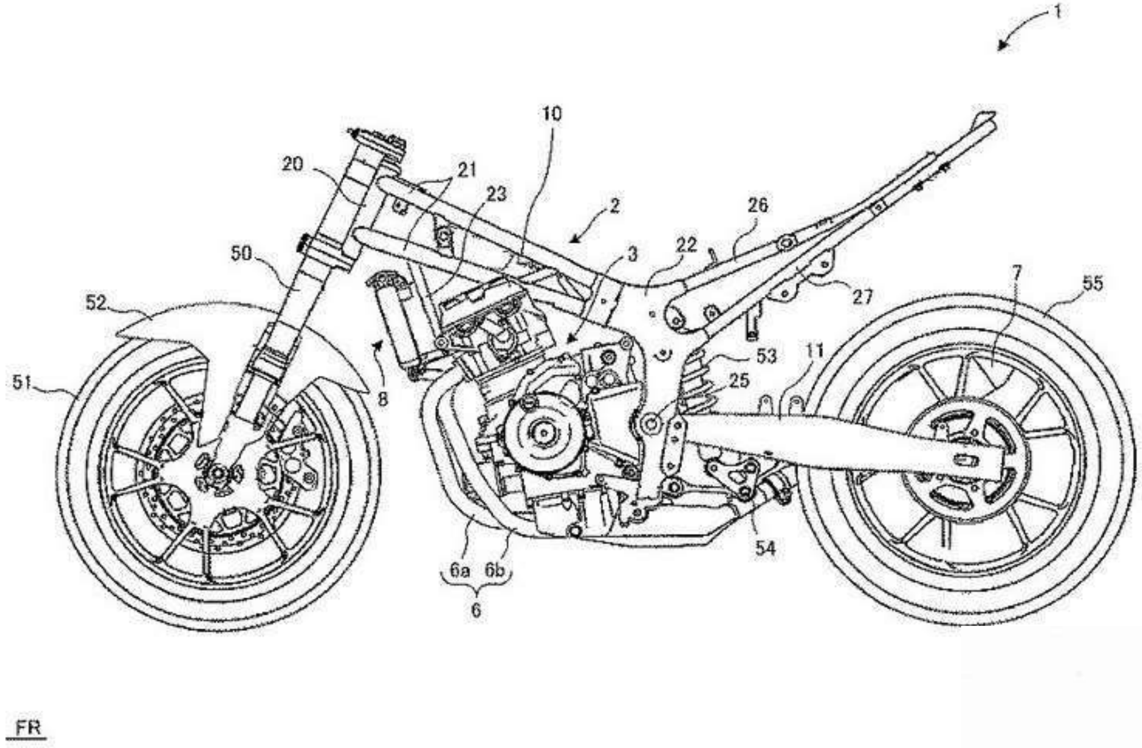
- Frame strength, durability
- Seat support
- Steering (including handlebar and fork) direction capabilities
- Wheels (including hubs and tires) etc.
- Power input (including crankset and freewheels)
- Power transmission/torque conversion (including front and rear derailleurs, gears, gear shift levers, chain)
- Brakes (including brake pads, calipers, cables, handgrips)


Process Flow Diagram
Frame tube bending
Frame-building work cells
Frame machining
Hot-paint frame painting
THE ASSEMBLY LINE
TESTING
28 tests
Incoming parts
Engines and transmissions
From Milwaukee on a JIT arrival schedule
Air cleaners
Fluids and mufflers
Fuel tank work cell
Wheel work cell
Oil tank work cell
Shocks and forks
Handlebars
Fender work cell
Roller testing
Crating
Figure 7.3
Departament d'Economia de l'Empresa /
Department of Business Economics & Administration
7 – 18

Phases of Product Development

Phase 3: Detail design

- The detail design phase includes the complete specification of the geometry, materials, and tolerances of all of the unique parts in the product and the identification of all of the standard parts to be purchased from suppliers.
- A process plan is established and tooling is designed for each part to be fabricated within the production system.
- The output of this phase is the control documentation for the product—the drawings or computer files describing the geometry of each part and its production tooling, the specifications of the purchased parts, and the process plans for the fabrication and assembly of the product.
- Three critical issues that are best considered throughout the product development process, but are finalized in the detail design phase, are: materials selection, production cost, and robust performance.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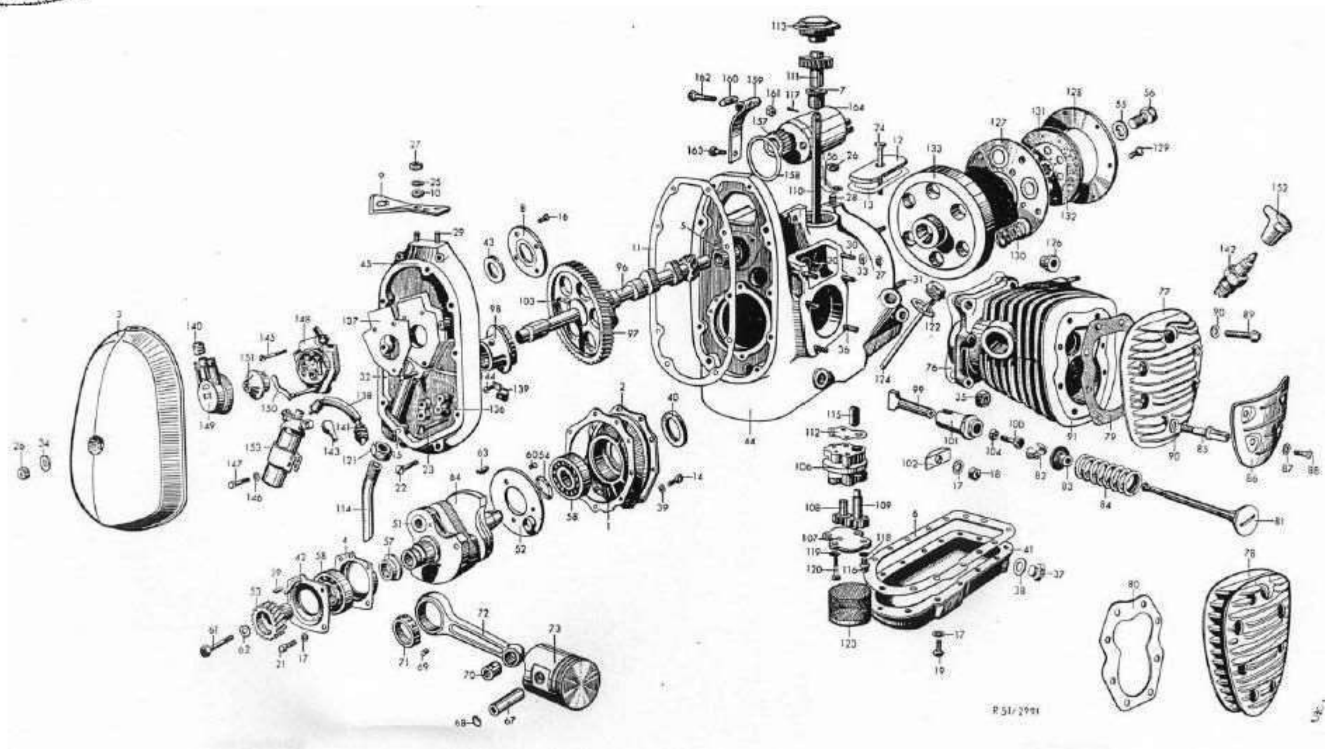


Phases of Product Development

Phase 4: Testing and refinement

- The testing and refinement phase involves the construction and evaluation of multiple preproduction versions of the product.
- Early (alpha) prototypes are usually built with production-intent parts—parts with the same geometry and material properties as intended for the production version of the product but not necessarily fabricated with the actual processes to be used in production.
  - *Alpha prototypes are tested to determine whether the product will work as designed and whether the product satisfies the key customer needs.*
- Later (beta) prototypes are usually built with parts supplied by the intended production processes but may not be assembled using the intended final assembly process.
  - *Beta prototypes are extensively evaluated internally and are also typically tested by customers in their own use environment.*
  - *The goal for the beta prototypes is usually to answer questions about performance and reliability in order to identify necessary engineering changes for the final product.*

Phases of Product Development

Phase 5: Production ramp-up

- In the production ramp-up phase, the product is made using the intended production system.
- The purpose of the ramp-up is to train the workforce and to work out any remaining problems in the production processes.
- Products produced during production ramp-up are sometimes supplied to preferred customers and are carefully evaluated to identify any remaining flaws.
- The transition from production ramp-up to ongoing production is usually gradual. At some point in this transition, the product is launched and becomes available for widespread distribution. A postlaunch project review may occur shortly after the launch and is intended to identify ways to improve the development process for future projects.

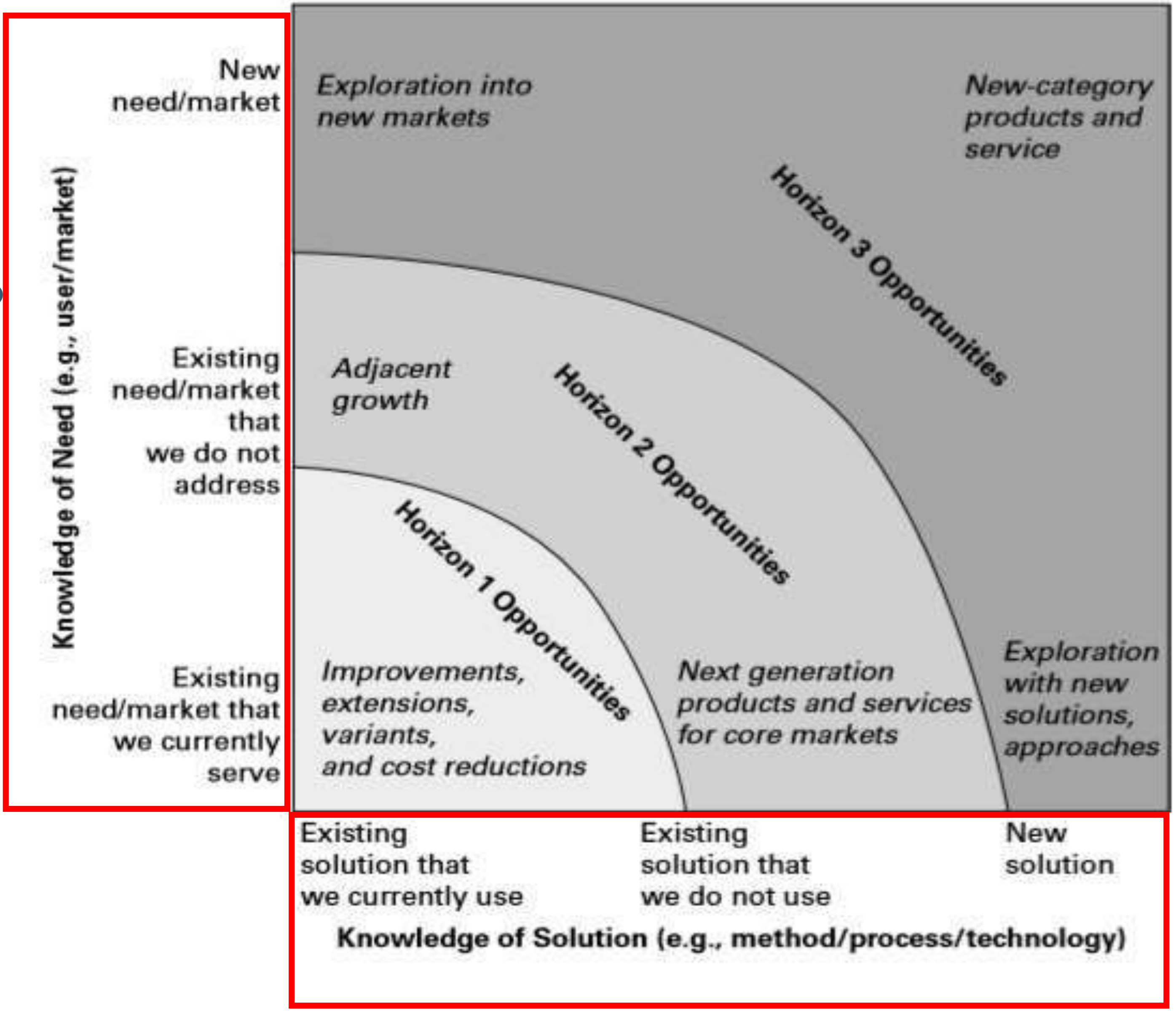
Phase 0 in detail

Phase 0: Opportunity Identification

Two main ways to categorize opportunities:

1. the extent to which the team is familiar with the solution likely to be employed
2. the extent to which the team is familiar with the need that the solution addresses.

- Horizons 1, 2, and 3 represent increasing levels of risk, reflecting different types of uncertainty.



Good Opportunities are defined by:

- **Valuable.** To be valuable, a resource must either allow a firm to achieve greater performance than competitors or reduce a weakness relative to competitors.
- **Rare.** Given competition, a valuable resource must be rare.
- **Inimitable.** For value and rarity to persist, a resource must not be easily imitated.
- **Nonsubstitutable.** Even if valuable, rare, and inimitable, a resource providing advantage can't be easily substituted.

Questions to ask in Phase 0: Real-Win-Worth-it (RWW) Framework

1. Is there a real market and a real product?

Is there a need? (What is the need? How is the need presently satisfied?)
Can the customer buy? (size of the market, customer decision-making process)
Will the customer buy? (perceived risks and benefits, expectations on price and availability)
Is there a viable concept for a product already? How likely are we to be able to develop a viable concept?
Is the product acceptable within the social, legal, and environmental norms?
Is the product feasible? Can it be made? Is the technology available? Does it satisfy the needs?
Will our product satisfy the market? Is there a relative advantage to other products?
Can it be produced at low cost?
Are the risks perceived by the customer acceptable? What are the barriers to adoption?

Questions to ask in Phase 0: Real-Win-Worth-it (RWW) Framework

2. Can we win? Can our product or service be competitive? Can we succeed as a company?

Do we have a competitive advantage? Is it sustainable? (performance, patents, barriers to entry, substitution, price)
Is the timing right?
Does it fit our brand?
Will we beat our competition? (How much will they improve? price trajectories, entrants)
Do we have superior resources? (engineering, finance, marketing, production; fit with core competencies)
Do we have the management that can win? (experience? fit with culture? commitment to this opportunity?)
Do we know the market as well as or better than our competitors? (customer behavior? channels?)

Questions to ask in Phase 0: Real-Win-Worth-it (RWW) Framework

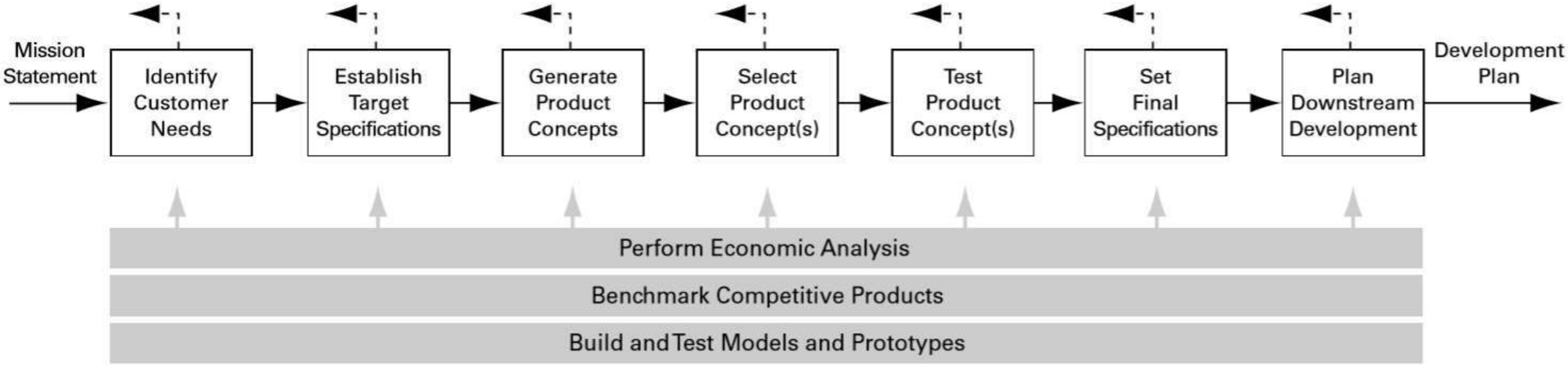
3. Is it worth doing? Is the return adequate and the risk acceptable?

Will it make money?
Do we have the resources and the cash to do this?
Are the risks acceptable to us? (What could go wrong? technical risk vs. market risk)
Does it fit our strategy? (fit with our growth expectation, impact on brand, embedded options)

Although we may not have all of the correct and exact answers for all of these questions early on in this stage of the development cycle we still need to ask these questions.

Phase 1 in detail

Phase 1: Concept Development



Phase 1: Concept Development Identifying customer needs

Identifying customer needs:

- *the goal of this activity is to understand customers' needs and to effectively communicate them to the development team.*
- *the output of this process is a set of carefully constructed customer need statements, organized in a hierarchical list, with importance weightings for many or all of the needs.*

Gather raw data from customers. → Interpret the raw data in terms of customer needs → Organize the needs into a hierarchy of primary, secondary, and (if necessary) third order needs → Establish the relative importance of the needs → Reflect on the results and the process.

Phase 1: Concept Development Identifying customer needs

Step 1: Choose how you will collect and who the customers you will gather information from are.

To do this you may use a **customer selection** matrix. **A customer selection matrix is useful for planning exploration of both market and customer variety.**

Customer Data Collection Methods
Interviews
Focus Groups
Observing Users

EXHIBIT 5-5
Customer selection matrix for the cordless screwdriver project.

	Lead Users	Users	Retailer or Sales Outlet	Service Centers
Homeowner (occasional use)	0	5	2	3
Handy person (frequent use)	3	10		
Professional (heavy-duty use)	3	2	2	

Phase 1: Concept Development

Identifying customer needs

Step 2: obtain customer statement and interpret them into technical needs

Customer:	Bill Esposito	**Interviewer(s):**	Jonathan and Lisa
Address:	100 Memorial Drive Cambridge, MA 02139	**Date:**	19 December 2010
Telephone:	617-864-1274	**Currently uses:**	Craftsman Model A3
Willing to do follow-up?	Yes	**Type of user:**	Building maintenance

Question/Prompt	Customer Statement	Interpreted Need
Typical uses	I need to drive screws fast, faster than by hand.	The SD drives screws faster than by hand.
	I sometimes do duct work; use sheet metal screws.	The SD drives sheet metal screws into metal duct work.
	A lot of electrical; switch covers, outlets, fans, kitchen appliances.	The SD can be used for screws on electrical devices.
Likes—current tool	I like the pistol grip; it feels the best.	The SD is comfortable to grip.
	I like the magnetized tip.	The SD tip retains the screw before it is driven.
Dislikes—current tool	I don't like it when the tip slips off the screw.	The SD tip remains aligned with the screw head without slipping.
	I would like to be able to lock it so I can use it with a dead battery.	The user can apply torque manually to the SD to drive a screw. (!)
	Can't drive screws into hard wood.	The SD can drive screws into hard wood.
	Sometimes I strip tough screws.	The SD does not strip screw heads.
Suggested improvements	An attachment to allow me to reach down skinny holes.	The SD can access screws at the end of deep, narrow holes.
	A point so I can scrape paint off of screws.	The SD allows the user to work with screws that have been painted over.
	Would be nice if it could punch a pilot hole.	The SD can be used to create a pilot hole. (!)

EXHIBIT 5-6 Customer data template filled in with sample customer statements and interpreted needs. SD is an abbreviation for screwdriver. (Note that this template represents a partial list from a single interview. A typical interview session may elicit more than 50 customer statements and interpreted needs.)

Phase 1: Concept Development

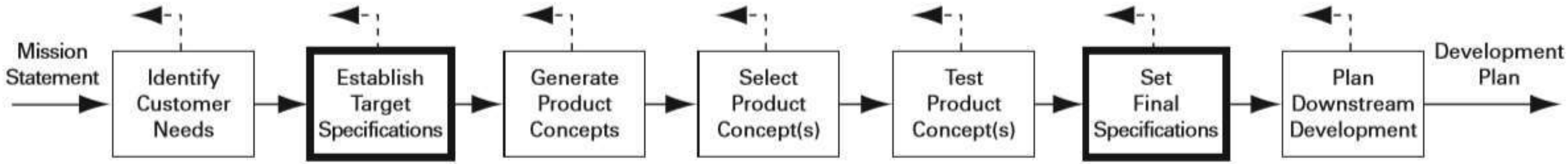
Identifying customer needs

Step 3: setting priorities for each need

EXHIBIT 6-2 Customer needs for the suspension fork and their relative importance (shown in a convenient spreadsheet format).

No.		Need	Imp.
1	The suspension	reduces vibration to the hands.	3
2	The suspension	allows easy traversal of slow, difficult terrain.	2
3	The suspension	enables high-speed descents on bumpy trails.	5
4	The suspension	allows sensitivity adjustment.	3
5	The suspension	preserves the steering characteristics of the bike.	4
6	The suspension	remains rigid during hard cornering.	4
7	The suspension	is lightweight.	4
8	The suspension	provides stiff mounting points for the brakes.	2
9	The suspension	fits a wide variety of bikes, wheels, and tires.	5
10	The suspension	is easy to install.	1
11	The suspension	works with fenders.	1
12	The suspension	instills pride.	5
13	The suspension	is affordable for an amateur enthusiast.	5
14	The suspension	is not contaminated by water.	5
15	The suspension	is not contaminated by grunge.	5
16	The suspension	can be easily accessed for maintenance.	3
17	The suspension	allows easy replacement of worn parts.	1
18	The suspension	can be maintained with readily available tools.	3
19	The suspension	lasts a long time.	5
20	The suspension	is safe in a crash.	5

Phase 1: Concept Development Identifying Product Specifications



- How could the relatively subjective customer needs be translated into precise targets for the remaining development effort?
- How could the team and its senior management agree on what would constitute success or failure of the resulting product design?
- How could the team resolve the inevitable trade-offs among product characteristics like cost and weight?

Phase 1: Concept Development Identifying Product Specifications

The process of establishing the target specifications contains four steps:

1. Prepare the list of metrics.
2. Collect competitive benchmarking information.
3. Set ideal and marginally acceptable target values.
4. Reflect on the results and the process.

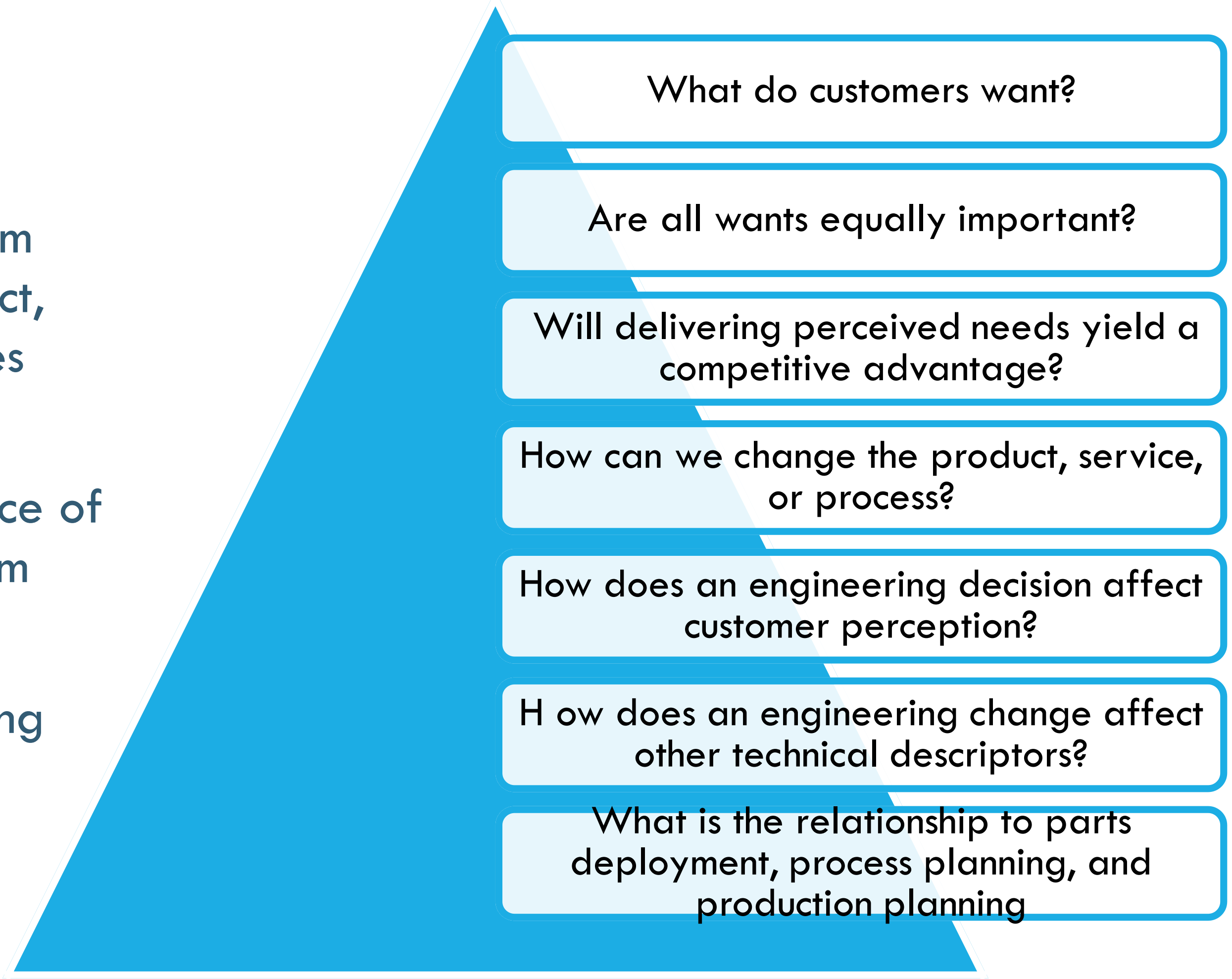
We can use the QFD in this step to help identify specifications and then carry through the information into the later stages of product development.

Phase 1: Concept Development

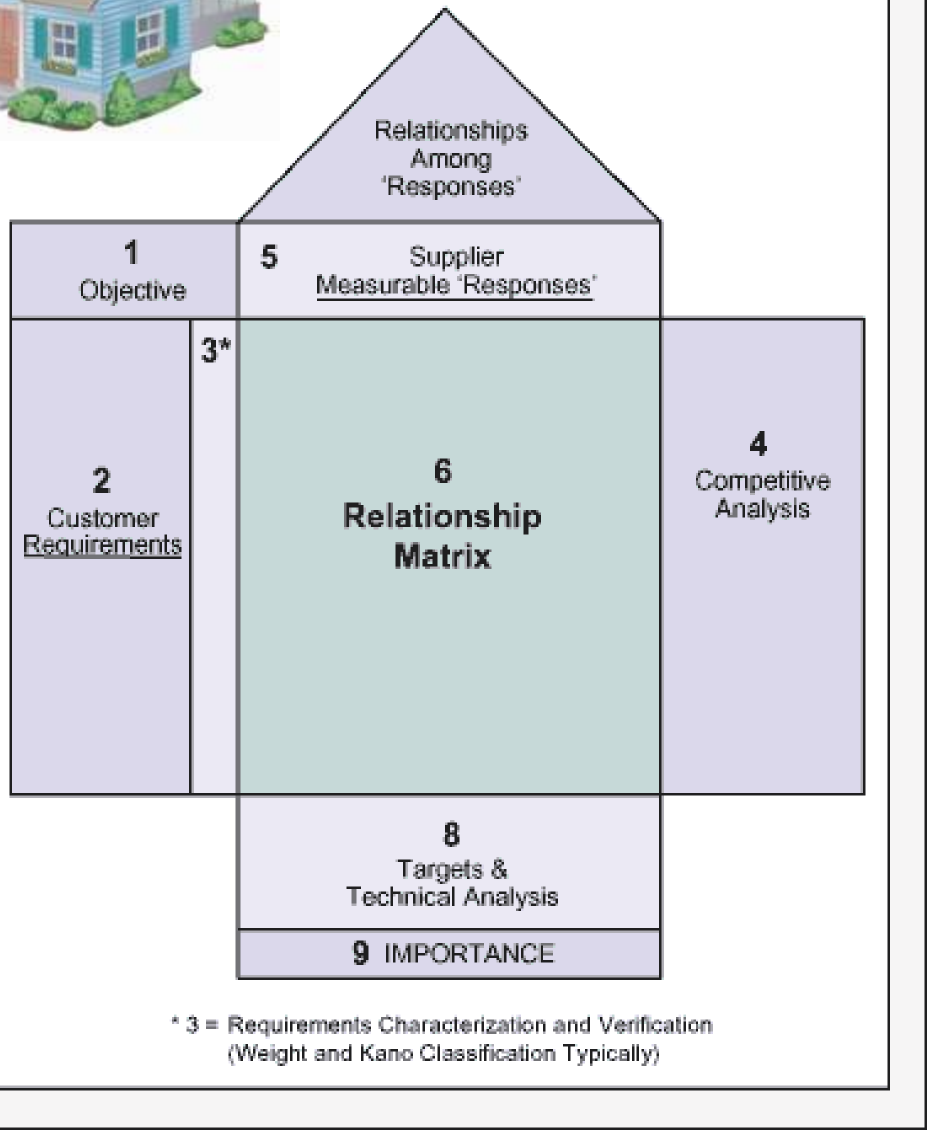
QFD for Identifying Product Specifications

- Quality Function Deployment (QFD) is a system that identifies and sets the priorities for product, service, and process improvement opportunities that lead to increased customer satisfaction.
- It ensures the accurate deployment of the "voice of the customer" throughout the organization, from product planning to field service.
- QFD reduces start-up costs, reduces engineering design changes, and, most important, leads to increased customer satisfaction.

The QFD process answers the questions



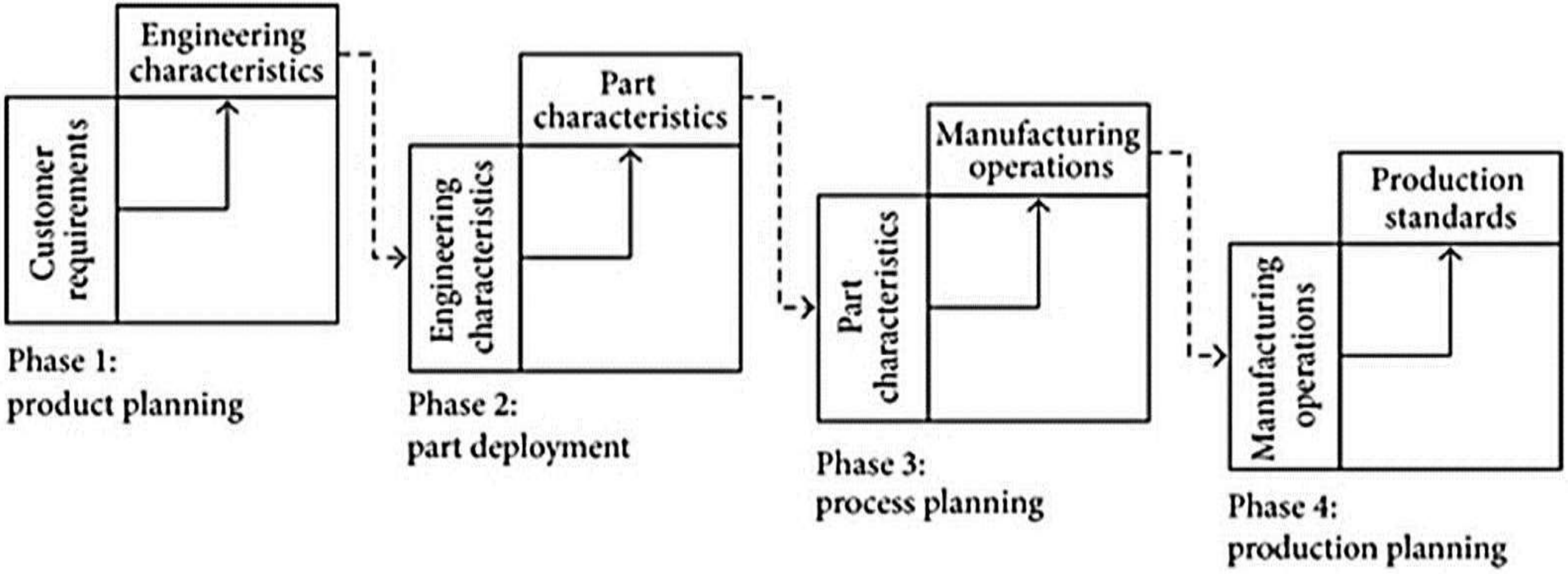
Phase 1: Concept Development QFD for Identifying Product Specifications



- The QFD process takes on the form of the "House" of Quality concept
- **House of Quality (QFD)** refers to a well-known process for product development that is inspired by customer desires for product or process development and anchored by the capabilities and resources of the organization seeking to meet those desires.
- It is a process of listening to customers, translating their desires into a written plan, prioritizing steps of execution based on what is most important to the customer, and putting a realistic plan on paper.

https://www.isixsigma.com/tools-templates/qfd-house-of-quality/qfd-when-and-how-does-it-fit-software-development/

Phase 1: Concept Development QFD for Identifying Product Specifications



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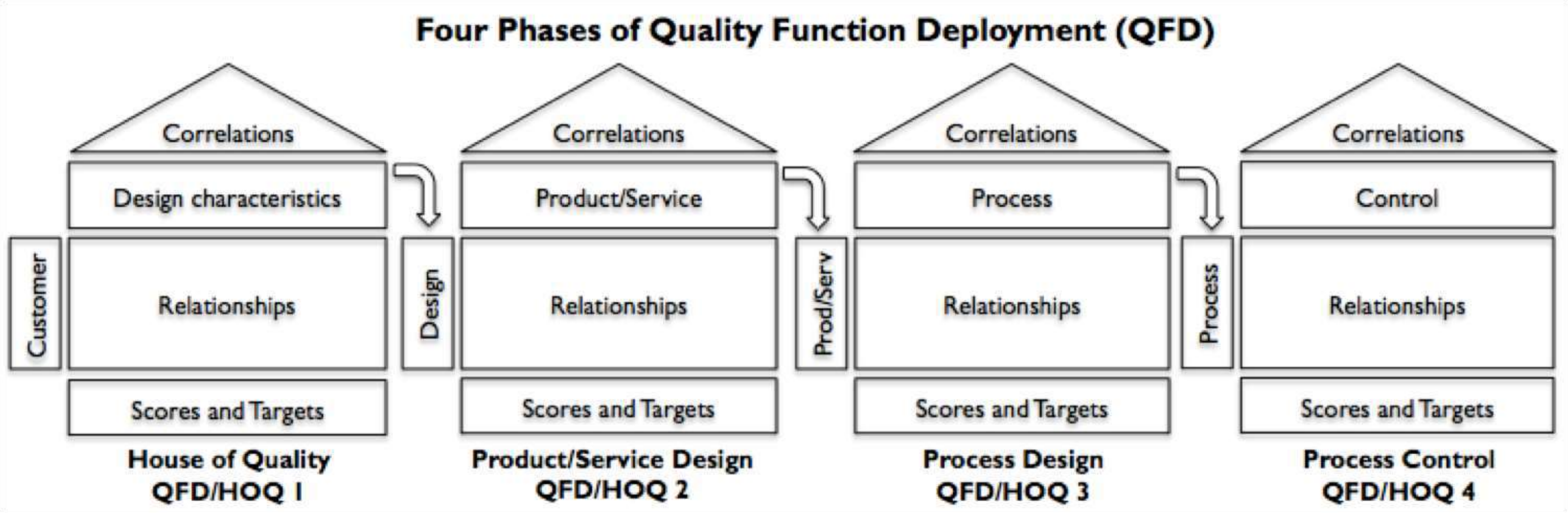
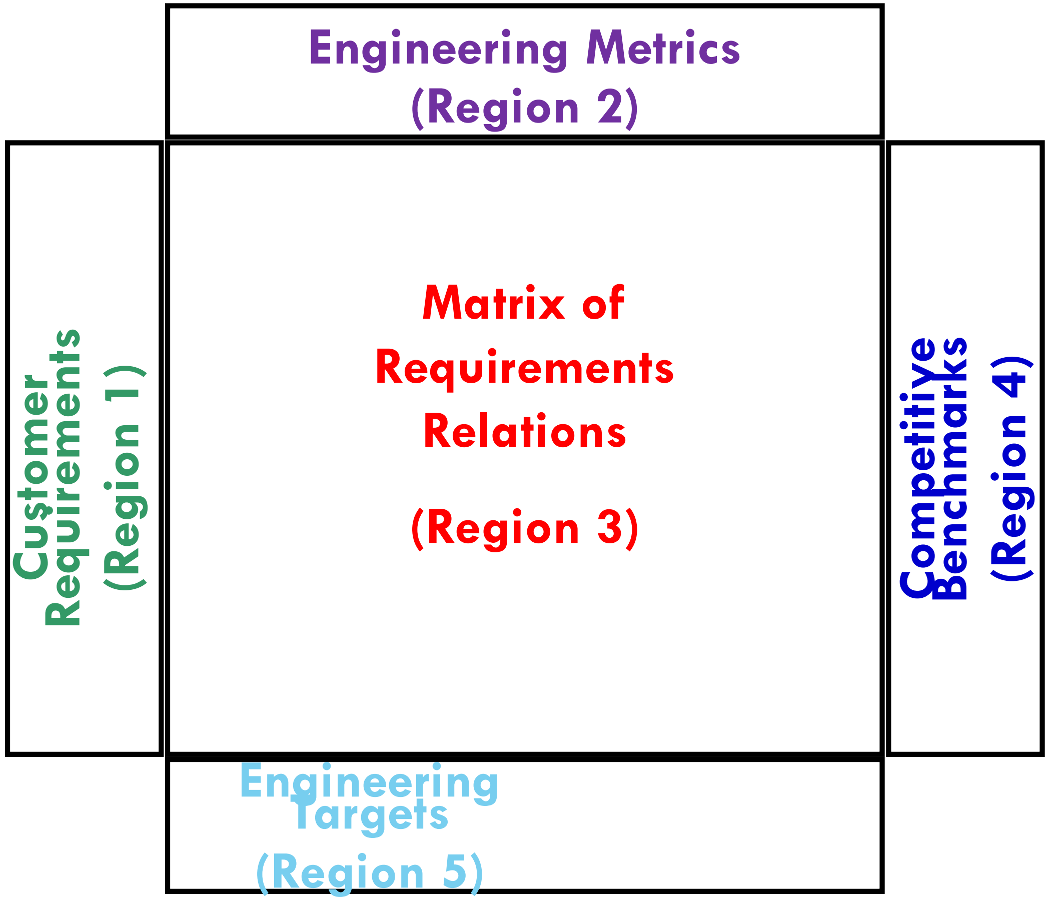
QFD

- https://www.youtube.com/watch?v=Bbc764jufTw
- https://vgpblog.files.wordpress.com/2015/05/house-of-quality-template-value-generation-partners.png



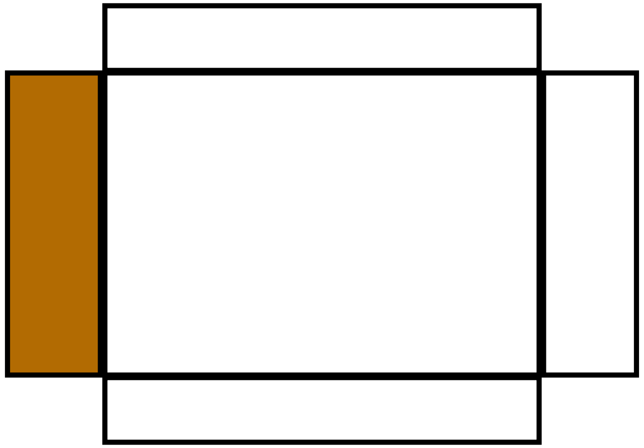
The general arrangement of phase 1/HQ1 QFD table consists of the following 5 regions:

1. Customer requirements
2. Engineering requirements
3. Matrix of requirements relations
4. Competitive benchmarks
5. Engineering targets

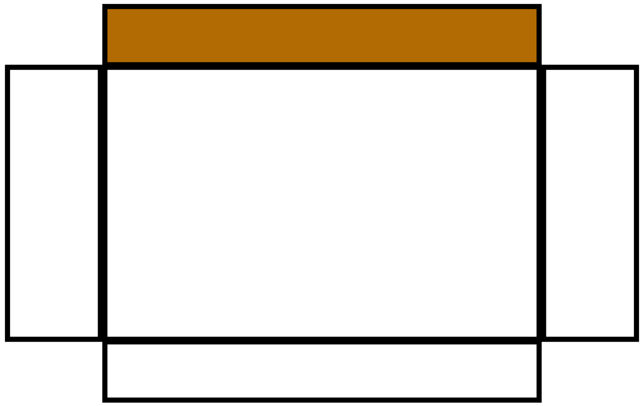


Contents of the Regions

- **Customer Requirements (1)**
  - *features or characteristics that the customer indicates as relevant*
  - *must be in customer's own words, not filtered by marketing or engineering*

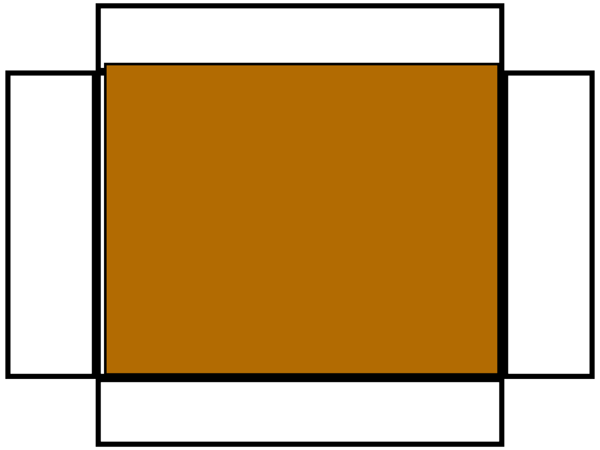


- **Engineering Metrics (2)**
  - *generated by engineering staff*
  - *quantifiable aspects of system that can contribute to satisfying customer requirements*
  - *mixture of performance parameters and design parameters*

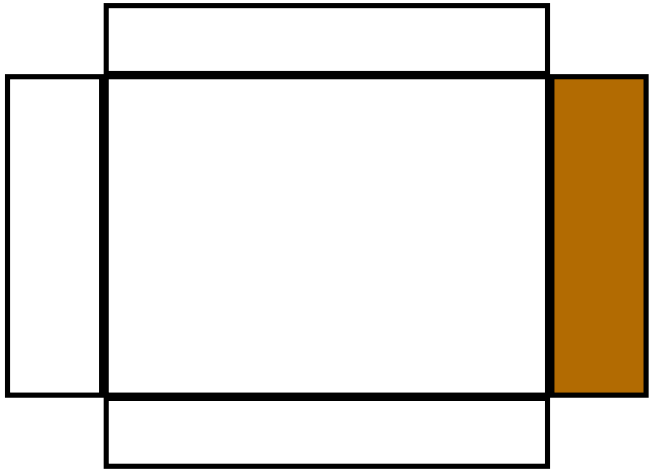


Contents of the Regions

- **Matrix of Requirements Relations (3)**
  - *"matrix"with rows of customer requirements and columns of engineering metrics*
  - *each relationship marked with an "x"*

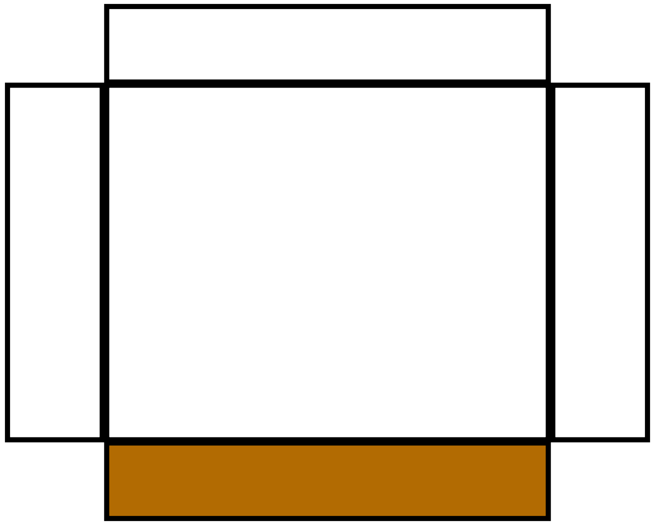


- **Competitive Benchmarking (4)**
  - *opportunity to explicitly compare your design to that of a competitor's*
  - *mark the customer requirements that are met with an "o".*



Contents of the Regions

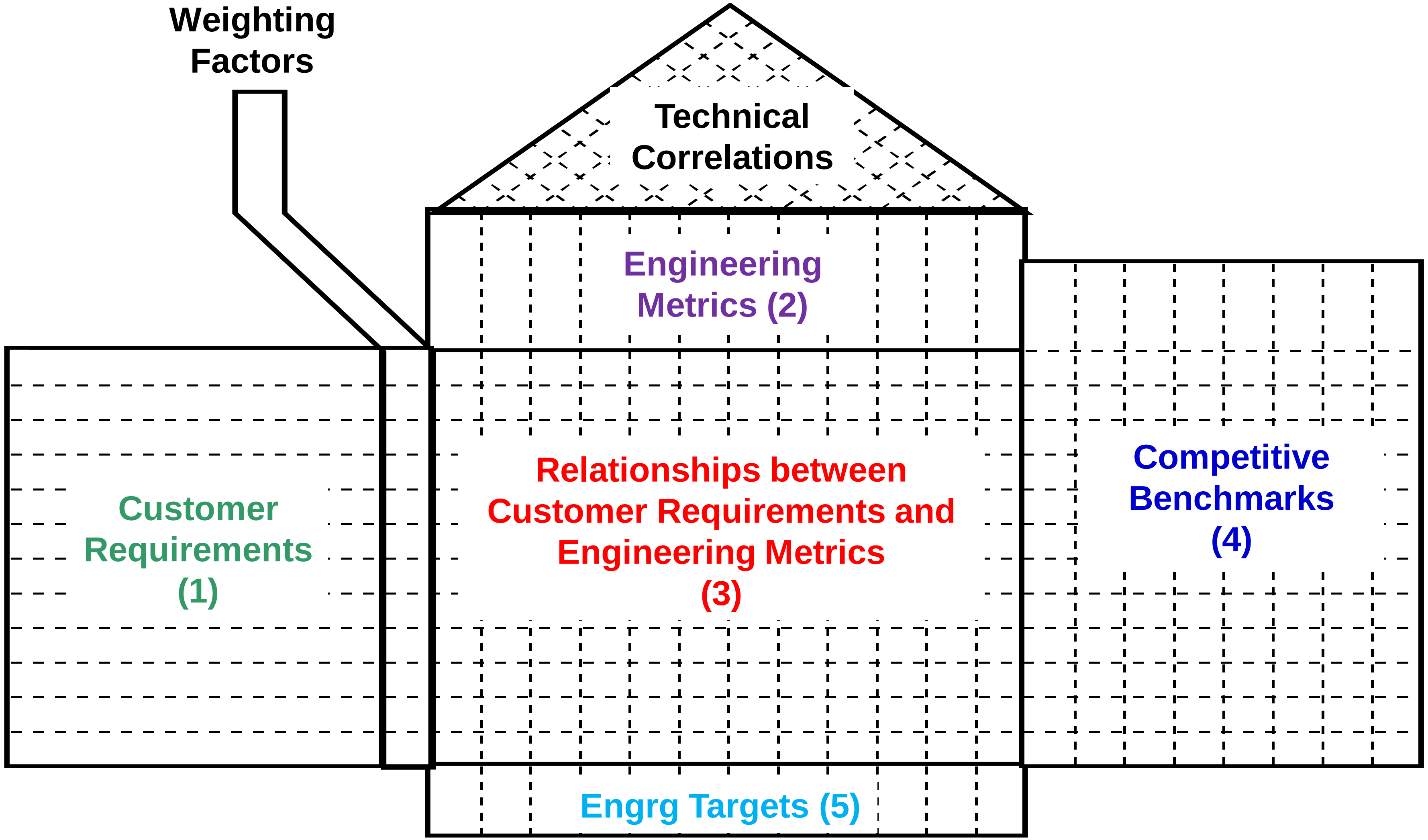
- **Engineering Targets (5)**
  - *list numerical values established for each engineering metric (2), along with units*
  - *target may be the value that the requirement must achieve in order to compete with the benchmarked products*



Variations to QFD Tables

- A region can be inserted next to (1) for weighting the relative importance the customer places on his/her requirements
- A "roof" can be put over (2) and used to show relationships between metrics (+ or -)
- Numerical values indicating relative weights may replace the "x's" and "o's" in the matrix

QFD – House of Quality



Pareto chart

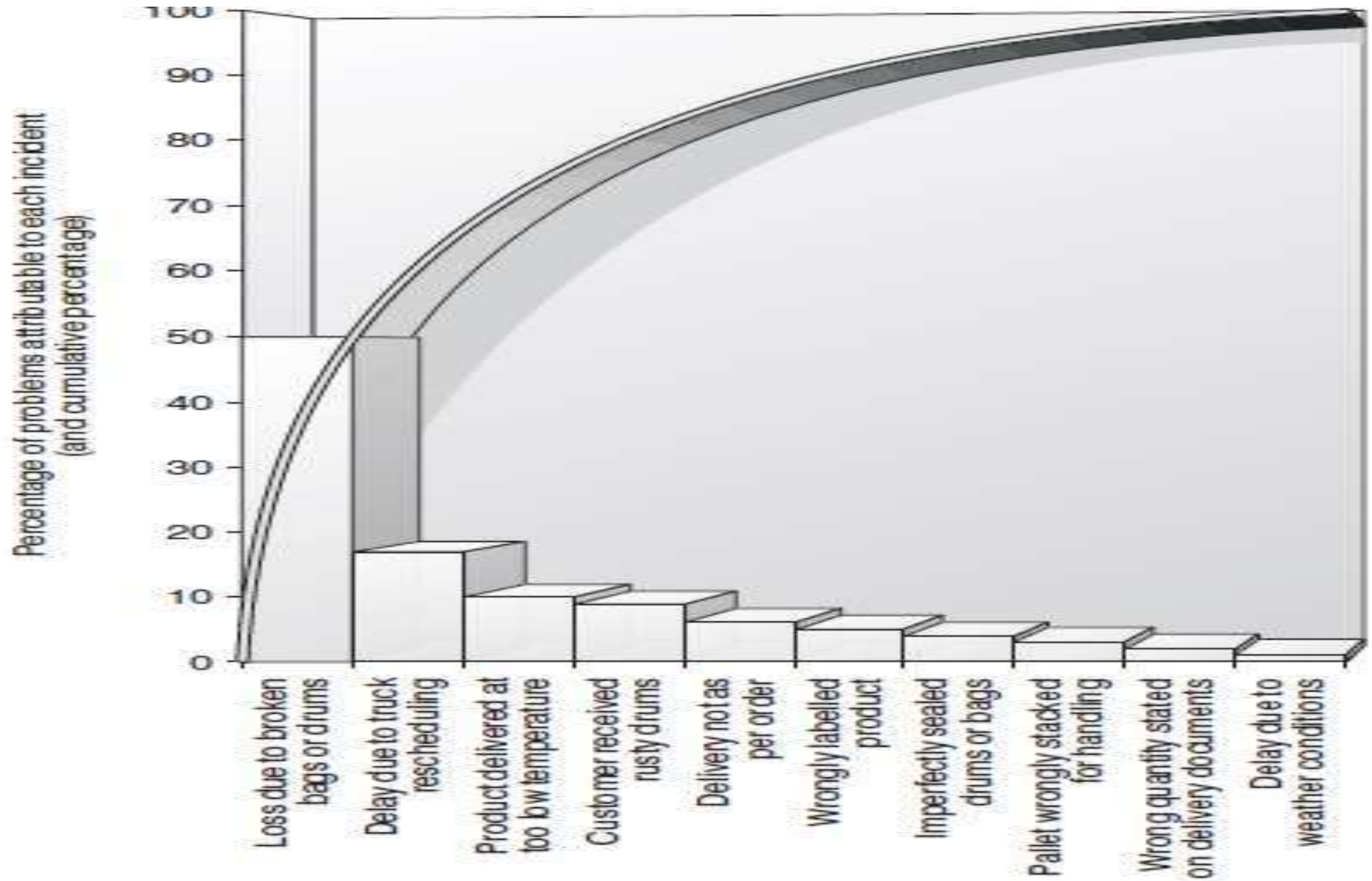
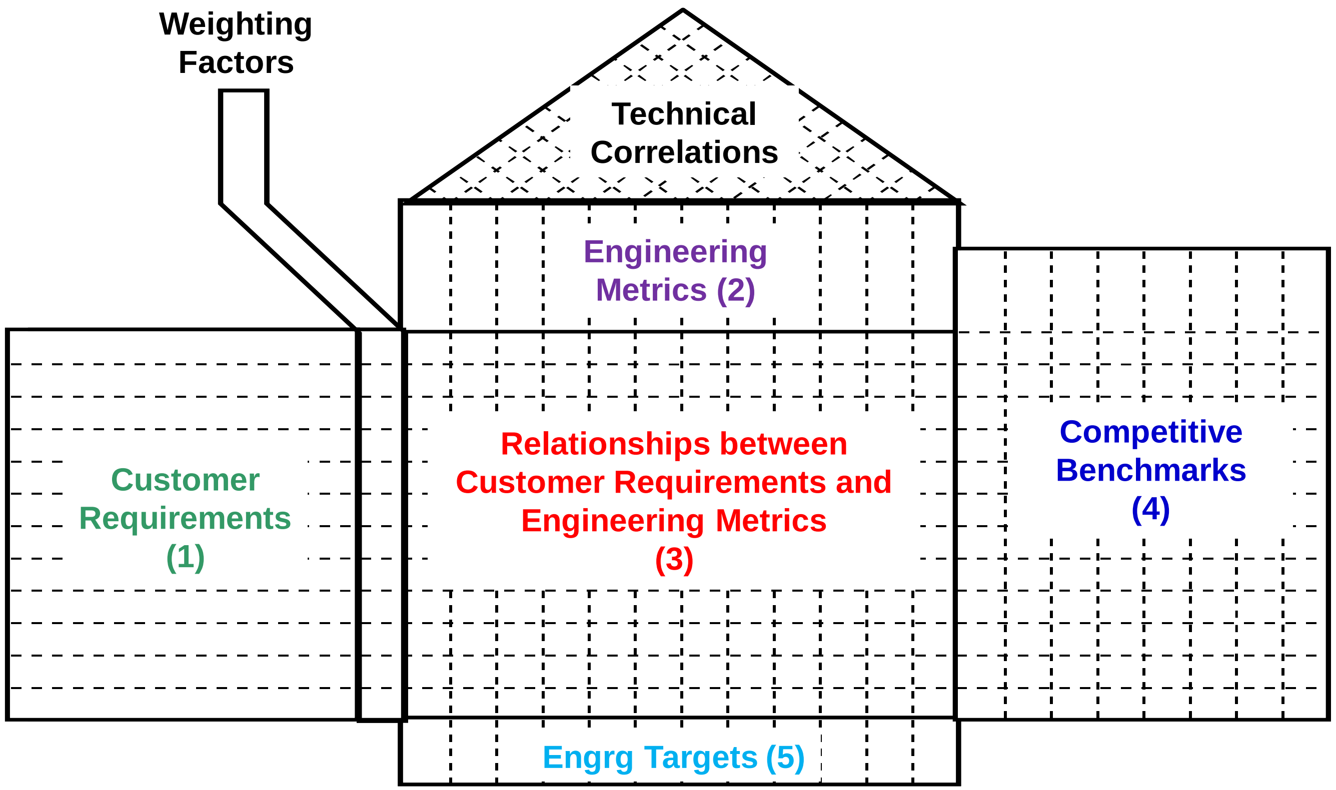
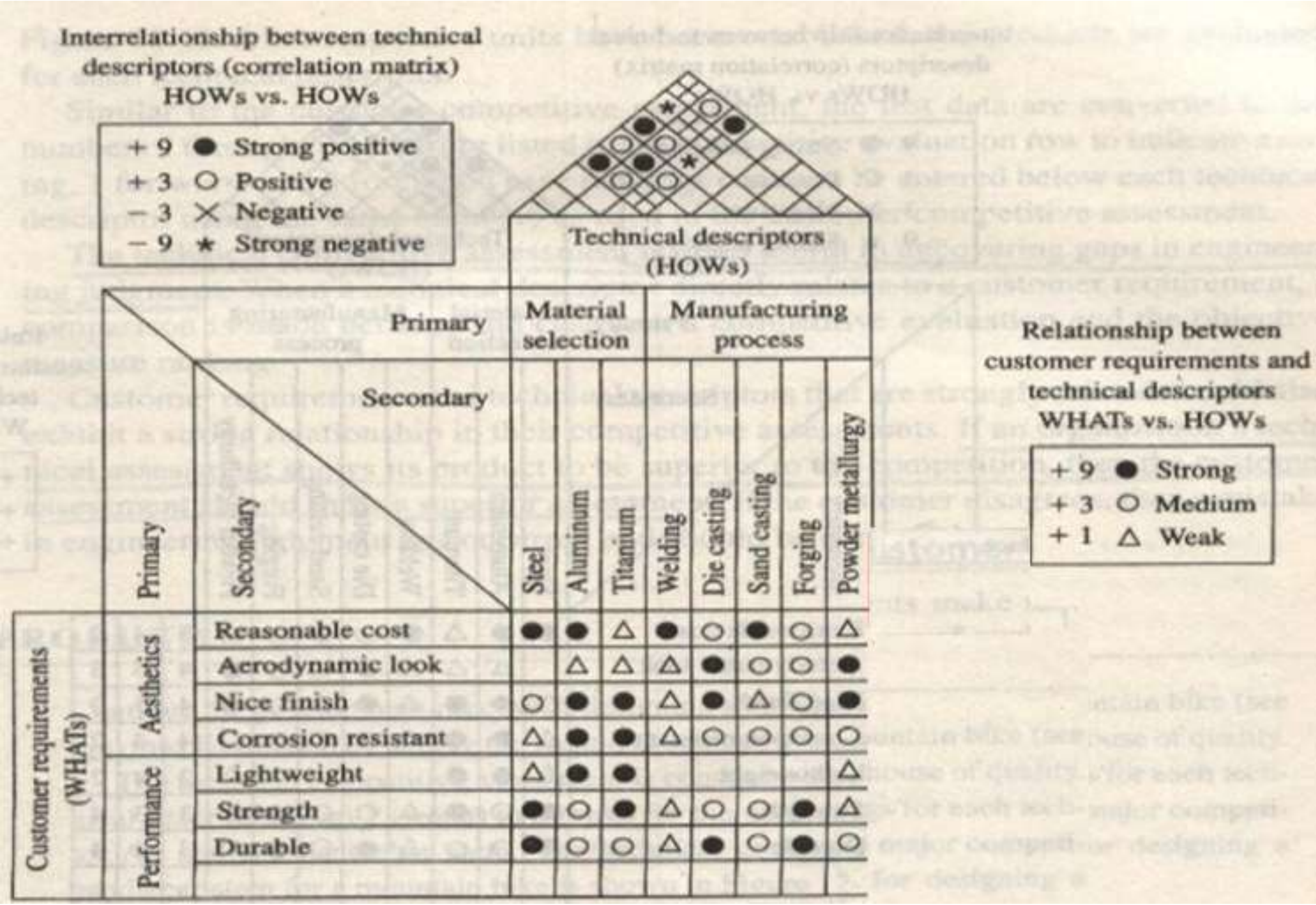


Figure 13.4

QFD – House of Quality




with large
insulated bag


Interrelationship between technical descriptors (correlation matrix) HOWs vs. HOWs
+ 9 ● Strong positive
+ 3 ○ Positive
− 3 ✕ Negative
− 9 ★ Strong negative
Technical descriptors (HOWs)
Primary
Secondary
Material selection
Manufacturing process
Steel
Aluminum
Titanium
Welding
Die casting
Sand casting
Forging
Powder metallurgy
Relationship between customer requirements and technical descriptors WHATs vs. HOWs
+ 9 ● Strong
+ 3 ○ Medium
+ 1 △ Weak
Customer requirements (WHATs)
Primary
Secondary
Aesthetics
Performance
Reasonable cost
Aerodynamic look
Nice finish
Corrosion resistant
Lightweight
Strength
Durable

Shopping cart

Critical to Quality (CTC)	Importance (VOC)	Main Basket	Seat basket	Lower shelf	Wheel hinges	Number of baskets	Wheel type	Our cart	Company A cart
Maneuverable wheels	4				9		9	4	3.5
Child seat safety	3.2	1	9		1		1	3.2	3
Large enough	3.7	9	1	9		3		3.7	4
Practical design	3.4	9	3	9	3	9	3	3.4	3
Size options	4	3	3	3		9		4	3
compartments	5	3	3	3		9		5	4
Column weight		94	70	91	49	123	49		
Rating of column weight		20%	15%	19%	10%	26%	10%		
selected metrics		2	4	3	5	1	5		

	Main Basket	Seat basket	Lower shelf	Wheel hinges	Number of baskets	Wheel type
Main Basket		--	+			
Seat basket					--	
Lower shelf				+		
Wheel hinges						++
Number of baskets						+
Wheel type						

	live Streem	electric cars	link the site with taxes centers	rating stream	refund and exchange centers	call centers	Certification to traders	fully discription	Inventory Managment system	3PL Company	3D Camera	Free Lance Drivers	online acountant	Mintotoring and Tracking System	increase number of trading centers	make deals and contract with small market
								+	-							
							+	-	-	-						
						+	-	-			-					
					-	-	-	+	-			-				
				+	+	-	+	-	-	-	-	-	+			
			-	-	-	+	-	-	-		-	+	-	+		
		-	-			+	-		-	-						
	+	-				-	-	-	-	-	-				-	-

Functional Requirements

Relative Weight	Customer Importance	Customer Requirements	live Streem	electric cars	link the site with taxes centers	rating stream	refund and exchange centers	call centers	Certification to traders	fully discription	Inventory Managment system	3PL Company	3D Camera	Free Lance Drivers	online acountant	Mintotoring and Tracking System	increase number of trading centers	make deals and contract with small market	Our Product	Sameh Mall	Carfor	Safway
		Direction of Improvemen	▲	▲	▲	▲	▲	▼	▼	▲	▼	▲	▲	▲	▲	▲	▲	▲	Customer Competitive Assessmen			
14%	9	Inability to check the q	▪	▽	▽	▪	▽	=	▪	▪	▽	▽	▪	▽	▽	▽	▽	▽	5	1	1	1
14%	9	The cost of shipping g	▽	▪	▽	▽	=	=	▽	▽	▽	▪	▽	▪	▽	▽	=	=	4	1	2	1
14%	9	knowing the final price	▽	▽	▪	▽	=	=	▽	▽	▽	▽	▽	▽	▪	▽	▽	▽	5	5	5	1
13%	8	quality of product is no	▪	▽	▽	▪	=	=	▪	▪	▽	▽	▪	▽	▽	▽	▽	▽	4	2	2	1
5%	3	refund or exchange po	▽	=	▽	=	▪	▪	▽	=	▽	▽	=	▽	=	▽	=	=	4	1	1	1
13%	8	quality of the product doe	▪	▽	▽	▪	=	▪	▪	▪	▽	▽	▪	▽	▽	▽	=	=	4	2	3	1
3%	2	Poor internet services i	▽	▽	▽	▽	=	▪	▽	▽	▽	▽	▽	▽	▽	▽	▪	▪	4	1	1	1
8%	5	lack of a comprehensiv	▪	▽	▽	▪	=	▪	▪	▪	▽	▽	▪	▽	▽	▽	=	=	5	2	3	1
3%	2	update the availability	▽	▽	▽	▽	▽	=	▽	▽	▪	▽	▽	▽	▽	▽	=	=	4	1	1	1
14%	9	The request does not a	▽	=	▽	▽	▽	=	▽	▽	=	▪	▽	▪	▽	▪	=	=	4	1	3	1
2%	1	Receive the required q	▽	▽	▽	▽	▽	▽	▽	▽	▪	▪	▽	▪	▽	▪	▽	▽	4	1	1	1
2%	1	Sometimes exposure to	▽	▽	▪	▽	▽	▽	▽	▽	▽	▽	▽	▽	▪	▽	▽	▽	4	1	1	1
2%	1	The lack of payment se	▽	▽	▪	▽	▪	▽	▽	▽	▽	▽	▽	▽	▪	▽	▽	▽	4	1	1	1
2%	1	Fail to take care of the	▽	=	▽	▽	=	▽	▽	▽	▽	▪	▽	▪	▽	▪	▽	▽	4	1	1	1
2%	1	Many customers find it	▽	▽	▽	▽	▽	▪	▽	▽	▽	▽	▽	▽	▽	▽	▪	▪	4	1	1	1
		Importance Rating Sum	482.8	261	245	492	289	489	483	492	173	358	492	358	255	245	258	258				
		Relative Weight	9%	5%	4%	9%	5%	9%	9%	9%	3%	6%	9%	6%	5%	4%	5%	5%				
		Our Product	5	5	4	5	4	4	5	5	4	5	5	4	4	4	4	4				
		Sameh Mall	1	1	1	1	1	4	1	4	1	4	1	1	4	1	3	3				
		Carfour	1	1	1	1	1	3	1	4	1	3	1	1	4	1	3	1				
		Safway	1	1	1	1	1	2	1	3	1	1	1	1	4	1	1	1				

Correlations	
Positive	+
Negative	-
No Correlation	

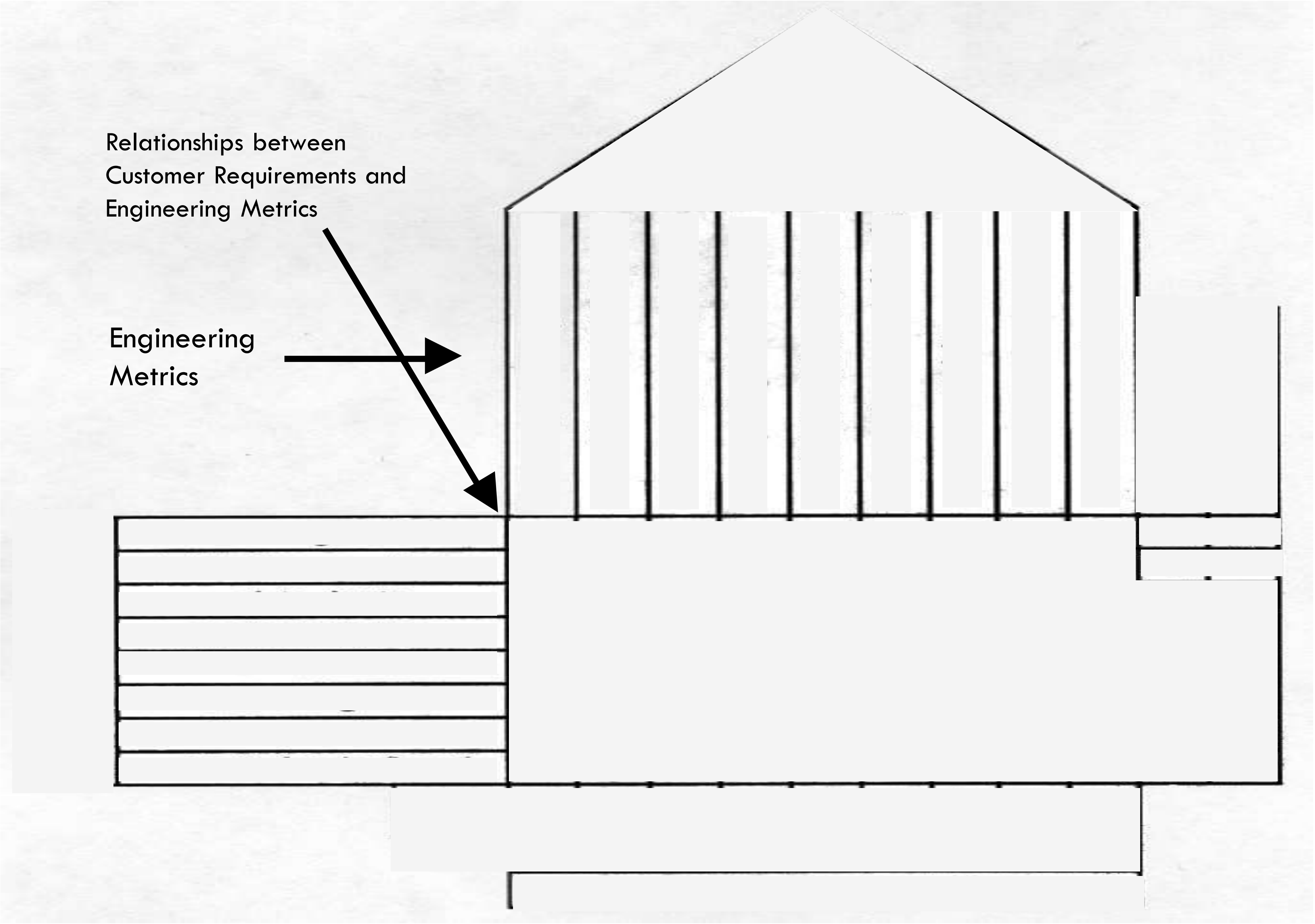
Relationships		Weight
Strong	▪	9
Medium	=	3
Weak	▽	1

Direction of Improvement	
Maximize	▲
Target	=
Minimize	▼

Example

- Goal
  - *Design an improved automobile bumper*
- Objectives
  - *Design an inexpensive front bumper to withstand a 5 mph head-on collision (concrete wall)*
  - *Bumper must be easily recyclable*
- Constraints
  - *must be installed 18" up from ground*
  - *weight $\leq$ 50 lb*
  - *must attach to mounting brackets on targeted automobile frames*

House of Quality for Automobile Bumper



Example Product

Courtesy of Specialized Bicycle Components

EXHIBIT 6-1
One of Specialized's existing mountain bikes with a suspension fork.

Phase 1: Concept Development

Identifying Product Specifications Steps

Step 0: Identify customer needs priority/importance

EXHIBIT 6-2
Customer needs for the suspension fork and their relative importance (shown in a convenient spreadsheet format).

No.		Need	Imp.
1	The suspension	reduces vibration to the hands.	3
2	The suspension	allows easy traversal of slow, difficult terrain.	2
3	The suspension	enables high-speed descents on bumpy trails.	5
4	The suspension	allows sensitivity adjustment.	3
5	The suspension	preserves the steering characteristics of the bike.	4
6	The suspension	remains rigid during hard cornering.	4
7	The suspension	is lightweight.	4
8	The suspension	provides stiff mounting points for the brakes.	2
9	The suspension	fits a wide variety of bikes, wheels, and tires.	5
10	The suspension	is easy to install.	1
11	The suspension	works with fenders.	1
12	The suspension	instills pride.	5
13	The suspension	is affordable for an amateur enthusiast.	5
14	The suspension	is not contaminated by water.	5
15	The suspension	is not contaminated by grunge.	5
16	The suspension	can be easily accessed for maintenance.	3
17	The suspension	allows easy replacement of worn parts.	1
18	The suspension	can be maintained with readily available tools.	3
19	The suspension	lasts a long time.	5
20	The suspension	is safe in a crash.	5

Phase 1: Concept Development

Identifying Product Specifications Steps

Step 1a: Set metrics

Metric No.	Need Nos.	Metric	Imp.	Units
1	1, 3	Attenuation from dropout to handlebar at 10 Hz	3	dB
2	2, 6	Spring preload	3	N
3	1, 3	Maximum value from the Monster	5	g
4	1, 3	Minimum descent time on test track	5	s
5	4	Damping coefficient adjustment range	3	N-s/m
6	5	Maximum travel (26-in. wheel)	3	mm
7	5	Rake offset	3	mm
8	6	Lateral stiffness at the tip	3	kN/m
9	7	Total mass	4	kg
10	8	Lateral stiffness at brake pivots	2	kN/m
11	9	Headset sizes	5	in.
12	9	Steertube length	5	mm
13	9	Wheel sizes	5	List
14	9	Maximum tire width	5	in.
15	10	Time to assemble to frame	1	s
16	11	Fender compatibility	1	List
17	12	Instills pride	5	Subj.
18	13	Unit manufacturing cost	5	US$
19	14	Time in spray chamber without water entry	5	s
20	15	Cycles in mud chamber without contamination	5	k-cycles
21	16, 17	Time to disassemble/assemble for maintenance	3	s
22	17, 18	Special tools required for maintenance	3	List
23	19	UV test duration to degrade rubber parts	5	hr
24	19	Monster cycles to failure	5	Cycles
25	20	Japan Industrial Standards test	5	Binary
26	20	Bending strength (frontal loading)	5	kN

EXHIBIT 6-4 List of metrics for the suspension. The relative importance of each metric and the units for the metric are also shown. "Subj." is an abbreviation indicating that a metric is subjective.

Phase 1: Concept Development

Identifying Product Specifications Steps

Step 1b: Relate Needs of customer with engineering requirements

Need		1 Attenuation from dropout to handlebar at 10 Hz	2 Spring preload	3 Maximum value from the Monster	4 Minimum descent time on test track	5 Damping coefficient adjustment range	6 Maximum travel (26-in. wheel)	7 Rake offset	8 Lateral stiffness at the tip	9 Total mass	10 Lateral stiffness at brake pivots	11 Headset sizes	12 Steertube length	13 Wheel sizes	14 Maximum tire width	15 Time to assemble to frame	16 Fender compatibility	17 Instills pride	18 Unit manufacturing cost	19 Time in spray chamber without water entry	20 Cycles in mud chamber without contamination	21 Time to disassemble/assemble for maintenance	22 Special tools required for maintenance	23 UV test duration to degrade rubber parts	24 Monster cycles to failure	25 Japan Industrial Standards test	26 Bending strength (frontal loading)
1	Reduces vibration to the hands	•		•	•																						
2	Allows easy traversal of slow, difficult terrain		•																								
3	Enables high-speed descents on bumpy trails	•		•	•																						
4	Allows sensitivity adjustment					•																					
5	Preserves the steering characteristics of the bike						•	•																			
6	Remains rigid during hard cornering		•						•																		
7	Is lightweight									•																	
8	Provides stiff mounting points for the brakes										•																
9	Fits a wide variety of bikes, wheels, and tires											•	•	•	•												
10	Is easy to install															•											
11	Works with fenders																•										
12	Instills pride																	•									
13	Is affordable for an amateur enthusiast																		•								
14	Is not contaminated by water																			•							
15	Is not contaminated by grunge																				•						
16	Can be easily accessed for maintenance																					•					
17	Allows easy replacement of worn parts																					•	•				
18	Can be maintained with readily available tools																						•				
19	Lasts a long time																							•	•		
20	Is safe in a crash																									•	•

EXHIBIT 6-5 The needs-metrics matrix.

Phase 1: Concept Development

Identifying Product Specifications Steps

Step 2: Collect Competitive Benchmarking Information

Metric Based

Metric No.	Need Nos.	Metric	Imp.	Units	ST Tritrack	Maniray 2	Rox Tahx Quadra	Rox Tahx Ti 21	Tonka Pro	Gunhill Head Shox
1	1, 3	Attenuation from dropout to handlebar at 10 Hz	3	dB	8	15	10	15	9	13
2	2, 6	Spring preload	3	N	550	760	500	710	480	680
3	1, 3	Maximum value from the Monster	5	g	3.6	3.2	3.7	3.3	3.7	3.4
4	1, 3	Minimum descent time on test track	5	s	13	11.3	12.6	11.2	13.2	11
5	4	Damping coefficient adjustment range	3	N-s/m	0	0	0	200	0	0
6	5	Maximum travel (26-in. wheel)	3	mm	28	48	43	46	33	38
7	5	Rake offset	3	mm	41.5	39	38	38	43.2	39
8	6	Lateral stiffness at the tip	3	kN/m	59	110	85	85	65	130
9	7	Total mass	4	kg	1.409	1.385	1.409	1.364	1.222	1.100
10	8	Lateral stiffness at brake pivots	2	kN/m	295	550	425	425	325	650
11	9	Headset sizes	5	in.	1.000 1.125	1.000 1.125 1.250	1.000 1.125	1.000 1.125 1.250	1.000 1.125	NA
12	9	Steertube length	5	mm	150 180 210 230 255	140 165 190 215	150 170 190 210	150 170 190 210 230	150 190 210 220	NA
13	9	Wheel sizes	5	List	26 in.	26 in.	26 in.	26 in. 700C	26 in.	26 in.

EXHIBIT 6-6 Competitive benchmarking chart based on metrics.

Phase 1: Concept Development

Identifying Product Specifications Steps

Step 2: Collect Competitive Benchmarking Information

Scoring Based

No.	Need	Imp.	ST Tritrack	Maniray 2	Rox Tahx Quadra	Rox Tahx Ti 21	Tonka Pro	Gunhill Head Shox
1	Reduces vibration to the hands	3	•	••••	••	•••••	••	•••
2	Allows easy traversal of slow, difficult terrain	2	••	••••	•••	•••••	•••	•••••
3	Enables high-speed descents on bumpy trails	5	•	•••••	••	•••••	••	•••
4	Allows sensitivity adjustment	3	•	••••	••	•••••	••	•••
5	Preserves the steering characteristics of the bike	4	••••	••	•	••	•••••	•••••
6	Remains rigid during hard cornering	4	•	•••	•	•••••	•	•••••
7	Is lightweight	4	•	•••	•	•••	••••	•••••
8	Provides stiff mounting points for the brakes	2	•	••••	•••	•••	•••••	••
9	Fits a wide variety of bikes, wheels, and tires	5	••••	•••••	•••	•••••	•••	•
10	Is easy to install	1	••••	•••••	••••	••••	•••••	•
11	Works with fenders	1	•••	•	•	•	•	•••••
12	Instills pride	5	•	••••	•••	•••••	•••	•••••
13	Is affordable for an amateur enthusiast	5	•••••	•	•••	•	•••	••
14	Is not contaminated by water	5	•	•••	••••	••••	••	•••••
15	Is not contaminated by grunge	5	•	•••	•	••••	••	•••••
16	Can be easily accessed for maintenance	3	••••	•••••	••••	••••	•••••	•
17	Allows easy replacement of worn parts	1	••••	•••••	••••	••••	•••••	•
18	Can be maintained with readily available tools	3	•••••	•••••	•••••	•••••	••	•
19	Lasts a long time	5	•••••	•••••	•••••	•••	•••••	•
20	Is safe in a crash	5	•••••	•••••	•••••	•••••	•••••	•••••

EXHIBIT 6-7 Competitive benchmarking chart based on perceived satisfaction of needs. (Scoring more "dots" corresponds to greater perceived satisfaction of the need.)

Phase 1: Concept Development Identifying Product Specifications Steps

Step 3: Set Ideal and Marginally Acceptable Target Values

➢ Two types of target value are useful:

1. The **ideal value** is the best result the team could hope for.
2. The **marginally acceptable value** is the value of the metric that would just barely make the product commercially viable.

Metric No.	Need Nos.	Metric	Imp.	Units	Marginal Value	Ideal Value
1	1, 3	Attenuation from dropout to handlebar at 10 Hz	3	dB	>10	>15
2	2, 6	Spring preload	3	N	480–800	650–700
3	1, 3	Maximum value from the Monster	5	g	<3.5	<3.2
4	1, 3	Minimum descent time on test track	5	s	<13.0	<11.0
5	4	Damping coefficient adjustment range	3	N-s/m	0	>200
6	5	Maximum travel (26-in. wheel)	3	mm	33–50	45
7	5	Rake offset	3	mm	37–45	38
8	6	Lateral stiffness at the tip	3	kN/m	>65	>130
9	7	Total mass	4	kg	<1.4	<1.1
10	8	Lateral stiffness at brake pivots	2	kN/m	>325	>650
11	9	Headset sizes	5	in.	1.000 1.125	1.000 1.125 1.250
12	9	Steertube length	5	mm	150 170 190 210	150 170 190 210 230
13	9	Wheel sizes	5	List	26 in.	26 in. 700C
14	9	Maximum tire width	5	in.	>1.5	>1.75
15	10	Time to assemble to frame	1	s	<60	<35
16	11	Fender compatibility	1	List	None	All
17	12	Instills pride	5	Subj.	>3	>5

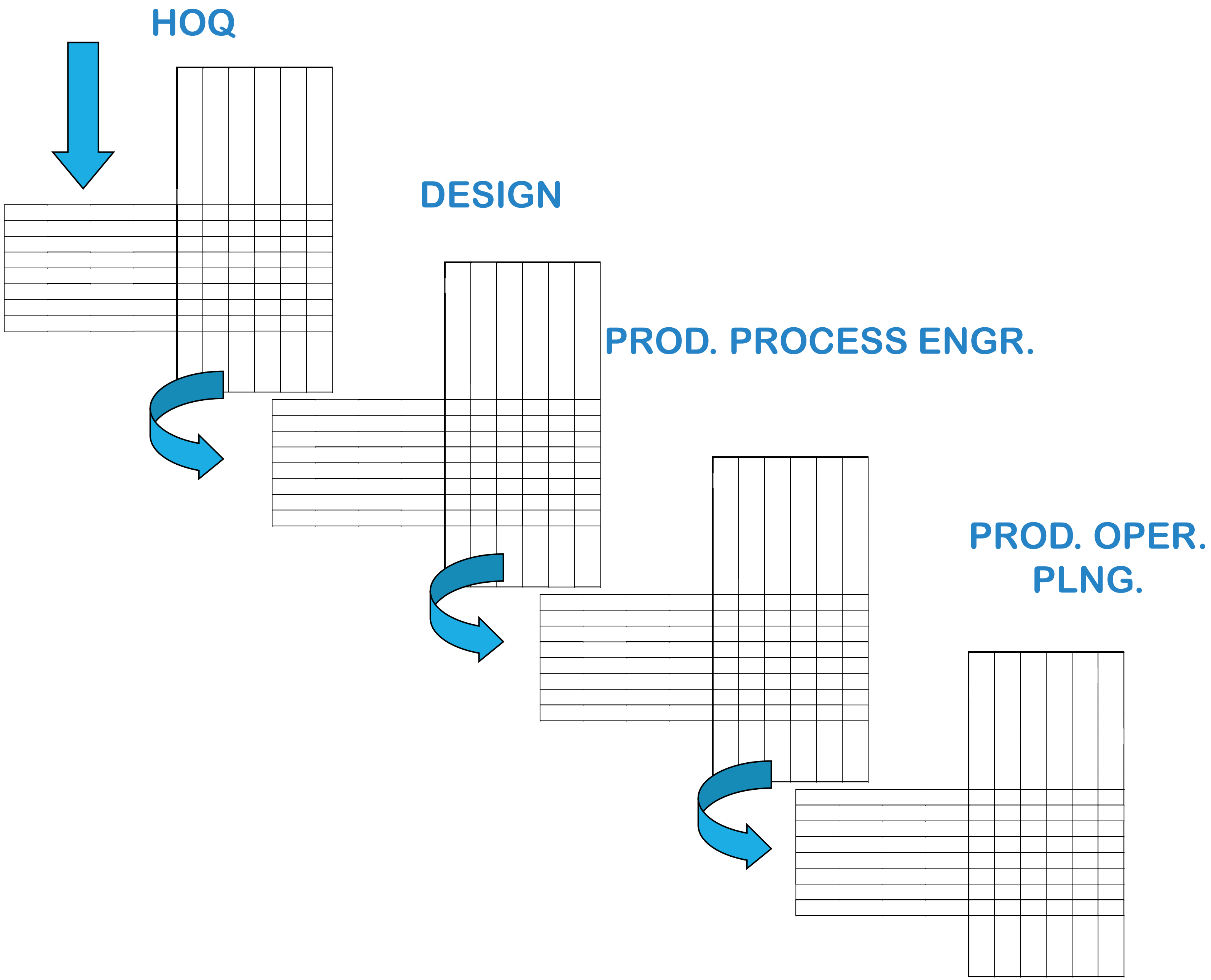
Step 4: Reflect on the Results and the Process

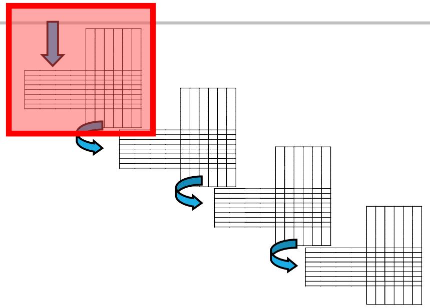
ENHANCED QUALITY FUNCTION DEPLOYMENT
4 phase

- Enhanced Quality Function Deployment is a broader QFD framework that applies a system perspective recognizing the need to decompose more complex products into subsystems and assemblies with supporting deployment matrices and concept selection matrices.

Example
Selecting a Xerox Copier based on Office needs.

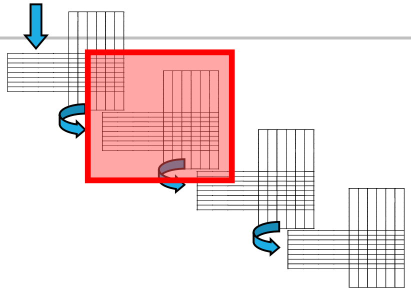
Phase 1	Office Employee Needs
Phase 2	Copier system Technical Requirements
Phase 3	Subsystem Requirements
Phase 4	Copying Operation


HOQ
DESIGN
PROD. PROCESS ENGR.
PROD. OPER.
PLNG.



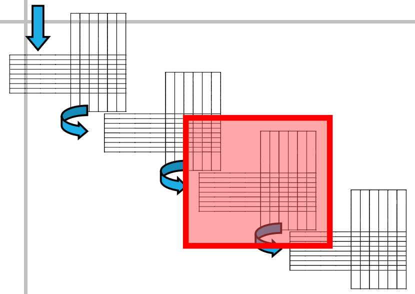
			Total System Expectations									
			Misfeed rate	Multifeed rate	Jam rate	Copy rate	Jam clearance time	Paper damage rate	UMC			
	Voice of the Customer		A	B	C	D	E	F	G			
1	Always get a copy		O									
2	No blank sheets			O								
3	No jams to clear			O	O							
4	Medium speed					O						
5	Copies on cheap paper		O	O	O							
6	Copies on heavy paper		O		O							
7	Copies on light paper			O	O							
8	Easy to clear jams						O					
9	No paper damage							O				
10	Low cost								O			
			$<50/10^6$	$<50/10^6$	$<100/10^6$	70+2/-0CPM	<20 sec	$<100/10^6$	<$6000			

Core of House of Quality Example: Xerox Copier



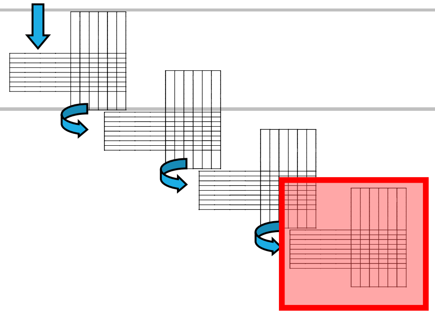
			System Design Decisions Subsystem Expectations									
			Misfeed rate	Multifeed rate	Jam rate	Copy rate	Jam clearance time	Paper damage rate	UMC	Paper speed	Delivery time	
	Total System Expectations		1	2	3	4	5	6	7	8	9	10
A	Misfeed rate	<50/10^6	O									
B	Multifeed rate	<50/10^6		O								
C	Jam rate	<100/10^6			O					O	O	
D	Copy rate	70+2/-0CPM				O				O		
E	Jam clearance time	<20 sec					O					
F	Paper damage rate	<100/10^6						O			O	
G	UMC	<$6000							O			
			<50/10^6	<50/10^6	<30/10^6	70+2/-0CPM	<20 sec	<40/10^6	<$250	11.7±3 ips	141±10 msec	

Total System Design Matrix



			Subsystem Design Decisions Piece-Part Expectations									
			Retard friction coefficient	Retard brake torque	Retard radius	Normal stack force	Enhanced stack force	Trigger time	TAR action time	TAR surface speed	Jam clearance strategy	UMC breakdown
	Subsystem Expectations		A	B	C	D	E	F	G	H	I	J
1	Misfeed rate	$<50/10^6$	O			O		O				
2	Multifeed rate	$<50/10^6$	O	O	O		O	O		O		
3	Jam rate	$<30/10^6$					O					
4	Copy rate	70+2/-0CPM							O			
5	Jam clearance time	<20 sec									O	
6	Paper damage rate	$<40/10^6$	O									
7	UMC	<$250										O
8	Paper speed	11.7±3 ips								O		
9	Delivery time	141±10 msec							O			
			1.50±0.25	40±4 in-oz	0.880±0.005 in	0.3 lb	0.7 lb	100 msec	120 msec	11.7±0.3 ips	Ref. Y	Ref. Z

Subsystem Design Matrix



	Copying Operation		MPU	MPU density	Friction brake	Retard radius						
		Piece-Part Design Decisions, Production Process Requirements	1	2	3	4						
A	Retard friction coefficient	1.50±0.25	O	Δ								
B	Retard brake torque	40±4 in-oz			O							
C	Retard radius	0.880±0.005 in				O						
			Grade X	20 lb/ft^3	Brand C	0.880±0.005						

Copying Operation