

Detailed Design Package

Module 2C Acceptable Quality Level

Motivation

Why is this module important?



- Most scale-up operations fail because of poor process design; it is critical that all the failure modes are identified and eliminated during the design and prototyping stages so nothing unexpected happens during scale-up
- □ Supplier quality can make a big difference for scale
- ☐ The amount of content from suppliers, in any product (with just a moderate number of components), can range from 50% to 70%
- ☐ Customer requirements may be very vague; you need a tool to translate those vague words to engineering specifications

Examples: Both the 2016 Takata Airbag recall and the 2009 Toyota Acceleration Pedal recall were due to supplier's product quality failure

Motivation

Why is customer input important?



□ Capturing the voice of the customer very early on is critical to product development because it will inform all the subsequent decisions, such as materials selection (Module 3B), process selection (Module 3C), and partnership selection (Module 5A)

Module Outline



- ☐ Learning objectives
- Introduction to quality functional deployment (QFD)
 - —A real world application of QFD (on a separate Excel file)
- □ Role of suppliers in quality management
 - —Supplier integration during design
 - —Supplier quality management checklist
- Process failure modes and effect analysis (PFMEA)
 - —What is PFMEA?
 - —How to conduct PFMEA

Learning Objectives



- □ LO1. Translate functional requirements into quality specifications
- □ LO2. Understand role of suppliers on necessary quality levels
- □ LO3. Construct process failure modes and effect analysis (PFMEA)

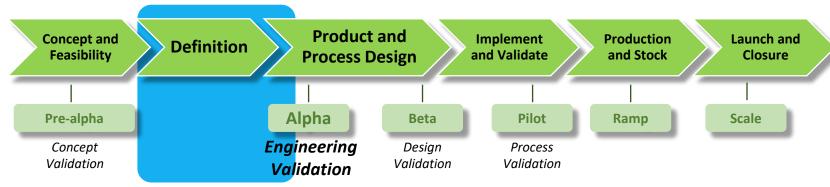
What This Module Addresses



- □ How does a company translate customer needs to a technical specifications by using a QFD analysis tool?
- What roles do suppliers play in managing quality?
- What are the benefits of supplier integration during design process?
- □ How to identify potential process failures before they occur?

QFD And PFMEA

Where does this fit into the development cycle?

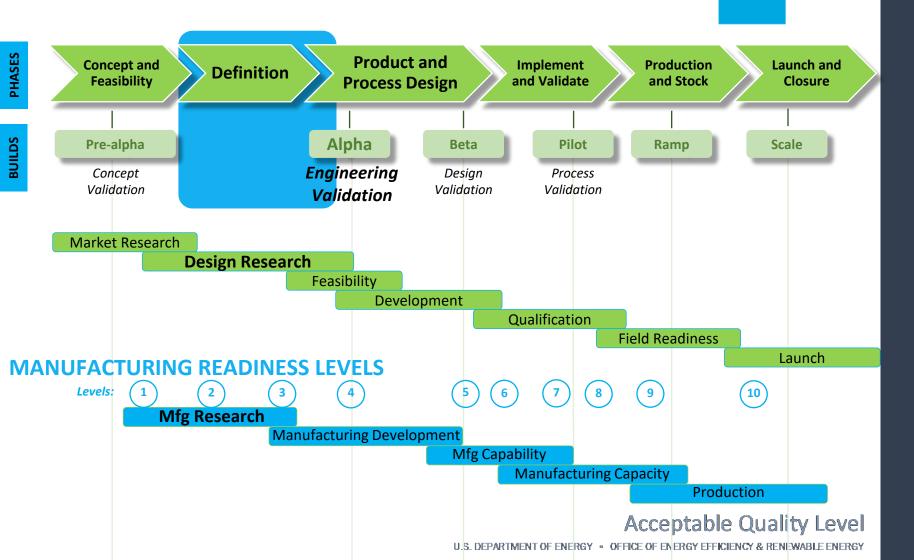


- □ Quality function deployment (QFD) is a tool to translate customer requirements into engineering specifications
- □ Clearly identifying the role of suppliers and integrating them early on during the product-development process can help you launch the product on time at lower costs
- □ Identifying the potential failure modes of your future manufacturing process at the definition stage can result in significant savings due to reduction in down time and defective products

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QFD And PFMEA

Where does this fit into the development cycle?



Basics



- □ Quality functional deployment (QFD) is a quality-planning tool originally developed in Japan in the 1960s, but is now widely used in many manufacturing and service companies in the U.S. and around the world
- ☐ It is a powerful tool for translating customer requirements into engineering specifications
- ☐ It consists of multiple steps that are organized in the form of relationship matrices, also known as house of quality (HOQ)

QFD/House Of Quality

Overview

- ☐ It requires significant time and commitment from top management
- □ Focuses on meeting or exceeding customer needs by using their actual statements (i.e., the "Voice of the customer")

 "House of Quality"

Customer

requirements

(voice of the

customer)

- □ It is multi-functional teamwork involving marketing, design, quality, finance, and manufacturing personnel
- ☐ It uses a comprehensive matrix called "House of Quality" or HOQ for documenting and analyzing the information

□ Depending upon the need, the number of matrices in a QFD analysis can vary

Interrelationship between technical descriptors

Technical descriptors (voice of the organization)

Relationship between requirements and descriptors

Prioritized customer requirements

(HOQ)

Prioritized technical descriptors

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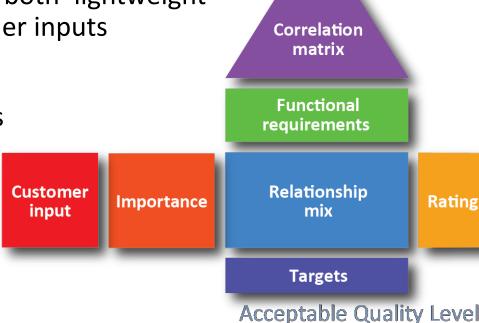
House Of Quality

Relationship matrix

- Displays relationship between customer inputs and functional requirements
- Usually indicates strength of the relationship (strong, medium, weak), which can be used to make trade-offs later

Example: Mass might affect both 'lightweight' and 'easy to handle' customer inputs

- ☐ Targets:
- ☐ First step is to assign units
- □ Define target ranges
- □ Define ideal value or direction of the current value



Ratings

House Of Quality

Correlation matrix

- ☐ Displays relationship among functional requirements (correlation matrix)
- ☐ Shows strength of correlation, which can be used to make tradeoffs later

Customer

input

Importance

■ Where physics and engineering govern

Example: automotive cabin volume is positively correlated with wheel base and width

Ratings:

- Used to rate competitive products
- Can also be used to evaluate alternative concepts

Correlation matrix

Functional requirements

Relationship mix

Ratings

Targets

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Step-by-step

7

- 1. Customer requirements
- 2. Regulatory requirements
- 3. Customer importance ratings
- 4. Customer rating of competition
- 5. Identify technical descriptors
- 6. Identify direction of improvement

Step-by-step (cont.)



- 7. Construct relationship matrix between customer inputs and technical descriptors
- 8. Assess organizational difficulty
- Conduct engagement assessment considering technical difficulty
- 10. Set target values for technical descriptors
- 11. Construct correlation matrix among the technical descriptors

To go through these steps, download the Excel file "QFD Illustration with Real-World Example" provided in the resource library

Exercise





Translating voice of the customer to improve the design of a refrigerator

Step 1 – Gather customer requirements





Enlarged on next page and printable from library

□ The customer inputs are gathered through a survey or focus group of customers and the phase documents all the customer requirements, also know as 'voice of the customer'

Low energy consumption
Quiet
Maintains temperature
Preserves food & freshness

Maximize storage space
Flexibility for changing storage needs
Easy access & visibility
Easy to clean
Handles large containers & items

Reliable, doesn't break
Easy & low cost to service
Easy to deliver & install
Fits in kitchen space
Coordinates with kitchen décor
Dispenses purified water
Provides & dispenses purified ice

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Step 1 – Gather customer requirements (cont.)

Operations	Low energy consumption Quiet Maintains temperature Preserves food & freshness
Storage	Maximize storage space Flexibility for changing storage needs Easy access & visibility Easy to clean Handles large containers & items
Reliability	Reliable, doesn't break Easy & low cost to service
Kitchen	Easy to deliver & install First in kitchen space Coordinates with kitchen décor
Dispense	Dispenses purified water Provides & dispenses purified ice
\$	Low price



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Step 2 – List regulatory requirements



- □ In this case, since there are no regulatory requirements, we can skip this step and go directly to Step 3
- ☐ However, if there are any regulator requirements, they will be listed in the "customer inputs" column

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Step 3 – Provide customer importance ratings





Customer Inputs	Priority

- ☐ On a scale from 1-5, customers then rate the importance of each requirement
- ☐ This number will be used later in the relationship matrix

Low energy consumption Maintains temperature 3 Preserves food & freshness Maximize storage space 3 Flexibility for changing storage needs Easy access & visibility Easy to clean 4 Handles large containers & items Reliable, doesn't break 3 Easy & low cost to service 1 4 Coordinates with kitchen décor 3 Dispenses purified water 3 Provides & dispenses purified ice

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Step 4 – Gather customer rating of competition



	Customer Inputs	Priority	 □ Customers are asked to rate the product/service in relation to the competition □ Additional room can be added for sales opportunities, goals for 	Your Company (U)	Maytag-M	vVhirlpool (VV)	GE (G) Frigidaire (F)	Amana (A)
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erati	Quiet Maintains temperature	3	continuous improvement, customer	5	3	4	4 :	3 3
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en	Easy to deliver & install	1		5	2	2	2	2 2
Citch	Fits in kitchen space	5		2	1	5	5	1 4
χ.	Coordinates with kitchen décor Dispenses purified water	3		2	3	5	5	3 3
(I)	Provides & dispenses purified ice	3		3	3	5	4	3 3
	Low price	3		4	2	3	3	5 5

Step 5 – Identify technical descriptors

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	Easy to clean	2			Ωr	ngi	nc	Ωr	,,																						5	2	2	2	2	2
	Handles large containers & items	4	H		CI	ıgı	110	וס																						\vdash	1	4	3	3	4	3
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benchmarked against the competition

Step 5 – Identify technical descriptors (cont.)



Customer Inputs	1	
Priority		
Compressor energy efficiency rating	Freezer width	Your Company (U)
Insulation Efficiency	Refrigerator shelf depth & width	
Noise measurement-front	Freezer shelf height	M aytag-M
Refrig.temp.range (on/off cycle)	Door tray depth	VVhirlpool (VV)
Refrig. temp. variation	Warranty period (years)	GE (G)
Refrig. cooling speed (from 30°C to 5°C)	Water filter replacement time & cost	Frigidaire (F)
Freezer.temp.range (on/off cycle)	10 years service contract cost	
Freezer.temp.variation	Time to disassb & reassb door	Amana (A)
Freezer cooling speed (from 30°C to -15°C)	Refrigerator depth	
Volume efficiency (total/usable)	Stainless & trim panel option prices	
% Shelf & tray area adjustable	Focus group rating - appearance	
Drawer/shelf pull force	Water temperature	
# of visibility features	Water filter indicator & life	
Dis-arry & re-assy time for cleaning	Ice produced daily	
% of features rated easy to clean	Manufacturing cost	
Freezer width	No. of adjustable temp. drawers	Accentable Quali

Step 6 – Identify direction of improvement

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Step 7 – Construct relationship matrix between customer inputs and technical descriptors



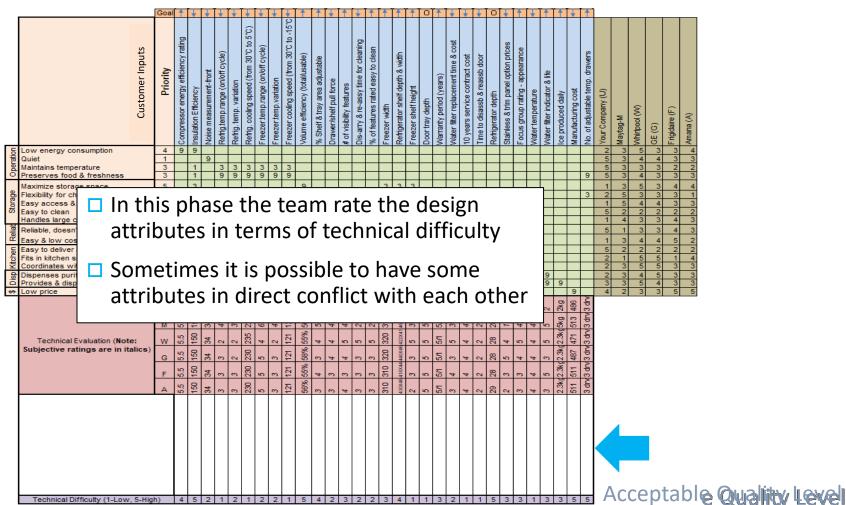
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Step 8 – Assess organizational difficulty



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	Customer Inputs	Priority	Compressor energy efficiency rating	Insulation Efficiency	Noise measurement-front	Refrig.temp.range (on/off cycle)	Refrig. temp. variation Refrig. cooling speed (from 30°C to 5°C)	Freezer.temp.range (on/off cycle)	Freezer.temp.variation	Freezer cooling speed (from 30°C to -15°C)	Volume efficiency (total/usable)	% Shelf & tray area adjustable	Drawer/shelf pull force	# of visibility features	Dis-arry & re-assy time for cleaning	% of features rated easy to clean	Freezer width	Refrigerator shelf depth & width	Freezer shelf height	Door tray depth	Warranty period (years)	Water filter replacement time & cost	Time to disassb & reassb door	Refrigerator depth	Stainless & trim panel option prices	Focus group rating - appearance		Water filter indicator & life	Ice produced daily	Manufacturing cost	No. of adjustable temp. drawers	Your Company (U)	Maytag-M	Whirlpool (W)	GE (G)	Frigidaire (F)	Amana (A)
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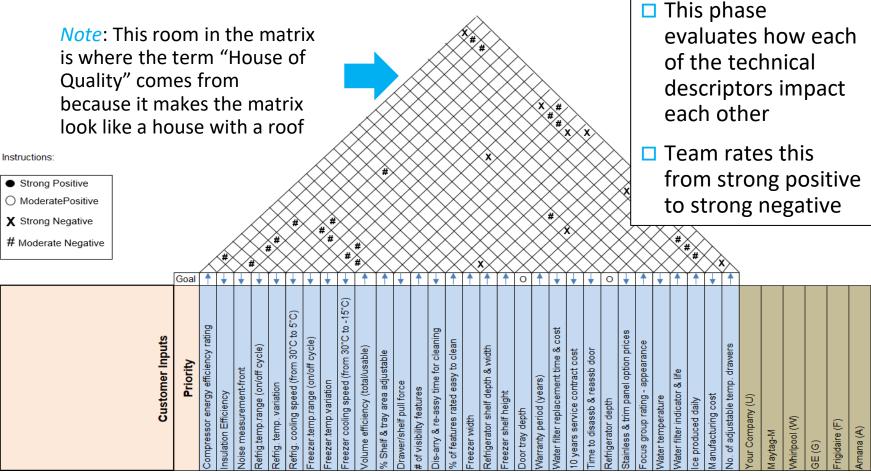
Step 9 – Conduct engagement assessment considering technical difficulty

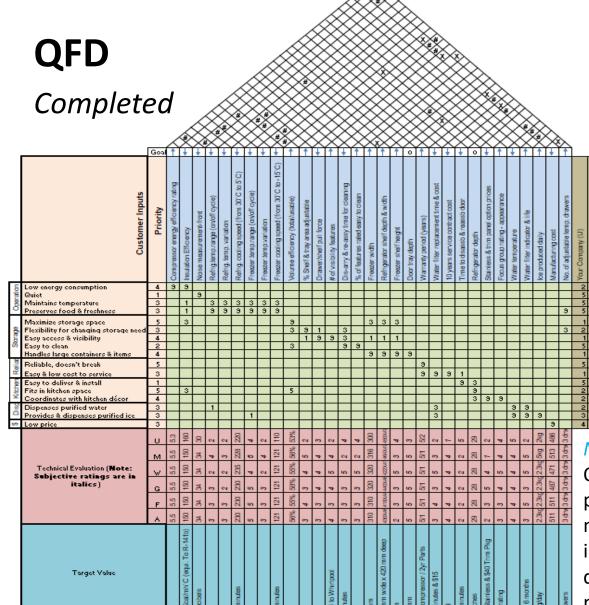


Step 10 – Set target values for technical descriptors

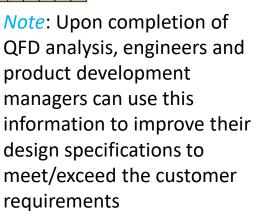
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	Customer Inputs	Priority	© Compressor energy efficiency rating	o Insulation Efficiency Noise measurement front	Refrig temp.range (on/off cycle)	Refrig. temp. variation	Refrig. cooling speed (from 30°C to 5°C)	Freezer.temp.variation	Freezer cooling speed (from 30°C to -15°C	Volume efficiency (total/usable)	% Shelf & tray area adjustable	Drawer/shelf pull force	Pis-arry & re-assy time for cleaning	% of features rated easy to clean	Refrigerator shelf depth & width	Freezer shelf height	Door tray depth Warranty period (years)	Water filter replacement time & cost	10 years service contract cost	Time to disassb & reassb door Refrigerator depth	Stainless & trim panel option prices	Focus group rating - appearance	Water filter indicator & life	Ice produced daily	Manufacturing cost	No. of adjustable temp. drawers	Your Company (U)	Maytag-M	, Whirlpool (W)	GE (G)	Frigidaire (F) Amana (A)
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Step 11 – Construct correlation matrix among the technical descriptors





Technical Difficulty (1-Low, 5-High)



Acceptable Quality Level

Product-Development Process

Integrating suppliers



- □ Every firm depends on its suppliers for parts and services to fulfill its production/technology/expertise requirements
- □ Involving suppliers early in the design process can minimize expensive engineering changes and extended lead times
- By including the suppliers in the quality assurance plan during design, an original equipment manufacturer (OEM) can leverage its design capability to gain a competitive advantage
- □ Integrating suppliers will also improve the suppliers' understanding of the overall assembly process and the quality requirements of the final product, thereby enabling them to better manage their component quality (e.g., tolerance stacking, tolerance allocation)

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Supplier Quality Checklist

Checklist – Sample questions



- □ Does the supplier measure its quality performance?
- □ Does the supplier have quality performance goals? What is current defects rate in parts per million? Is it acceptable?
- □ Does the supplier have a documented continuous quality improvement process with prior quality data?
- □ Does the supplier follow a preventive approach or only depend on inspection?
- □ Does the supplier have a formal and documented sustainable quality management program including training programs for its employees?

Supplier Quality Checklist

Checklist – Sample questions (cont.)



- □ Can the supplier demonstrate if its process is in control? What tools are used to demonstrate control?
- What is the supplier's current process capability index (Cpk) for a desired process?
- ☐ Is the supplier ISO9001 (or similar standards applicable to its sector) certified?
- ☐ Is the supplier implementing any quality assurance program with its own suppliers?
- ☐ Has the supplier used any Lean Six Sigma quality improvement practices in the past?

PFMEA

What it is and when to use it



- □ Process failure modes and effects analysis (PFMEA) is a step-bystep approach for identifying all potential failure modes in a manufacturing or assembly process
- □ PFMEA is recommended when a process is being designed for a new product, or being redesigned after quality improvement
 - —It should be done periodically throughout the lifecycle of a process for analyzing potential failures due to changes in the process over time
- □ It ranks the 'severity' level, 'occurrence' probability, and 'detectability' probability of every possible failure mode in a process

PFMEA

What it is and when to use it (cont.)



- □ A risk priority number (RPN) is calculated for each failure mode by multiplying the three factors on the pervious slide by one another (severity, occurrence, and detectability)
- ☐ The RPN number is used to prioritize the reliability-improvement decisions

Note: This module only introduces the concept of FMEA, which can be applied to evaluate the reliability of both design and manufacturing process

See Module 3E for a FMEA example



- Assemble a cross-functional team (design, manufacturing, quality, supplier, sales, and marketing)
- □ Identify the scope of PFMEA; such as process functions and boundaries, customer requirements, and product or parts to analyze
- ☐ For each process function, identify all the ways failure can occur
- □ Determine the severity of each effect (severity is usually rated on a scale of 1 to 10, where 1 is insignificant and 10 is fatal or catastrophic)

(cont.)



- ☐ For each failure mode, determine all of the potential root causes
- ☐ For each cause, determine the occurrence rating (O).
 - —This rating estimates the probability of failure occurring for that reason during the lifetime of your scope
 - —Occurrence is usually rated on a scale of 1–10, where 1 is extremely unlikely and 10 is inevitable
- ☐ For each cause, identify current process controls: these are tests, procedures, or mechanisms that you now have in place to keep failures from reaching the customer

(cont.)



- ☐ For each control, determine the detection rating (D)
 - —This rating estimates how well the controls can detect either their cause or their failure mode after they have occurred, but before the customer is affected
 - —Detection is usually rated on a scale of 1 to 10, where 1 means the control is absolutely certain to detect the problem and 10 means the control is certain not to detect the problem (or no control exists)
 - —On the PFMEA table, list the detection rating for each cause

(cont.)



□ Calculate the risk priority number (RPN) =

Severity (S) × Occurrence (O) × Detectability (D)

- \square Calculate the criticality = S \times O
 - —These numbers provide guidance for ranking potential failures in the order they should be addressed
- □ Identify recommended actions
 - —These actions may be design or process changes to lower severity or occurrence
 - —They may be additional controls to improve detection
 - —Identify the key person for the actions and target-completion dates

Resources



- □ Otto, K. and Wood, K., 2001—Product Design: Techniques in Reverse Engineering and New Product Development, Prentice Hall
- □ Julie K. Spoerre, 1998—Quality Function Deployment as a Tool for Integrated Product and Process Design (in Concurrent Design of Products, Manufacturing Processes and Systems edited by Ben Wang, Vol 3. Chapter 3, Gordon and Breach Science Publisher
- □ Dominick, C., 2012. A 12-point Supplier Quality Checklist, Next level Purchasing

https://www.nextlevelpurchasing.com/resources/supplier-quality-management.pdf

List Of Terms

In glossary



- <u>Engineering Validation</u> measures and analyzes the process, audits and calibrates equipment and creates a document trail that shows the process leads to a consistent result to ensure the highest quality products are produced.
- Quality Function Deployment QFD is a tool to translate customer requirements into engineering specifications.
- Process Failure Modes and Effect Analysis (PFMEA) is a step-by-step approach for identifying all potential failure modes in a manufacturing or assembly process.
- Failure Mode Effect Analysis (FMEA) is often the first step of a system reliability study. It involves reviewing as many components, assemblies, and subsystems as possible to identify failure modes, and their causes and effects.
- □ <u>Design Failure Mode Effect Analysis (DFMEA)</u> is an analytical technique used in quality control, to ensure that the potential failure modes of a product or process (including their associated causes and mechanisms) have been studied and addressed to the extent possible.
- Process Failure Mode Effect Analysis (PFMEA) is an analytical technique employed to reasonably ensure that potential causes of process failure, and the associated mechanisms, have been identified and addressed.
- Original Equipment Manufacturer (OEM) is a producer or manufacturer of a complete end product (such as a car engine, cooling unit, or a circuit board) or a sub-assembly (such as a carburetor, compressor, or a chip).
- Risk Priority Number (RPN) measures the Severity (of the event), Probability (of the event occurring) and Detection (Probability that the event would not be detected before the user was aware of it.)

List Of Acronyms



- MRL Manufacturing Readiness Level
- □ QFD Quality Function Deployment
- ☐ FMEA Failure Mode Effect Analysis
- □ DFMEA Design Failure Mode Effect Analysis
- □ PFMEA Process Failure Mode Effect Analysis
- □ OEM Original Equipment Manufacturer
- □ RPN Risk Priority Number