A Laboratory Manual for

Quality and Reliability Engineering (3171929)

B.E. Semester 7 (Mechanical)

Directorate of Technical Education, Gandhinagar, Gujarat

Lukhdhirji Engineering College, Morbi

Certificate

This is to certify that Mr./Ms. ______________________________________ Enrollment No. ______________________of B.E. Semester VIIth Mechanical Engineering of Lukhdhirji Engineering College, Morbi (GTU Code: 031) has satisfactorily completed the Practical work for the subject **Quality and Reliability Engineering (3171929)** for the academic year 2024-25

Place: ___________

Date: ___________

Name and Sign of Faculty member

Head of the Department

Preface

Main motto of any laboratory/practical/field work is for enhancing required skills as well as creating ability amongst the students to solve real time problem by developing relevant competencies in psychomotor domain. By keeping in view, Gujarat Technological University (GTU) has designed competency focused outcome-based curriculum for engineering degree programs where sufficient weightage is given to practical work. It shows importance of enhancement of skills amongst the students and it pays attention to utilize every second of time allotted for practical amongst students, instructors and faculty members to achieve relevant outcomes by performing the experiments rather than having merely study type experiments. It is must for effective implementation of competency focused outcome-based curriculum that every practical is keenly designed to serve as a tool to develop and enhance relevant competency required by the various industry among every student. These psychomotor skills are very difficult to develop through traditional chalk and board content delivery method in the classroom. Accordingly, this lab manual is designed to focus on the industry defined relevant outcomes, rather than old practice of conducting practical to prove concept and theory.

By using this lab manual students can go through the relevant theory and procedure in advance before the actual work which creates an interest and students can have basic idea prior to performance. This in turn enhances pre-determined outcomes amongst students. Each experiment in this manual begins with competency, industry relevant skills, course outcomes as well as practical outcomes (objectives).

Quality and Reliability Engineering is the demand of the time to avail competitive advantages. It is the preliminary requirement to incorporate domain concepts in each executed event in every industry. It is the fundamental to know the basic steps before execution of any activity or process. Whereas, it is significant to execute process more precise and accurate in conformance to the standards. This emerge a well- known term quality, further associated with consistent performance that calls to understand reliability and product development process. It develops product worth and brand name as whole. Work reported by different Quality Guru’s is the fundamental pillar that prospered to the world class manufacturing. In an era of Industry 4.0, backed by human centric activities of Industry 5.0 this subject is driving parameter towards benchmarking. Furthermore, students can apply sound concepts of related course during their final semester industrial internship and in future endeavors.

Utmost care has been taken while preparing this lab manual however always there is chances of improvement. Therefore, we welcome constructive suggestions for improvement and removal of errors if any.

Practical – Course Outcome matrix

Course Outcomes (COs):

CO-1: Interpret Quality and Total quality management

CO-2: Make use of design of experiments, concepts of just in time and quality management

CO-3: Illustrate Total Productive maintenance and ISO

CO-4: Utilize knowledge of contemporary trends in quality engineering and Reliability Engineering in Industry

Sr. No.	Objective(s) of Practical	CO1	CO2	CO3	CO4
1.	To interpret word quality and to develop quality control tools related to manufacturing and automobile industry	√			
2.	To analyze problem solving techniques and to construct Quality Function Deployment for automobile case study	√			
3.	To study Failure Mode and Effect Analysis (FMEA) and construct FMEA for manufacturing industries problems	√			
4.	To construct Failure Tree Analysis (FTA), and case study of Poka yoke and Kaizen with Toyota case study	√			
5.	To study about Just in Time Production System		√		
6.	Design of Experiments		√		
7.	To Study Total Productive Maintenance			√	
8.	Quality Standards and their role			√	
9.	Problems on failure mechanism and reliability				√
10.	Recent trends and World Class Manufacturing				√
11.	Discuss your internship as industrial case study and analyze it with supportive similar other study	√	√	√	√
12.	Submission	√	√	√	√

Industry Relevant Skills

The following industry relevant competencies are expected to be developed in the student by undertaking the practical work of this laboratory.

1. To understand, adopt, and inculcate quality practices, approaches and tools used in Industries
2. Capable to analyze root cause of problems and sense the importance of reliability.
3. To know the significance of total quality management in product and service industries to gain competitive advantage in the global market

Guidelines for Faculty members

1. Teacher should provide the guideline with demonstration of practical to the students with all features.
2. Teacher shall explain basic concepts/theory related to the practical to the students before starting of each practical
3. Involve all the students throughout the task.
4. Teacher is expected to share the skills and competencies to be developed in the students and ensure that the respective skills and competencies are developed in the students after the completion of the practical.
5. Teachers should give opportunity to students to demonstrate their understanding.
6. Teacher may provide additional knowledge and skills to the students even though not covered in the manual but are expected from the students by concerned industry.
7. Give practical assignment and assess the performance of students based on task assigned to check whether it is as per the instructions or not.
8. Teacher is expected to refer complete curriculum of the course and follow the guidelines for implementation.

Instructions for Students

1. Students are expected to carefully listen to all the theory classes delivered by the faculty members and understand the Cos, content of the course, teaching and examination scheme, skill set to be developed etc.
2. Students shall organize the work in the group and should read relevant research papers and case studies.
3. Students shall develop skill as expected by industries.
4. Student shall attempt to develop group exercises and build confidence.
5. Student shall develop the habits of evolving more ideas, innovations, skills etc. apart from those included in scope of manual.
6. Student shall refer technical magazines and data books.
7. Student should develop a habit of submitting the work as per the schedule and s/he should be well prepared for the same.

Index
(Progressive Assessment Sheet)

Sr. No.	Objective(s) of Experiment	Page No.	Date of performance	Date of submission	Assessment Marks	Sign. Of Teacher with date	Remarks
1.	To interpret word quality and to develop quality control tools related to manufacturing and automobile industry						
2.	To analyze problem solving techniques and to construct Quality Function Deployment for automobile case study						
3.	To study Failure Mode and Effect Analysis (FMEA) and construct FMEA for manufacturing industries problems						
4.	To construct Failure Tree Analysis (FTA), and case study of Poka yoke and Kaizen with Toyota case study						
5.	To study about Just in Time Production System						
6.	Design of Experiments						
7.	To Study Total Productive Maintenance						
8.	Quality Standards and their role						
9.	Problems on failure mechanism and reliability						
10.	Recent trends and World Class Manufacturing						
11.	Discuss your internship as industrial case study and analyze it with supportive similar other study						
	Total						

Experiment No: 1
To Interpret word Quality and to develop Quality Control Tools related to manufacturing and automobile industry

Date:

Relevant CO: Interpret Quality and Total quality management (CO1)

Objectives:
- To understand Quality and Total Quality Control (TQC)
- To assess 7 QC Tools from industrial application view point

Quality: Each and every industry focuses on various parameters that affects the performance (product/ service) thus it accounts to quality and finally to the organization and brand value as a whole. It is basic need and demand of time that offers additional benefits, this concept is not a newer one still it significance, weightage and adoption is constantly growing with advent of time in scenario of globalization. It means many things to many people. Prior to twentieth century quality was an art and an era of workmanship. The advancement of quality has taken place over centuries and it has huge historical background of evolution with associated different concepts. Many quality Gurus have given different definitions and views and it means different perspectives. To name a few developments in 1930 beginning of study of quality control, statistics applications, control charts etc. American Society for Quality Control (ASQC) was founded in 1946, Quality Circle started in Japan in 1962, between 1970-80 concept of just in Time and designing robust systems and products by Taguchi were famous, between 1987-99 standards on quality management systems were released (ISO 9000, 9001, 9002, 9003, 9004) and in 2000 revision of standards quality management system to make it more user friendly application to manufacturing and service industries with withdrawn of ISO 9002:1994 and ISO 900: 1994 and launching of ISO 9000:2000, ISO 9004:2000.

Quality Control (QC): It is an essential process to deliver designated desired outputs. It focuses on uniformity and deals with inspection, statistical tools and techniques. It is setting related standards, checks and corrections. Thereby firms evaluate all production aspects and missing any of criteria creates non-conformance. QC includes management task with well-defined processes, requirements and to create well define records. This is achieved by knowledge, ability and competency of person and sufficient checks and inspections of product by the teamwork and well quality culture in an organization.

Quality assurance (QA): It is associated from design to field test observations that deals with assurance of defined quality, reliability and services of the product. It works to enhance and stabilize production and related processes to avoid, or at least minimize, issues that led to the defects, quality control emphasizes testing of products to uncover defects and reporting to management who make the decision to allow or deny product release.

7 Quality Control Tools: W. Edward Deming was recruited by the Japanese Union of Scientists and Engineers (JUSE) to teach statistical process control to Japanese engineers, managers, and academics in 1950. Kaoru Ishikawa from the University of Tokyo, was one of the JUSE members and was influenced by Deming's theory, formalized the Seven Basic Tools of Quality Control in an effort to make quality control understandable to all employees. With the adoption of control charts, he thought that 90% of a company's problems could be solved with these seven tools adoption.

The basic seven QC tools are as follows:

1. Histograms. **2**. Pareto Charts. **3.** Cause and effect diagrams (fish bone chart).
4. Scatter Diagrams. **5.** Flow Charts. **6.** Check sheet. **7**. Control Charts.

Figure 1.1 Seven Quality control tools

1. Histogram:

Histogram is useful tool to describe the frequency distribution of observed values of a variable. It is a type of bar chart that visualizes both attribute and variable data of a product or process, also assists users to show the distribution of data and the amount of variation within a process. It displays different measures of central tendency namely mean, mode, and average and simple for data evaluation. Example of histogram as in Figure 1.2

Student	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Marks	96	31	60	67	80	48	39	77	4	80	70	81	63	50	97	56	83	35	32	98

Class (marks)	No. of students
1 – 20	1
21 – 40	4
41 – 60	4
61 – 80	6
81 – 100	5
Total	20

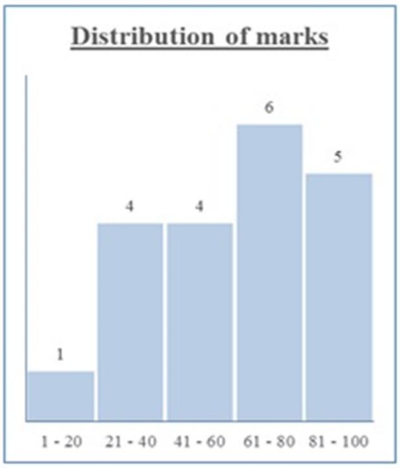


Figure 1.2 Example of Histogram

2. Pareto Chart:

Pareto chart identifies the most critical problems and its principle is known as 80:20 rule which had a base that 80% problems are created because of 20% of causes. It breakdown the problem and are constructed by plotting the cumulative frequency of the relative frequency data or event count data, in a descending order. Specifically identifies the factors that possess highest effect on the system and less significant on side. It is use with cause and effect diagram to determine what contributes the most in the selected problem. One most important use is focus on critical issues by ranking in terms of importance.

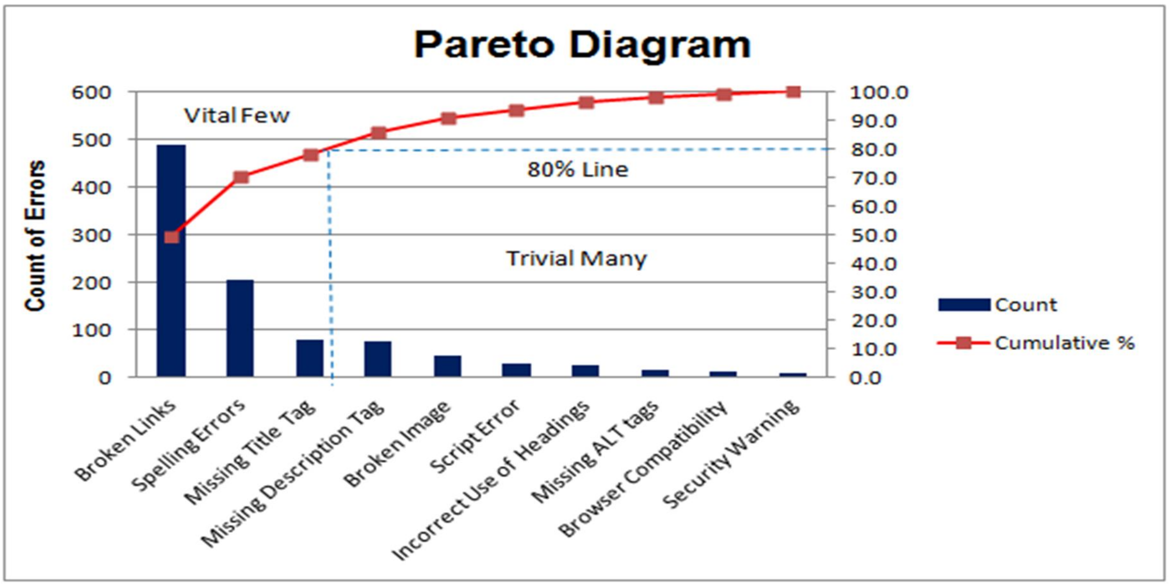


Figure 1.3 Example of Pareto Chart

3. **Cause and Effect Diagram (Fish bone diagram):**

It is also known as fish bone diagram because of the shape of the diagram and also as Ishikawa diagram. It showcase the root cause analysis that can be developed based on the cause and effect relationship. The basic use of the tool is to find root causes of problems; hence, it is also called root cause analysis. The selected problem is placed at right as fish head with causes on the left of the skeleton. The branches denote major causes and sub-branches shows root causes. This provides clear visualization of cause and its effect. It provides insight on the causes of the problem. In simple words first, clearly identify and define the problem or effect for which the causes must be identified. Place it at the right head of the diagram. Identify all the broad areas of the problem. Write in all the detailed possible causes in each of the broad areas. Now each identified cause to be linked with detail of specific causes. Flight delay is shown in Figure 1.4

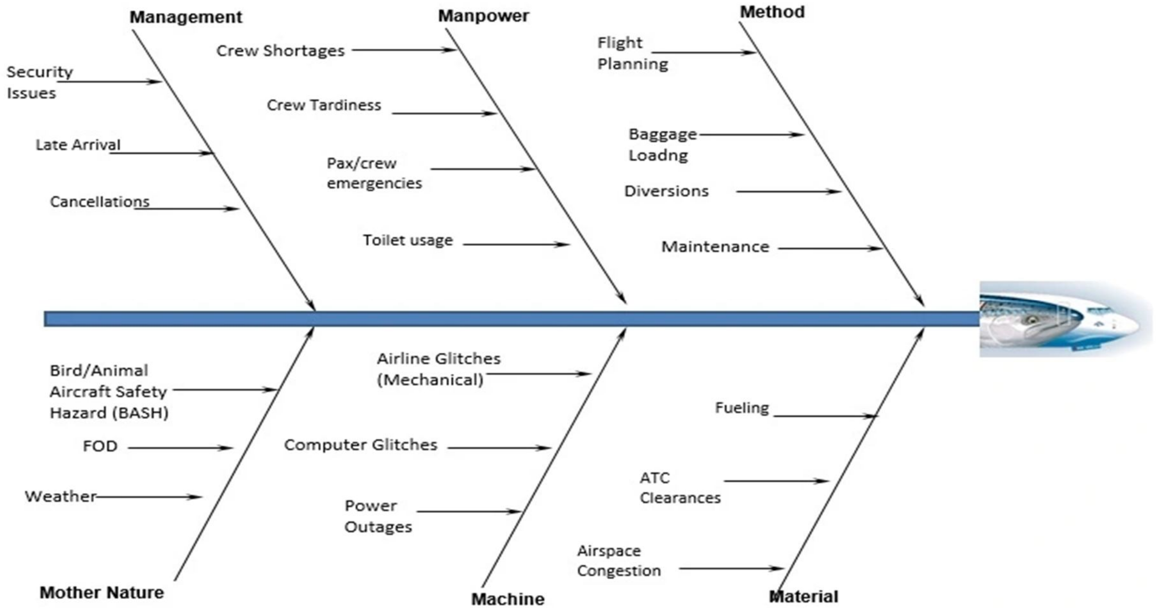


Figure 1.4: Example of Cause-and-effect Diagram (Fish Bone Diagram)

4. <u>Scatter Diagram:</u>

Scatter diagrams are used to study possible relationship between two variables and they do indicate the existence of a relationship, with the strength of that relationship. It demonstrates change of one variable over another with two axis as two variables. Slope shows relationship and pattern can be no relation, positive or negative

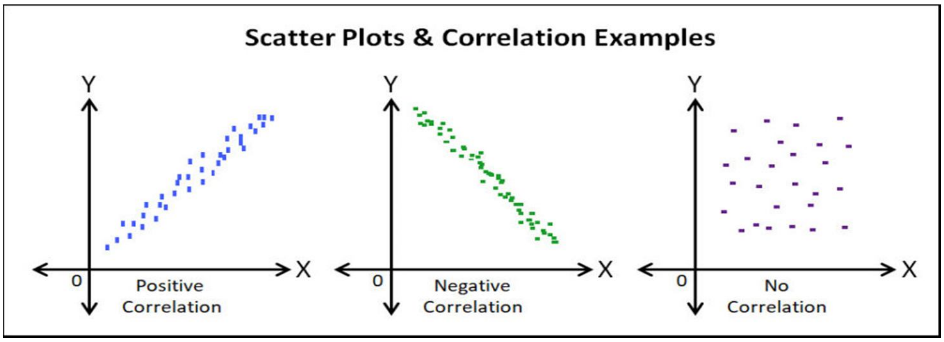


Figure 1.5 Scatter diagram

5. <u>Flow Chart:</u>

It shows the steps of the process to be executed in schematic diagram. It show a correct sequence of execution of the process majorly use for complex problems. It is developed by adopting standards symbols easy to understand. It helps in decision making and clarifying the flow of the process execution. Figure 1.6 shows the symbols and Figure 1.7 shows an example

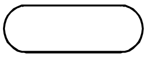
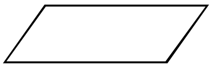
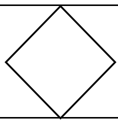
Symbol	Name	Function
	Start/End	An Oval represents a start or end point
	Arrow	A line is a connector that shows relationship between the representative shapes
	Input/ Output	A parallelogram represents input or output
	Process	A rectangle represents a process
	Decision	A diamond indicates a decision

Figure 1.6: Symbols for flow Diagram

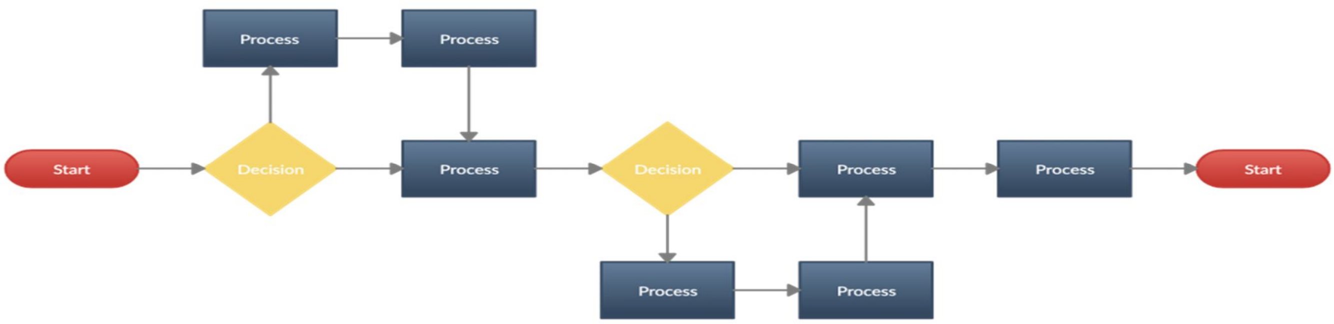


Figure 1.7: Example of Flow Diagram

6: Check Sheet:

As the name suggests it shows which defect occur for how many times during the selected span. This can be used as further actions for improvements. Motor assembly check sheet example is shown in Figure 1.8

Motor Assembly Check Sheet

Name of Data Recorder: Lester B. Rapp

Location: Rochester, New York

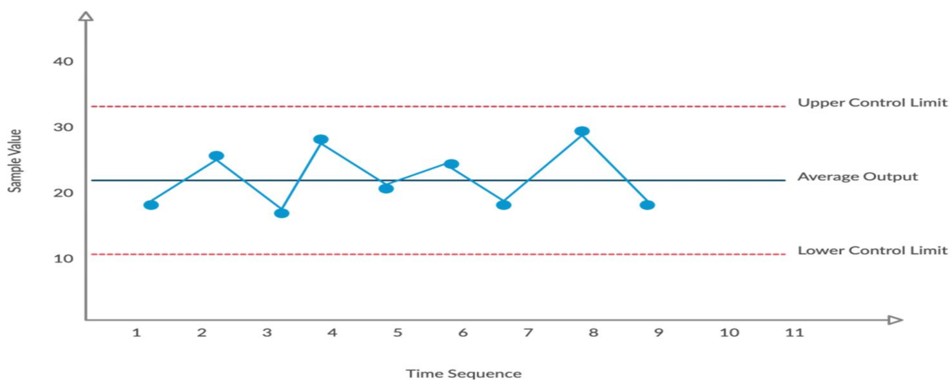
Data Collection Dates: 1/17 - 1/23

Defect Types/ Event Occurrence	Dates							
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	TOTAL
Supplied parts rusted		IIIIIIIII	IIIII	IIII	II			20
Misaligned weld			III			II		5
Improper test procedure								0
Wrong part issued		I		II				3
Film on parts								0
Voids in casting				IIII	II			6
Incorrect dimensions						II		2
Adhesive failure								0
Masking insufficient					I			1
Spray failure			IIIII					5
TOTAL		10	13	10	5	4		

Figure 1.8: Example of Check sheet

7. Control Charts:

Shewhart and Deming provide statistical means of assessment and they are different types of control charts that are more specific used is statistical process control. It is plotting the data and to assess whether the process is under control or not to develop the chart it need minute attention. Normally 3σ deviation is desired outcome. Their exist different types of control charts based on attributes and variables. A simple control chart with limits is shown in Figure 1.9

- 

1.9 Example of Control Chart

❖ 7 New Quality Improvement Tools

The following are the new 7 QC Tools:

- ✓ AffinityDiagrams.
- ✓ Relation Diagrams.

- ✓ Tree Diagrams.
- ✓ Matrix Diagrams.
- ✓ Matrix Data Analysis.
- ✓ Arrow Diagrams.
- ✓ Process Decision Program charts (PDPC)

Activity and Quiz:

Q-1: Construct cause and effect diagram for any one welding defect.
Q-2: Develop cause and effect diagram for less two-wheeler giving less average.
Q-3: Differentiate between Histogram and Pareto chart with example.
Q-4: Explain 80/20 rule of Pareto chart by taking suitable example from manufacturing firm.
Q-5: Construct a process flow chart for sand casting.
Q-6: State definitions coined by different Quality Gurus

Suggested References:

1. Kuendee, Punyisa. "Application of 7 quality control (7 QC) tools for quality management: A case study of a liquid chemical warehousing." In 2017 4th International Conference on Industrial Engineeringand Applications (ICIEA), pp. 106-110. IEEE, 2017 (DOI: 10.1109/IEA.2017.7939188)

2. Memon, I. A., Ali, A., Memon, M. A., Rajput, U. A., Abro, S. A. K., &Memon, A. A. (2019). Controlling the Defects of Paint Shop using Seven Quality Control Tools in an Automotive Factory. Engineering, Technology & Applied Science Research, 9(6), 5062-5065.

3. Neyestani, B. (2017). Seven basic tools of quality control: The appropriate techniques for solving quality problems in the organizations. Available at SSRN 2955721(DOI: dx.doi.org/10.2139/ssrn.2955721)

4. Total Quality Management And Six Sigma Edited by Tauseef Aized ISBN 978-953-51-0688-3

References used by the students:

Rubric wise marks obtained:

Criteria	%	10	9-8	7-6	5
Knowledge	30	Correct answers 90% or more by student.	Correct answers between 70-89%.	Correct answers between 50-69%.	Correct answers less than 50%.
Quality of report	20	Proper formatting and well attempted quiz and case study with excellent reported work	Only formatting is improper (Location of figures/tables, use of pencil and scale). Good	A few required elements (labeling/ notations) are missing. Average	Several elements are missing (content in paragraph, labels, figures, tables). Poor report
Participation type	30	Participation 25% Excellent focused attention in the exercise.	Moderately focused attention on exercise.	Focused limited attention in the exercise.	Less Participation
Punctuality	20	Timely Submission	Submission late by one laboratory.	Submission late by two laboratories.	Submission late by more than two laboratories.
Criteria	**%**	**Level of Marks**	**Multiplication**	**Total**	**Remarks**
Knowledge	30		0.3 *_____		
Quality of report	20		0.2*_____		
Participation	30		0.3*_____		
Punctuality	20		0.2*______		
			Total Marks		

Sign of Faculty

Experiment No: 2
To analyze problem solving techniques and to construct Quality Function Deployment for automobile case study

Date:

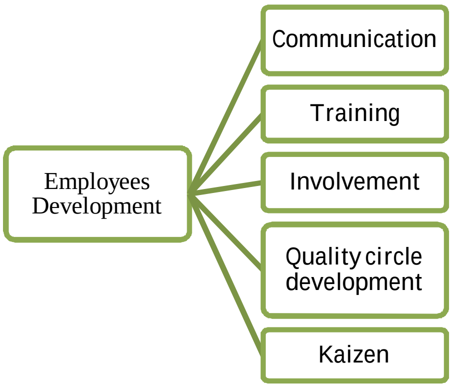
Relevant CO: Interpret Quality and Total quality management (CO1)

Objectives:

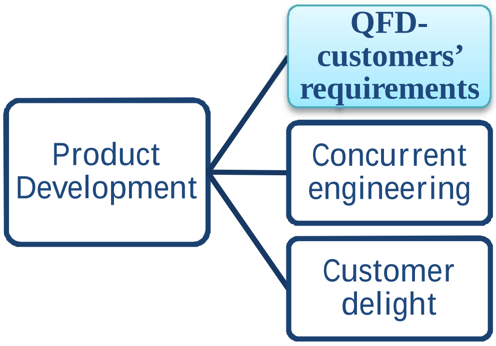
- To understand and develop Quality function deployment (QFD) a Quality engineering tools and techniques of Total quality management (TQM)

TQM is the continual process of detecting and reducing or eliminating errors in manufacturing, streamlining supply chain management, improving customer satisfaction, and ensuring that employees are with training. It aims altogether production process accountable for the overall quality of the final product or service and is a structured approach for overall organization management. Main focus is to improve the quality of an organization's outputs, including goods and services with continual improvement of internal practices. The standards set as part of the TQM approach can reflect internal priorities. TQM tools and techniques consists of three pillars Employee development, Product development and process development as shown in Figure 2.1

1) Employee development



2) Product development



3) Process development

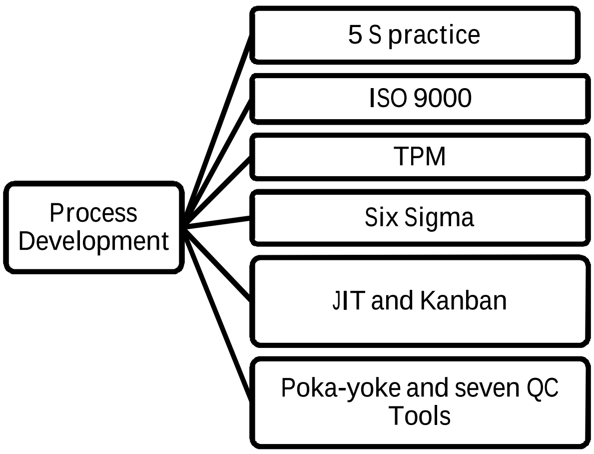


Figure 2.1 TQM tools and techniques

Quality Function Deployment (QFD)

Definition: It involves identifying customer needs and transforming those needs into product or service in production stages so that customer needs are met. It is used by both profit and non-profit organizations. Developed by oji Akao in Japan for Mitsubishi's shipyard later adopted by Toyota. It is defined as method to change qualitative demands of end users into quantitative, i.e. translates customer's needs into what the organization produces Every product developed aims to fill a specific customer need, but pinpoint is what customers actually need is more difficult than it seems. So, QFD is way to this problem with clear focus on needs, starting with a matrix known as the House of Quality.

House of Quality

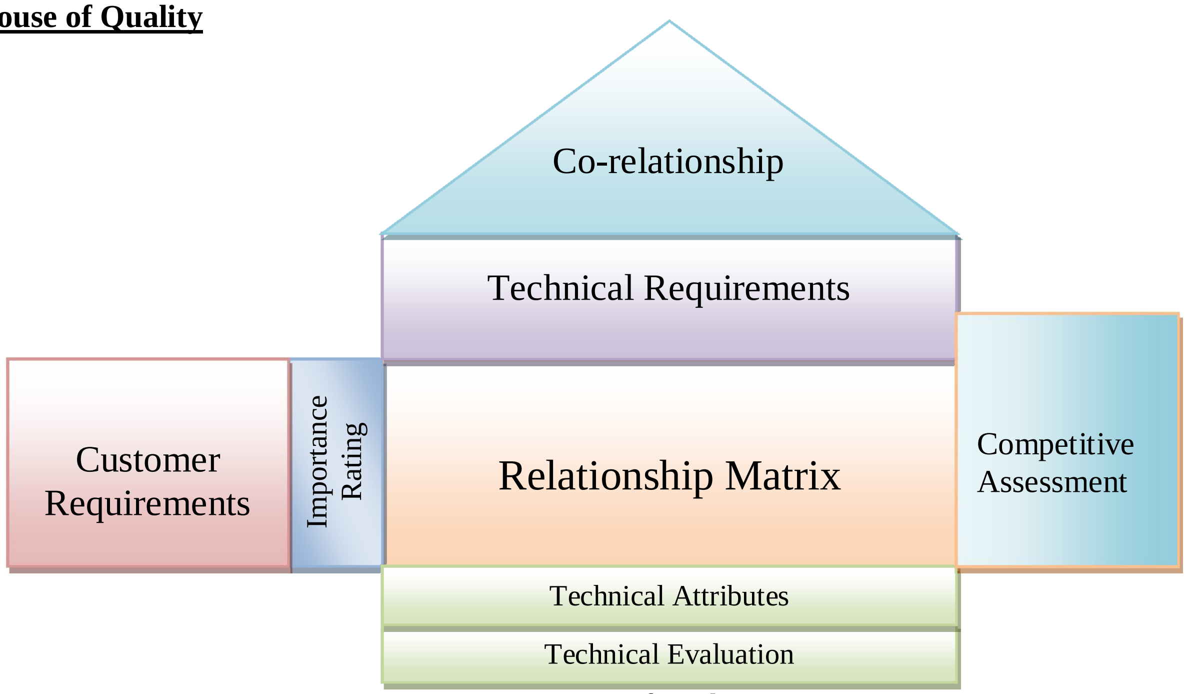


Figure 2.2: House of Quality structure

QFD is also known as House of Quality. It translates the voice of customers into the design requirements that meet the specific target values and ways of matching them against how an organization will meet those requirements. It is the 1st matrix that a product development team uses to initiate the QFD processes.

Steps for House of Quality:

List what customer needs, list its technical descriptions, to develop relationship and interrelationship, prioritize and optimize customers and technical descriptions.

Step 1: Customer Requirements – "Voice of the Customer"

First to figure out which things are most important to the customers in terms of their need with the score from 1 to 5 where highest is most important

Step 2: Technical measures

The next step is engineering parameters in relation to a product. This step can be quite difficult and parameters should be meaningful, measurable, and global.

Direction of Improvement	
▲	Maximize
◇	Target
▼	Minimize

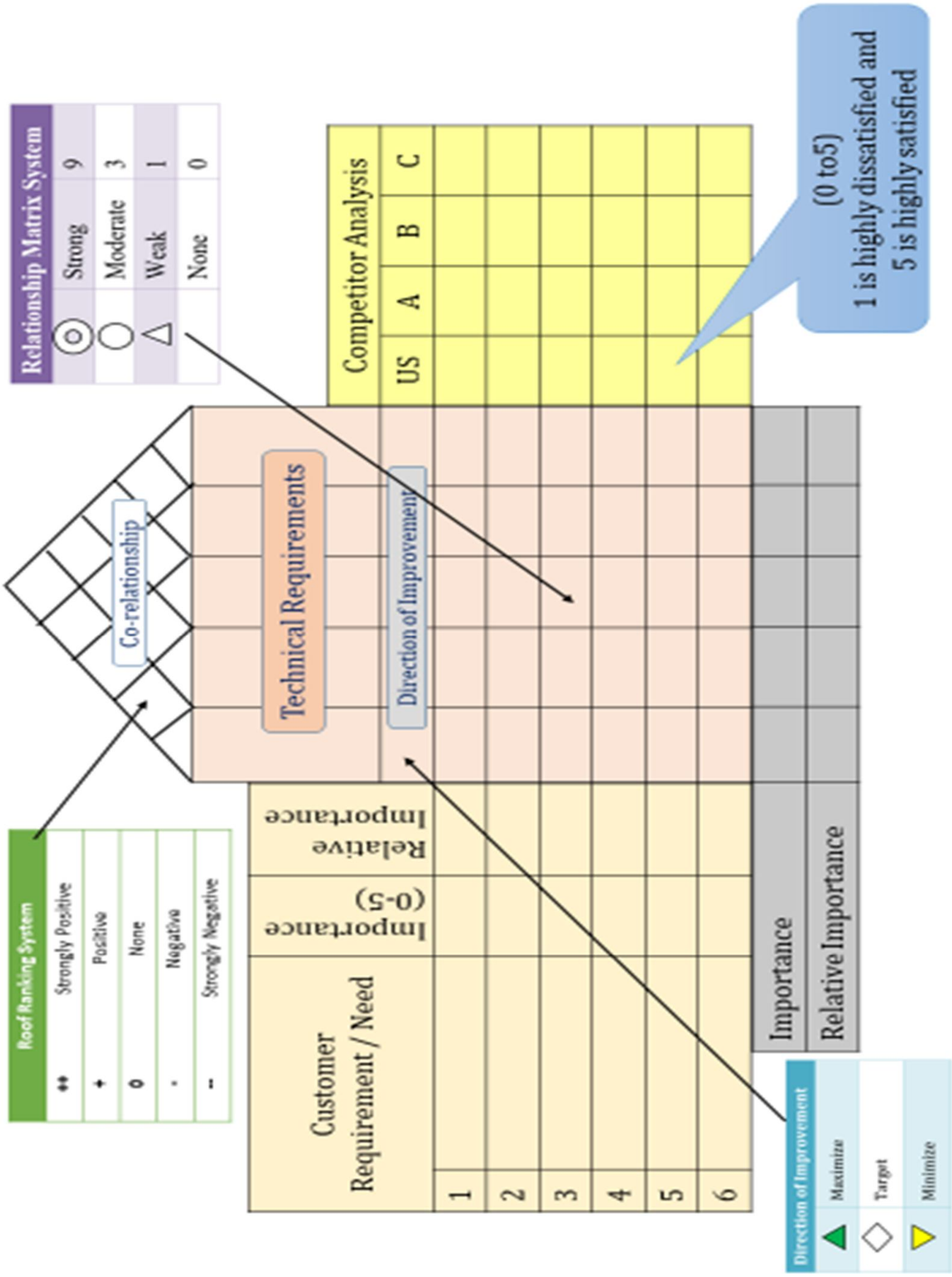


Figure 2.3: Template of Quality Function Deployment (QFD)

Step 3: Roof / Correlation Matrix

The triangular "roof" matrix of the House of Quality is to identify how the design requirements interact

Roof Ranking System	
++	Strongly Positive

with each other. The first row is called up or down. This column describes whether the following parameter is better with a high value or low. Similarly, now comparing the effects of changing one alternative on the others. The symbol uses, such as ++ to represent a strongly positive effect, + for a positive effect, 0 for no effect, – for a negative, and – – for a strongly negative effect.

+	Positive
0	None
-	Negative
--	Strongly Negative

Step 4: Relationship Matrix

Develop a correlation between customer requirements (or the voice of the customer) and the technical requirements. All empty box in the columns for the design specifications to be filled. This is the largest and most difficult part of the design process. The ranking system use is a set of symbols for strong, medium, and weak relationships.

Relationship Matrix System		
⊙	Strong	9
○	Moderate	3
△	Weak	1
	None	0

Step 5: Importance Rating

The Importance Rating is the result of calculating the total sum of each column when multiplied by the customer importance factor. It helps to determine where to assign the most resources. Then, calculate the percentage of importance. It will also shed some light on the relative importance of each parameter in the design process.

Step 6: Competitive Evaluation

Competitive Evaluation helps to understand competitor products that fulfill customer requirements. It is a good idea to ask customers how the product or service rates are in relation to the competition. Use surveys, customer meetings, or focus groups/clinics to obtain feedback. Measure the satisfaction on a scale of 1 to 5, where 1 is highly dissatisfied and 5 is highly satisfied.

Advantages and Limitations of QFD

Few advantages of QFD are increased customer satisfaction, early design changes, improved quality control, reduced development costs, etc. Limitations are data needed to be accurate, Customer expectations need to be aligned with technical capabilities, Customer expectations change rapidly etc.

Quiz:

Q-1: What is meant by Quality Function Deployment?

Q-2: Explain the purpose of QFD with example.

Q-3: What are the types in quality function deployment QFD?

Q-4: Prepare QFD for basic design of car in automobile sector.

Activity: Study the following research paper.

– Patil, V. S., Phafat, N. G., & Dolas, D. R. (2018). Quality function deployment: case study on roadmap for impeller design. Industrial Engineering Journal, 11(1), 25-29. (DOI: 10.26488/IEJ.11.1.1034)

– Hadi, H. A., Purba, H. H., Indarto, K. S., Simarmata, R. G. P., Putra, G. P., Ghazali, D., &Aisyah, S. (2017). The implementation of quality function deployment (QFD) in tire industry.ComTech: computer, mathematics and engineering applications, 8(4), 223-228.(DOI/10.21512/comtech.v8i4.3792)

Suggested Reference:

1. Ficalora, Joseph & Cohen, Louis & St, Cahyono. (2022). A QFD Handbook Quality Function Deployment and Six Sigma, Second Edition.
2. Total Quality Management by Dale H. Besterfield, Carol Besterfield-Michna, Glen H. Besterfield and Mary Besterfield-Sacre, Pearson Educaiton

References used by the students:

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Criteria	**%**	**Level of Marks**	**Multiplication**	**Total**	**Remarks**
Knowledge	30		0.3 *_____		
Quality of report	20		0.2*_____		
Participation	30		0.3*_____		
Punctuality	20		0.2*______		
			Total Marks		

Sign of Faculty

Experiment No: 3

To study Failure Mode and Effect Analysis (FMEA) and construct FMEA for manufacturing industries problems

Date:

Relevant CO: Interpret Quality and Total quality management (CO1)

Objectives:

- To understand the Failure Mode and Effects Analysis (FMEA) as a proactive analytical team tool for reliability improvement
- Brief overview of FMEA formats and rating system for design and process FMEA

Failure Mode and Effect Analysis(FMEA)

The Failure Mode and Effect Analysis (FMEA) adopted in the 1940s by the US Military. It was further developed by the aerospace and automotive industries were several industries maintain formal FMEA standards. The aerospace industry used the FMEA during the Apollo mission in the 1960s. Later in 1974 the US Navy developed MIL-STD-1629 which discussed the proper use of the tool. Today it is universally used by many different industries. It is an analytical technique that combines the technology, and persons experience in identifying foreseeable failure modes of a product or process and planning for its elimination. In other words can be explained as a group of activities intended to

- Recognize and evaluate the potential failure of a product or process and its effects.
- Identify actions that could eliminate or reduce the chance of potential failures.
- Document the process.

There are several types of FMEA: design FMEA, process FMEA, equipment FMEA, maintenance FMEA, concept FMEA, service FMEA, system FMEA, environmental FMEA, and others. However, for all intents and purposes, all of the types can be broadly categorized under either design FMEA or process FMEA.

Stages of FMEA:

The four stages of FMEA are given below:

1. Specifying Possibilities:

a. Functions:

Item/ functions is the name and item number of the thing being examined are noted in this section. If an item has multiple functions, each function should be listed and examined independently.

b. Possible Failure Modes:

The item being analyzed might not meet the design requirements due to the method used to analyze it. Second, it might be a technique that could lead to failure in a higher-level system or be the effect of a lower-level system failing. Every probable failure mode needs to be taken into account and listed.

c. Root Causes

Every possible failure mechanism and/or cause must be clearly and completely listed. Multiple causes and/or mechanisms of failure may contribute to some failure modes; each of them must be studied and listed separately. Following that, each of these causes and/or mechanisms needs to be examined equally.

d. Potential effects

The customer's perception of the failure's effects constitutes the failure's prospective impacts. If conditions are provided by the customer, it will be clear which mode generated the specific failure effect. Failure effects must be stated in terms of what the consumer would observe or feel. Need to predict the potential impacts the specific failure may have on other systems or sub-systems that are in close proximity to it

e. Detection/Prevention: Detection of the cause of failure (DET)

It provides comparative evaluation of the design control's capacity to identify a potential cause or mechanism or the ensuing failure mode prior to the completion of the component, subsystem, or system for production. One sample example is given in below table for ranking the detection of failure

Chances of detection of failure mode	Rank
No known control available	10
Very remote chances of detection	9
Remote chances of detection	8
Very low chances of detection	7
Low chances of detection	6
Moderate chances of detection	5
Moderately high chances of detection	4
High chances of detection	3
Very high chances of detection	2
Almost certain to detect	1

<u>2. Quantifying Risk:</u>

a. Occurrence (OCC):

Occurrence is the chance that one of the specific causes/mechanisms will occur. This must be done for every cause and mechanism listed. Reduction or removal in occurrence ranking must not come from any reasoning except for a direct change in the design. Design change is the only way a reduction in the occurrence ranking can be effected. Like severity criteria, the likelihood of occurrence is based on a 1-to-10 scale, with 1 being the least chance of occurrence and 10 being the highest chance of occurrence. Below table shows one sample example for ranking occurrence.

Occurrence	Failure Rate	Criteria	Rank
Very High	>1 in 2	Failure is almost inevitable	10
	1 in 3		9
High	1 in 8	Repeated Failure	8
	1 in 20		7
Moderate	1 in 80	Occasional Failure	6
	1 in 400		5
	1 in 2000		4
Low	1 in 15000	Relatively few Failure	3
	1 in 150000		2
Remote	<1 in 1500000	Failure is unlikely	1

b. Severity (SEV)

Severity is the assessment of the seriousness of the effect of the potential failure mode to the next component, sub-system, system, or customer if it occurs. It is important to realize that the severity applies only to the effect of the failure, not the potential failure mode. Reduction in severity ranking must not come from any reasoning except for a direct change in the design. It should be stressed that no single list of severity criteria is applicable to all designs; the team should agree on evaluation criteria and on a ranking system that are consistent throughout the life of the document. Severity should be rated on a 1-to-10 scale, with a 1 being none and a 10being the most severe. Below table shows one typical example of ranking system.

Criteria for ranking Severity	Effect	Rank
Failure occurs without warning	Deadly	10
Failure occurs with warning	Hazardous	9
Product inoperable, with loss of function	Very serious	8
Product operable, with loss of function	Serious	7
Product operable, with loss of comfort	Moderate	6
Product operable, with low effect of performance	Low	5
Noticeable effect by most customer	Very Low	4
Noticeable effect by average customer	Minor	3
Noticeable effect by discriminating customer	Very Minor	2
No effect	None	1

c. Effectiveness of Control to Prevent Cause

d. Risk Priority Number

Risk Priority Number (RPN):

By definition, the Risk Priority Number is the product of the severity (SEV), occurrence (OCC), and detection (DET)rankings, as shown below:

$$RPN = (S)\times (O) \times (D)$$

Values for the RPN can range from1 to 1000, with 1 being the smallest design risk possible. This value is then used to rank order the variousconcerns in the design. For concerns with a relatively high RPN, the engineering team must makeefforts to take corrective action to reduce the RPN.In general, the purpose of the RPN is to rank the various concerns on the document.

3. Correcting High Risk Causes

a. Prioritizing Work
b. Detailing Action
c. Assigning Action Responsibility
d. Check Points on Completion

4. Re-evaluation of Risk

a. Recalculation of Risk Priority Number

<u>FMEA Procedure:</u>

1. For each process input (start with high value inputs), determine the ways in which the input can go wrong (failure mode)
2. For each failure mode, determine effects

✓ Select a severity level for each effect

3. Identify potential causes of each failure mode

✓ Select an occurrence level for each cause

Failure Mode Effect Analysis

Product/ Process Functional requirement	Potential Failure Mode	Potential Effect of Failure	SEV	Class	Potential Causes/ Mechanism of failure	OCC	Current Control	DET	RPN	Recommended Actions	Responsibilities and Target Completion dates	Action Results				
												Action Taken	SEV	OCC	DET	RPN

4. List current controls for each cause
5. Select a detection level for each cause
6. Calculate the Risk Priority Number(RPN)
7. Develop recommended actions, assign responsible persons, and take actions

- ✓ Give priority to high RPNs

Implementation of FMEA:

- ➢ Team identifies potential failure modes for design functions or process requirements
- ➢ They assign severity to the effect of this failure mode
- ➢ They assign frequency of occurrence to the potential cause of failure and likelihood of detection
- ➢ Team calculates a Risk Priority Number by multiplying severity times frequency of occurrence times likelihood of detection
- ➢ Team uses ranking to focus process improvement efforts.

When to conduct FMEA?

- ✓ Early in the process improvement investigation
- ✓ When new systems, products, and processes are being designed
- ✓ When existing designs or processes are being changed
- ✓ When carry-over designs are used in new applications
- ✓ After system, product, or process functions are defined, but before specific hardware is selected or released to manufacturing

Benefits of FMEA:

- ➢ Prevention Planning and cost reduction, reduced non value operations
- ➢ Identifies changes requirements
- ➢ Increased output and decreased weight
- ➢ Decreased warranty costs.
- ➢ It increases the likelihood that potential failures, and their effects and cases, will be considered prior to the final design and/or release to production.
- ➢ To plan preventive actions and is used in initial point, later trouble shooting guide, etc.

Activity: Study the following research paper.

- ➢ Rozak, A., Jaqin, C., &Hasbullah, H. (2020). Increasing overall equipment effectiveness in automotive company using DMAIC and FMEA method. Journal Européen des Systèmes Automatisés, 53(1), 55-60. (DOI: doi.org/10.18280/jesa.530107)
- ➢ Patil, R. B., &Kothavale, B. S. (2018). Failure modes and effects analysis (FMEA) of computerized numerical control (CNC) turning center. Int Rev Mech Eng, 12(1), 78-87 (DOI: 10.15866/ireme.v12i1.14156)

Quiz:

Q-1: Explain the steps of FMEA in detail.

Q-2: Explain the influence of RPN in FMEA.

Q-3: What are the needs of Failure Mode and Effects Analysis (FMEA) in manufacturing industries?

Q-4: Differentiate between Design FMEA and Process FMEA.

Q-5: Generate sample FMEA for Tire (TYRE) of the car.

Suggested Reference:

1. Rozak, A., Jaqin, C., &Hasbullah, H. (2020). Increasing overall equipment effectiveness in automotive company using DMAIC and FMEA method. Journal Européen des SystèmesAutomatisés, 53(1), 55-60. (DOI: doi.org/10.18280/jesa.530107)

2. Patil, R. B., &Kothavale, B. S. (2018). Failure modes and effects analysis (FMEA) of computerized numerical control (CNC) turning center. Int Rev Mech Eng, 12(1), 78-87 (DOI: 10.15866/ireme.v12i1.14156)

3. Besterfield, D. H., Besterfield-Michna, C., Besterfield, G. H., Besterfield-Sacre, M., Urdhwareshe, H., &Urdhwareshe, R. (1995). Total Quality Management Revised Edition: For Anna University, 3/e. Pearson Education India.

4. A First Course in Quality Engineering Integrating Statistical and Management Methods of Quality Third Edition K. S. Krishnamoorthi ,V. Ram Krishnamoorthi & Arunkumar Pennathur CRC Press.

References used by the students:

Rubric wise marks obtained:

Criteria	**%**	**10**	**9-8**	**7-6**	**5**
Knowledge	30	Correct answers 90% or more by student.	Correct answers between 70-89%.	Correct answers between 50-69%.	Correct answers less than 50%.
Quality of report	20	Proper formatting and well attempted quiz and case study with excellent reported work	Only formatting is improper (Location of figures/tables, use of pencil and scale). Good	A few required elements (labeling/ notations) are missing. Average	Several elements are missing (content in paragraph, labels, figures, tables). Poor report
Participation type	30	Participation 25% Excellent focused attention in the exercise.	Moderately focused attention on exercise.	Focused limited attention in the exercise.	Less Participation
Punctuality	20	Timely Submission	Submission late by one laboratory.	Submission late by two laboratories.	Submission late by more than two laboratories.
Criteria	**%**	**Level of Marks**	**Multiplication**	**Total**	**Remarks**
Knowledge	30		0.3 *_____		
Quality of report	20		0.2*_____		
Participation	30		0.3*_____		
Punctuality	20		0.2*______		
			Total Marks		

Sign of Faculty

Experiment No: 4

To construct Failure Tree Analysis (FTA), and case study of Poka yoke and Kaizen with Toyota case study

Date:

Relevant CO: Interpret Quality and Total quality management (CO1)

Objectives:

- To understand Failure Tree Analysis (FTA),
- To Study the TQM approaches: Kaizen, Poka yoke with any of the case study or research paper

❖ Fault Tree Analysis (FTA):

It is a top down approach failure analysis in which an undesired state of a system is analyzed using Boolean logic to combine a series of lower-level events. This analysis method is mainly used in the field of safety engineering and Reliability engineering to determine the probability of a safety accident or a particular system level (functional) failure. System Failure Condition is used for the "undesired state" / Top event of the fault tree. These conditions are classified by the severity of their effects. The most severe conditions require the most extensive fault tree analysis. These system failure conditions and their classification are often previously determined in the functional Hazard analysis. It can be used to minimize and optimize resources and show compliance with system reliability requirements by understanding the undesired state.

Methodology

An undesired effect is taken as the root ('top event') of a tree and it can be only one event with logic behind it. All concerns must tree down from it. Then, each situation that could cause that effect is added to the tree as a series of logic expressions and fault trees are labeled with actual numbers about failure probabilities.

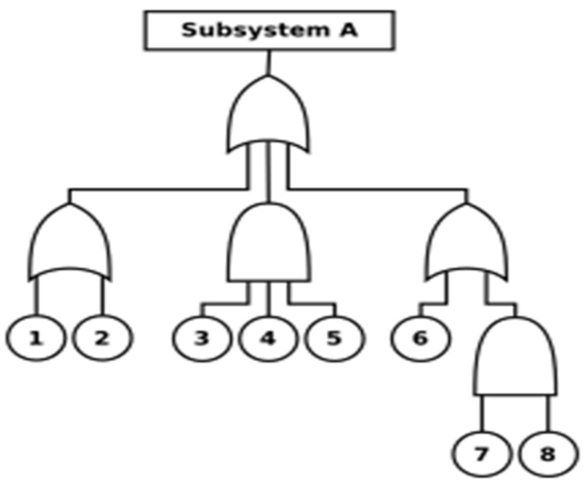


Figure 4.1: Methodology of FTA

Graphic Symbols

The basic symbols used in FTA are grouped as events, gates, and transfer symbols. Minor variations may be used in FTA software.

Event Symbols

Event symbols are used for primary events and intermediate events. Primary events are not further developed on the fault tree. Intermediate events are found at the output of a gate. The event symbols are shown below:

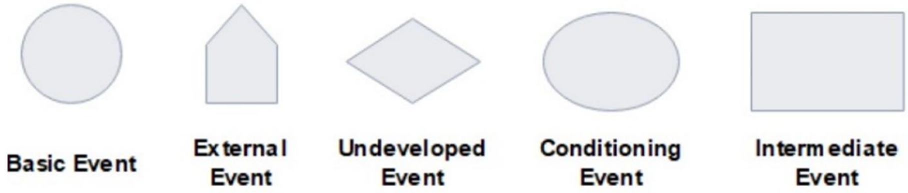


Figure 4.2: Event Symbols of Fault Tree Diagram

The primary event symbols are typically used as follows:

- Basic event - failure or error in a system component or element (example: switch stuck in open position)
- Initiating event - an external event (example: bird strike to aircraft)
- Undeveloped event - an event about which insufficient information is available, or which is of no consequence
- Conditioning event - conditions that restrict or affect logic gates (example: mode of operation in effect)

An intermediate event gate can be used immediately above a primary event to provide more room to type the event description. FTA is top to bottom approach.

Gate Symbols

Gate symbols describe the relationship between input and output events. The symbols are derived from Boolean logic symbols:

Figure 4.3: Gates used in Fault Tree Diagram

The gates work as follows:

- Gate symbols describe the relationship between input and output events. The symbols are derived from Boolean logic symbols:
- OR gate - the output occurs if any input occurs
- AND gate - the output occurs only if all inputs occur (inputs are independent)
- Exclusive OR gate - the output occurs if exactly one input occurs
- Priority AND gate - the output occurs if the inputs occur in a specific sequence specified by a conditioning event
- Inhibit gate - the output occurs if the input occurs under an enabling condition specified by a conditioning event

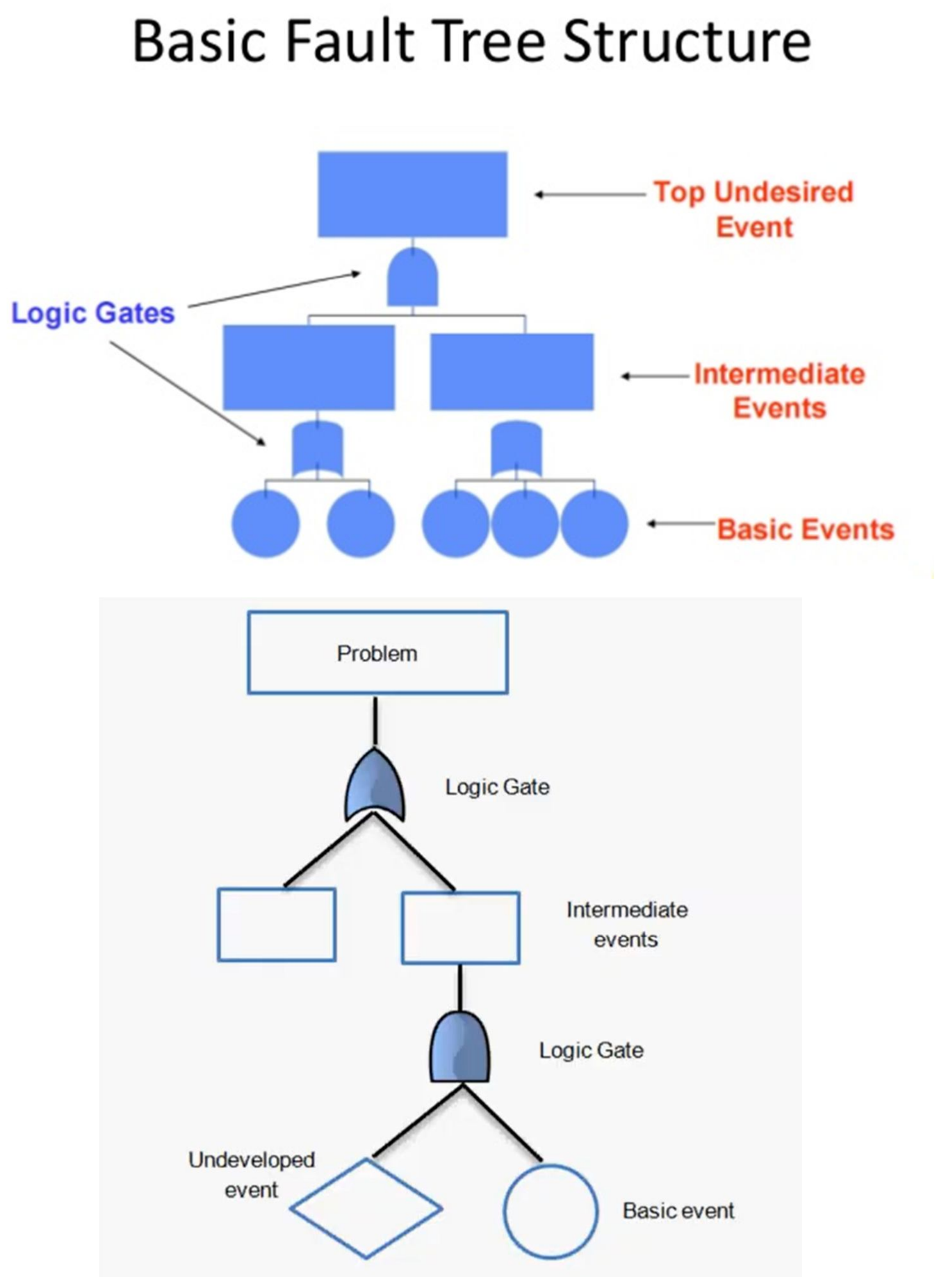


Figure 4.4: Fault Tree Structure

❖ <u>Poka-yoke:</u>

Poka yoke is word derived from two Japanese words and it is a quality management concept developed by a Matsushita manufacturing engineer, Shigeo Shingo, to prevent the human errors from occurring in the production line. It means avoiding errors. It is also referred as fool-proofing. However, this is not correct if applied to the employees, and therefore the English equivalent used by Shingo was the error avoidance. Other meaning such as ‘mistake-proofing’ or ‘fail-safe operation’ convey similar meanings.

It is any mechanism in a Lean manufacturing process that helps to avoid mistakes The main objective of poka-yoke is to achieve zero defects.

Figure 4.5: Example of poke yoke

It is very simple concept and can be widely used, in operations. For example, if one part fits into hole and it must fit in only one orientation, then fool-proofing the assembly of the parts requires that the part fit in only one orientation, and then fool-proofing the assembly of the parts requires that the part fit in the hole in only the correct orientation. Many mistakes can be avoided in processing, assembly etc. Thus, its implementation is governed by what people think they can do to prevent the errors in their workplace, and not by a set of the step-by- step instructions on how they should do their job. A good poka-yoke solution is one that requires no attention from the operator.

A poka-yoke device should have the following characteristics:

(a) Usable by all workers,

(b) Simple to install and low cost

(c) Does not require continuous attention from the operator (ideally, it should work even if the operator is not aware of it),

(d) Provide instantaneous feedback, prevention or correction.

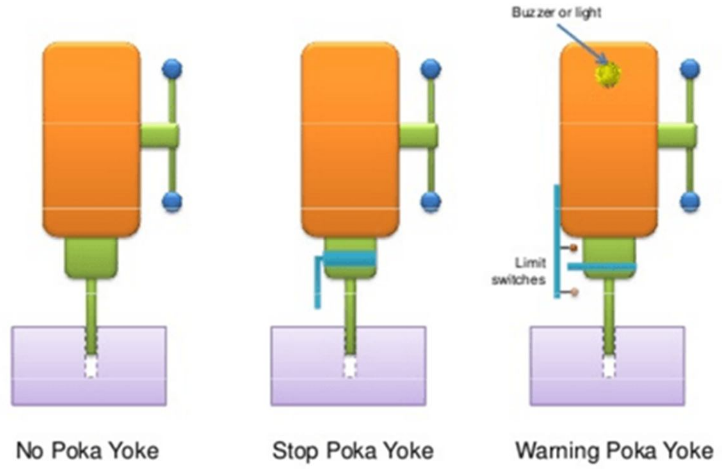


Figure 4.6: Poke yoke in Vertical Drill Machine

Some simple examples of Poka-Yoke applications are

- One of the most common is when a car driver with a manual gearbox must press on the clutch pedal (a process step – Poka-Yoke) before starting the engine. The interlock prevents an unintended movement of the car.
- Another example is a car with an automatic transmission, which has a switch that requires the vehicle to be in "Park" or "Neutral" before it can start.
- Washing machine that does not start if the door is not close properly to prevent accident. These types of automation do not allow mist69+akes or incorrect operation from the start.

❖ Kaizen:

Kaizen is a Japanese word for improvement, or "change for the better" and relates to practices that focus upon continuous improvement of processes in manufacturing, engineering, and business management. It is a routine process that goes beyond simple productivity improvement if correctly done humanizes the workplace, eliminates overly hard work and teaches people how to perform experiments on their work using the scientific method and how to learn to spot and eliminate waste in business processes and increase productivity. Each member has to participate and from all hierarchical structure for successful implementation. Kaizen on a broad, cross-departmental scale in companies generates total quality management, and frees human efforts through improving productivity using machines and computing power.

At Toyota, delivers a small improvement it is usually a local improvement within a workstation or local area and involves a small group in improving their own work environment and productivity. This group is often guided through the kaizen process by a line supervisor. It includes making changes, monitoring results and adjusting and suggesting new improvements. With time it is designed to address issue over the week and is referred as kaizen event. It is known as Deming cycle or PDCA cycle other techniques used with PDCA include 5 Whys, which is a form of root cause analysis in which the user asks "why" to a problem and its answer five successive times. There are normally a series of root causes stemming from one problem, and they can be visualized using fishbone diagrams or tables.

The cycle of kaizen activity can be defined as:

- Standardize an operation and activities and measure it
- Innovate to meet requirements and increase productivity
- Standardize the new, improved operations

Activity: Study the following research paper.

❖ FTA:

- Patil, R. B., Mhamane, D. A., Kothavale, P. B., &Kothavale, B. (2018, December). Fault tree analysis: a case study from machine tool industry. In Proceedings of TRIBOINDIA-2018 An International Conference on Tribology. (dx.doi.org/10.2139/ssrn.3382241)
- Kang, J., Sun, L., & Soares, C. G. (2019). Fault Tree Analysis of floating offshore wind turbines. Renewable energy, 133, 1455-1467. (doi.org/10.1016/j.renene.2018.08.097)

❖ Poka Yoke:

- Kumar, B., & Rakesh, P. K. (2017). Implementation of Poka Yoke in needle bearing assembly process. Int. J. Eng. Sci. Invention. ISSN (Online), 2319-6734.
- Moosavian, A. (2022). The Machine Vision Approach as a Poka-Yoke System in Conrod Bearing Assembly Station of Engine Production Line. Engine Research, 65(65), 88-99.(10.22034/er.2022.697908)

❖ Kaizen:

- Kumar, N. (2015). Kaizen Implementation in Visi Cooler Industry: A Case Study. Available at SSRN 2628082. (dx.doi.org/10.2139/ssrn.2628082)
- Knechtges, P., & Decker, M. C. (2014). Application of kaizen methodology to foster departmental engagement in quality improvement. Journal of the American college of radiology, 11(12), 1126-1130. (doi.org/10.1016/j.jacr.2014.08.02)

Quiz:

Q-1: Create a fault tree analysis for starting problems of automobile in winter season.

Q-2: Why Fault Tree Analysis is worth the effort

Q-3: What are the limitations of fault tree analysis

Q-4: Why Poka yoke is known as mistake proofing technique and explain with two examples

Q-5: What is Kaizen? Discuss brief in relation with any of the case study and show how it improves the productivity.

Q-6 : Develop PDCA cycle for an example

Q-7: The Toyota Production System is known for kaizen so read Toyota case study and discuss briefly in your words.

Suggested Reference:

1. Patil, R. B., Mhamane, D. A., Kothavale, P. B., &Kothavale, B. (2018, December). Fault tree analysis: a case study from machine tool industry. In Proceedings of TRIBOINDIA-2018 An International Conference on Tribology. (doi.org/10.2139/ssrn.3382241)
2. Kang, J., Sun, L., & Soares, C. G. (2019). Fault Tree Analysis of floating offshore wind turbines. Renewable energy, 133, 1455-1467. (doi.org/10.1016/j.renene.2018.08.097)
3. Kumar, B., & Rakesh, P. K. (2017). Implementation of Poka Yoke in needle bearing assembly process. Int. J. Eng. Sci. Invention. ISSN (Online), 2319-6734.
4. Moosavian, A. (2022). The Machine Vision Approach as a Poka-Yoke System in Conrod Bearing Assembly Station of Engine Production Line. Engine Research, 65(65), 88-99.(10.22034/er.2022.697908)
5. Kumar, N. (2015). Kaizen Implementation in Visi Cooler Industry: A Case Study. Available at SSRN 2628082. (dx.doi.org/10.2139/ssrn.2628082)
6. Knechtges, P., & Decker, M. C. (2014). Application of kaizen methodology to foster departmental engagement in quality improvement. Journal of the American college of radiology, 11(12), 1126-1130. (doi.org/10.1016/j.jacr.2014.08.02)
7. Total Quality Management – Dr. S. Kumar, Laxmi Publication Pvt. Ltd.

References used by the students:

Rubric wise marks obtained:

Criteria	**%**	**10**	**9-8**	**7-6**	**5**
Knowledge	30	Correct answers 90% or more by student.	Correct answers between 70-89%.	Correct answers between 50-69%.	Correct answers less than 50%.
Quality of report	20	Proper formatting and well attempted quiz and case study with excellent reported work	Only formatting is improper (Location of figures/tables, use of pencil and scale). Good	A few required elements (labeling/ notations) are missing. Average	Several elements are missing (content in paragraph, labels, figures, tables). Poor report
Participation type	30	Participation 25% Excellent focused attention in the exercise.	Moderately focused attention on exercise.	Focused limited attention in the exercise.	Less Participation
Punctuality	20	Timely Submission	Submission late by one laboratory.	Submission late by two laboratories.	Submission late by more than two laboratories.
Criteria	**%**	**Level of Marks**	**Multiplication**	**Total**	**Remarks**
Knowledge	30		0.3 *_____		
Quality of report	20		0.2*_____		
Participation	30		0.3*_____		
Punctuality	20		0.2*______		
			Total Marks		

Sign of Faculty

Experiment No: 5

To study about Just in Time Production System

Date:

Relevant CO: Make use of design of experiments, concepts of just in time and quality management. (CO2)

Objectives:

- To understand concepts of just in time in production system.

Just-In-Time Production System

History:

1960's: Developed as Toyota Production System by Taiichi Ohno and his colleagues

1970's: U.S. and European auto makers began to apply JIT to improve quality and productivity

1990's and beyond: Expanded the JIT concept to streamline all types of operations

About JIT:

A philosophy of manufacturing based on planned elimination of all waste and on continues improvement of productivity. When Companies use Just in Time (JIT) manufacturing and inventory control system, they purchase materials and produce units only as needed to meet actual customers demand. In just in time manufacturing system inventories are reduced to the minimum and in some cases are zero. JIT approach can be used in both manufacturing and merchandising companies

Just in Time or JIT is a management philosophy that strives to eliminate the sources of manufacturing waste by producing the right part in the right place at the right time.

It is system that aims at successful completion of a product or service at each stage of the production activity from the vendor to the customer just in time for its use and at a minimum cost. JIT is a strategy or guiding philosophy whose goal is to seek manufacturing excellence.

Waste is the result of any activity that adds cost without adding value, such as moving and storing. JIT improves the profit and the return on investment by reducing the inventory levels, increasing the inventory turnover rate, reducing the variability, improving the product quality, reducing the production and delivery lead times and reducing the other costs associated with the machine set-up and equipment breakdown. JIT system, an underutilized or an excess capacity is used instead of the buffer inventories to compensate against the probable problems that may arise. Application of JIT is focused on identifying a production flow and product quality-related problems. As the production flow increases, the productivity improves and the cost decreases while if the quality improves, the scrap and customer complaints will reorganization, making the logical result of JIT to dominate the market possible.

Principles of JIT (how to implement JIT):

1. Set up production flow process.
2. Solve problems concurrently.
3. Reduce inventory more.
4. Improve product and process.
5. Apply scrap/quality control.

6. Apply Kanban pull system.
7. Stabilize master production schedule
8. Work with suppliers.

Figure 5.1: Just In Time frame

❖ **Elimination of waste**

Any activity that does not add value to the product or service in the eyes of the customer is a waste. Poor product design such as the inclusion of fancy functions not required by the customer is a waste. A product design causing difficulty in manufacturing is a waste.

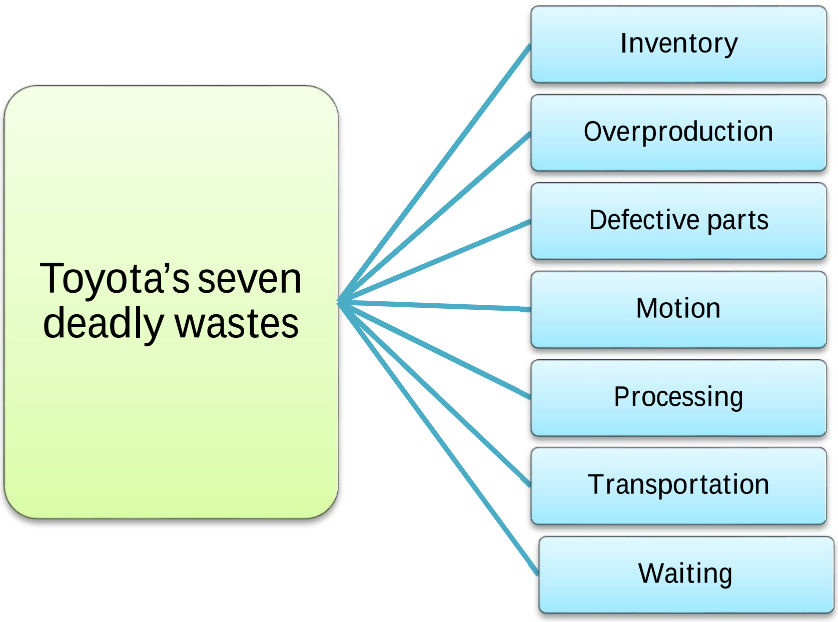


Figure 5.2: Toyota's seven deadly wastes

Standardization reduces the planning and control efforts, the number of parts, and the inventory required. A poor product design without enough standardization leads to waste. In addition to waste resulting from poor design, Toyota identifies seven examples of waste resulting from poor manufacturing methods.

1. Waste of overproduction

Overproduction is the production of goods more than what are immediately needed. Overproduction causes extra material handling, quality problems, and unnecessary inventories. Consuming materials for unnecessary products may cause a shortage of material for other products that are needed. Never overproduce products to keep men and machines busy. If the required loading is less than the capacity, leave it alone. The labor can be switched to other departments, cleaning or maintaining the machines, accepting training and education, etc.

2. Waste of waiting

A material waiting in queue is a waste. An operator waiting for material or instruction and having no productive work to do is a waste.

3. Waste of movement

Poor plant layout results in materials having to be moved extra distances and cause unnecessary material handling costs. Work centers should be close to each other in order to reduce the move distance. Someone may say that close work centers provide no room for WIP inventories. That is fine! No room for WIP inventory forces the WIP to decrease.

4. Waste of inventories

Inventory causes costs of interest, space, record keeping, and obsolescence. Moreover, inventory can mask problems which could cause more inventory buildup. For example, WIP inventory between work centers can hide the symptoms of an unbalanced production rate. Finished goods inventory can mask poor forecasting, poor quality, and poor production control. Inventory is not an asset; it is a waste!

5. Waste of motion

Improper methods of performing tasks by the operators cause wasted motions. Reaching far for materials or machine buttons is a waste of motion. Searching for tools is a waste of motion. Any activity that does not add value to the products should be eliminated. Bad layout or training causes waste of motion.

6. Waste of making defects

The cost of scraps is a waste. But it is the least important compared with other wastes caused by making defects. Defects interrupt the smooth flow of materials in the production line. If the scrap is not identified, next workstation will try using it to produce more wastes, or waste time waiting for good materials.

7. Waste of process itself

Bad process design is a waste. For example, wrong type or size of machines, wrong tools, and wrong fixtures are wastes.

The principle of eliminating the wastes includes:

- ✓ All waste should be eliminated.
- ✓ Waste can gradually be eliminated by removing small amounts of inventory from the system, correcting the problems that ensue, and then, removing more inventory.

- ✓ The customers' definitions of quality should drive product design and manufacturing system.
- ✓ Manufacturing flexibility is essential to maintain high quality and low cost with an increasingly differentiated product line.
- ✓ Mutual respect and support should exist among an organization, its employees, its suppliers, and its customers.
- ✓ A team effort is required to achieve world-class manufacturing capability.
- ✓ The employee who performs a task is the best source of suggested improvements.

JIT as a Control Technique

In daily operations, JIT provides useful control methods. The characteristics of a JIT control technique include uniform loading, repetitive processes, pull system, using production cards, and synchronized production.

Pull System

JIT control pulls materials from the previous workstation. The workstation replenishes any materials consumed by its following workstation. Since only the consumed materials are produced, the inventories between workstations never accumulate. For the first workstation of the factory, the supplier is its preceding workstation. For the last workstation in a factory, the customer is its following workstation. Customers pull the products from the factory, and factory pulls the materials from the suppliers.

Uniform Loading

The loads for jobs in every workstation are equal. This makes the pull system possible. If uneven loading exists, the following workstation may have to wait for the materials from the preceding workstation. Uniform loading allows the materials to flow through the production line smoothly. Every workstation runs at a constant rate. If the demand increases, the production rates in all workstation increase together. If the demand drops, all workstations may have the same level of idleness.

Production Card

JIT control uses various cards to transmit production signals. During the production, these cards are attached to and detached from the materials. Production signals are transmitted from the following workstation back to the preceding workstation. The cards have various shapes and colours to indicate different purposes. Sometimes material containers or the material itself are themselves the signals.

Synchronized Production

Synchronized production is a manufacturing practice in which production activities in each workstation are synchronized with certain control signals. The production rates of workstations are related to each other, and the work-in-process inventories are limited to a predetermined level. Synchronized production can be seen in JIT environments or theory-of-constraints (TOC) environments. The control signals are carried by Kanban's in a JIT environment. In the TOC environment, drum-buffer-rope (DBR) is used to synchronize the workstations. Synchronized production will be discussed in the next chapter.

Activity: Study the following research paper.

- Amasaka, K. (2002). "New JIT": A new management technology principle at Toyota. International Journal of Production Economics, 80(2), 135-144.(https://doi.org/10.1016/S0925-5273(02)00313-4)
- Rahmani, K. A. M. R. A. N., & Nayebi, M. A. (2014). Effect of JIT Implementation in

Iran Automotive Industry (Case Study: Iran Khodro's Assembly Line 2). Indian J. Sci. Res, 7(1), 001-016.

- Aradhye, A. S., & Kallurkar, S. P. (2014). A case study of just-in-time system in service industry. Procedia Engineering, 97, 2232-2237(https://doi.org/10.1016/j.proeng.2014.12.467)

Quiz:

Q-1: How does Toyota use JIT?
Q-2: What are the wastes in industries?
Q-3: How do the suppliers benefit from JIT purchasing?
Q-4: What is the key to the successful implementation of JIT?
Q-5: Discuss the differences between a traditional push system and a JIT demand pull system.

Suggested Reference:

1. Amasaka, K. (2002). "New JIT": A new management technology principle at Toyota. International Journal of Production Economics, 80(2), 135-144.(https://doi.org/10.1016/S0925-5273(02)00313-4)
2. Rahmani, K. A. M. R. A. N., & Nayebi, M. A. (2014). Effect of JIT Implementation in Iran Automotive Industry (Case Study: Iran Khodro's Assembly Line 2). Indian J. Sci. Res, 7(1), 001-016.
3. Aradhye, A. S., & Kallurkar, S. P. (2014). A case study of just-in-time system in service industry. Procedia Engineering, 97, 2232-2237(https://doi.org/10.1016/j.proeng.2014.12.467)
4. Lai, K. H., & Cheng, T. E. (2016). Just-in-time logistics. CRC Press.
5. Total Quality Management by K C Arora, S K Kataria & Sons

References used by the students:

Rubric wise marks obtained:

Criteria	**%**	**10**	**9-8**	**7-6**	**5**
Knowledge	30	Correct answers 90% or more by student.	Correct answers between 70-89%.	Correct answers between 50-69%.	Correct answers less than 50%.
Quality of report	20	Proper formatting and well attempted quiz and case study with excellent reported work	Only formatting is improper (Location of figures/tables, use of pencil and scale). Good	A few required elements (labeling/ notations) are missing. Average	Several elements are missing (content in paragraph, labels, figures, tables). Poor report
Participation type	30	Participation 25% Excellent focused attention in the exercise.	Moderately focused attention on exercise.	Focused limited attention in the exercise.	Less Participation
Punctuality	20	Timely Submission	Submission late by one laboratory.	Submission late by two laboratories.	Submission late by more than two laboratories.
Criteria	**%**	**Level of Marks**	**Multiplication**	**Total**	**Remarks**
Knowledge	30		0.3 *_____		
Quality of report	20		0.2*_____		
Participation	30		0.3*_____		
Punctuality	20		0.2*______		
			Total Marks		

Sign of Faculty

Experiment No: 6
Design of Experiments (DOE)

Date:

Relevant CO: Make use of design of experiments, concepts of just in time and quality management. (CO2)

Objectives:

- To understand need, importance and process for Design of Experiments.
- How to achieve robust product design by Taguchi techniques
- To know brief about Minitab or any quality software (Optional beyond the syllabus)

Task 1: Discuss DOE and taguchi quality loss function
Task 2: Clarify how Robust design method can be an alternative for DOE
Task 3: Identify or develop practical applications or examples of DOE with and discuss its detail steps.

Activity:
Study Following research paper

- Kim, D. W., Cho, M. W., Seo, T. I., & Lee, E. S. (2008). Application of design of experiment method for thrust force minimization in step-feed micro drilling. Sensors, 8(1), 211-221. (DOI: doi.org/10.3390/s8010211)
- Nagarwala, F., Mankikar, P., & Kanthale, V. S. Design of Experiments for optimization of Cutting Parameters for Turning of AA7075 aluminium alloy. MITCOE, &DIAT, Pune, AMET-2017, IJCET INPRESSOSpecial Issue-7, 27-31.
- Țîțu, A. M., Sandu, A. V., Pop, A. B., Țîțu, Ș., Frățilă, D. N., Ceocea, C., & Boroiu, A. (2020). Design of experiment in the milling process of aluminum alloys in the aerospace industry. Applied Sciences, 10(19), 6951. (DOI: doi.org/10.3390/app10196951)

References:

1. Pukelsheim, F. (2006). Optimal design of experiments. Society for Industrial and Applied Mathematics.
2. Cox, D. R., & Reid, N. (2000). The theory of the design of experiments. CRC Press

References used by the students:

Rubric wise marks obtained:

Criteria	**%**	**10**	**9-8**	**7-6**	**5**
Knowledge	30	Correct answers 90% or more by student.	Correct answers between 70-89%.	Correct answers between 50-69%.	Correct answers less than 50%.
Quality of report	20	Proper formatting and well attempted quiz and case study with excellent reported work	Only formatting is improper (Location of figures/tables, use of pencil and scale). Good	A few required elements (labeling/ notations) are missing. Average	Several elements are missing (content in paragraph, labels, figures, tables). Poor report
Participation type	30	Participation 25% Excellent focused attention in the exercise.	Moderately focused attention on exercise.	Focused limited attention in the exercise.	Less Participation
Punctuality	20	Timely Submission	Submission late by one laboratory.	Submission late by two laboratories.	Submission late by more than two laboratories.
Criteria	**%**	**Level of Marks**	**Multiplication**	**Total**	**Remarks**
Knowledge	30		0.3 *_____		
Quality of report	20		0.2*_____		
Participation	30		0.3*_____		
Punctuality	20		0.2*______		
			Total Marks		

Sign of Faculty

Experiment No: 7
To Study about Total Productive Maintenance

Date:

Relevant CO: Illustrate Total Productive maintenance and ISO. (CO3)

Objectives:

- To understand concept of Total Productive Maintenance
- To know the method of evaluating Overall Equipment Effectiveness(OEE)

Total Productive Maintenance (TPM):

- Total productive maintenance (TPM) is a strategy that operates according to the idea that everyone in a facility should participate in maintenance, rather than just the maintenance team.
- This approach uses the skills of all employees and seeks to incorporate maintenance into the everyday performance of a facility.
- It's the process of getting employees involved in maintaining their own equipment while emphasizing proactive and preventive maintenance techniques.
- It can be considered as the medical science of machines. Total Productive Maintenance (TPM) is a maintenance program which involves a newly defined concept for maintaining plants and equipment.
- The goal of the TPM program is to markedly increase production while, at the same time, increasing employee morale and job satisfaction. TPM brings maintenance into focus as a necessary and vitally important part of the business.
- It is no longer regarded as a non-profit activity. Down time for maintenance is scheduled as a part of the manufacturing day and, in some cases, as an integral part of the manufacturing process. The goal is to hold emergency and unscheduled maintenance to a minimum.

TPM was introduced to achieve the following objectives. The important ones are listed below.

- ✓ Avoid wastage in a quickly changing economic environment.
- ✓ Producing goods without reducing product quality.
- ✓ Reduce cost.
- ✓ Produce a low batch quantity at the earliest possible time.
- ✓ Goods send to the customers must be non-defective

Similarities and differences between TQM and TPM :

The TPM program closely resembles the popular Total Quality Management (TQM) program. Many of the tools such as employee empowerment, benchmarking, documentation, etc. used in TQM are used to implement and optimize TPM. Following are the similarities between the two.

1. Total commitment to the program by upper level management is required in both Programmes

2. Employees must be empowered to initiate corrective action, and

3. A long range outlook must be accepted as TPM may take a year or more to implement and is an on-going process. Changes in employee mind-set toward their job responsibilities must take place as well.

Category	TQM	TPM
Object	Quality (Output and effects)	Equipment (Input and cause)
Mains of attaining goal	Systematize the management. It is software oriented	Employees participation and it is hardware oriented
Target	Quality for PPM	Elimination of losses and wastes.

Eight Pillars of TPM:

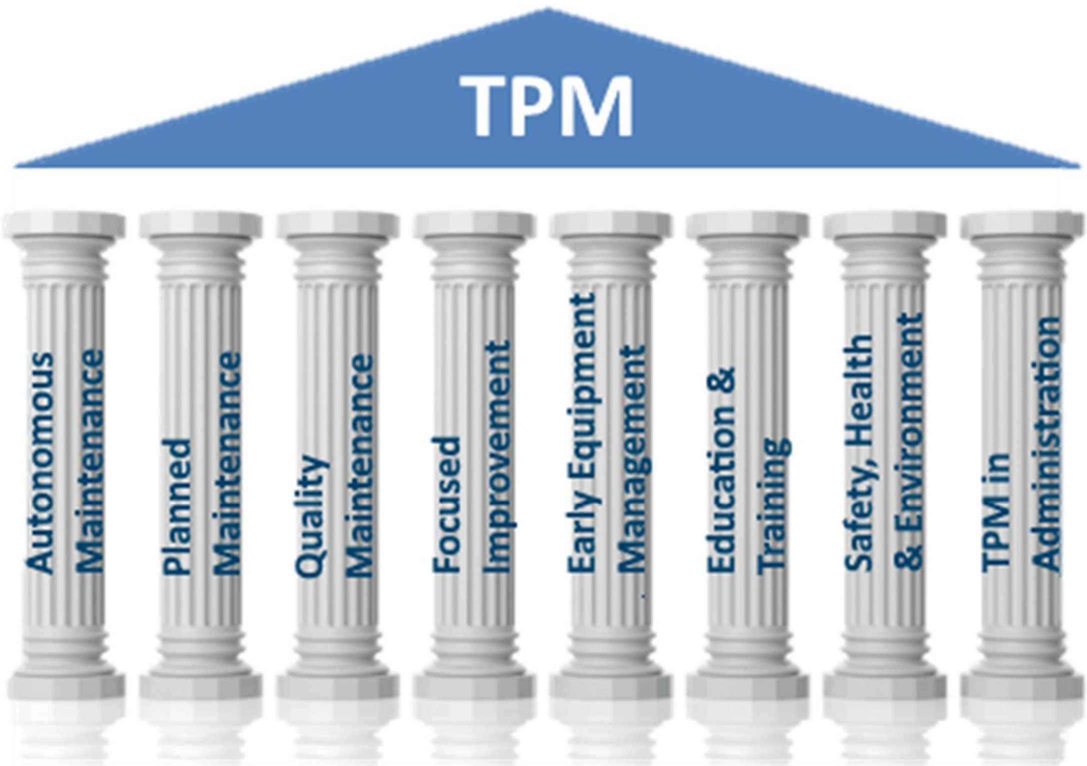


Fig: 7.1 : Eight pillars of TPM

Autonomous Maintenance:

- Autonomous Maintenance is the first of the eight pillars of TPM. It follows a structured approach to increase the skill levels of personnel so that they can understand, manage and improve their equipment and processes. The goal is to change operators from being reactive to working in a more proactive way, to achieve optimal conditions that eliminate minor equipment stops as well as reducing defects and breakdowns.
- The Autonomous Maintenance pillar activity is broken down into three phases and is owned by the team who use the equipment on a daily basis.

- ✓ The first phase establishes and maintains basic equipment conditions through restoration and eliminating causes of forced deterioration and sources of contamination. Standards are introduced for cleaning, inspection, tightening and lubrication to ensure the conditions are sustained.
- ✓ The second phase increases the capabilities of the team by training them in the detailed operating principles of the equipment and then improving the standard basic condition.
- ✓ During the third phase, the operators take total ownership of the equipment as self-directed teams, continuously improving equipment condition and performance to further reduce losses.

Benefits of the Pillar:

- ✓ The deployment of Autonomous Maintenance will improve Overall Equipment Effectiveness (OEE) by reducing performance loss and increasing equipment availability. In addition there will be measurable improvement to employee engagement and capability levels.

Planned Maintenance:

- Planned Maintenance is the second pillar of TPM and aims to achieve zero breakdowns. It follows a structured approach to establish a management system that extends the equipment reliability at optimum cost.
- The Planned Maintenance pillar activities are normally led by the maintenance team. The initial phase prioritizes equipment and involves evaluating current maintenance performance and costs to set the focus for the pillar activity. Support is provided to the Autonomous Maintenance pillar to establish a sustainable standard basic condition and the team focusses on eliminating the causes of breakdowns.
- Information management systems are used to provide detailed data on the maintenance process and the use of spares. The team identify the optimum approach to maintaining the equipment, starting with a Periodic Maintenance (Time-Based Maintenance) system before introducing Predictive Maintenance (Condition-Based
- Maintenance) systems where they are appropriate and cost effective. Finally the team drive continuous improvement of the process, eliminating reactive activities and assuring machine reliability.

Benefits of the Pillar:

- ✓ The primary benefit from implementing Planned Maintenance is the reduction in breakdowns, which leads to reduced cost and improved machine efficiency. The pillar will also contribute to improved quality and safety performance.

Quality Maintenance:

- Quality Maintenance is the third pillar of TPM and aims to assure zero defect conditions. It does this by understanding and controlling the process interactions between manpower, material, machines and methods that could enable defects to occur. The key is to prevent defects from being produced in the first place, rather than installing rigorous inspection systems to detect the defect after it has been produced.
- Quality Maintenance is launched later in the overall TPM deployment process because certain conditions must be in place for it to be successful. These conditions are delivered

by full implementation of the first four pillars.

- Forced deterioration must be abolished, process problems must be eliminated and any variation in materials must be under control. Operators and maintenance must have the required capability to sustain equipment conditions.
- Quality Maintenance is implemented in two phases. The first phase aims to eliminate quality issues by analyzing the defects, so that optimum conditions can be defined that prevent defects occurring. Then, the current state is investigated and improvements are implemented. The second phase ensures that quality is sustained, by standardizing the parameters and methods to achieve a zero defect system.

Benefits of the Pillar:

- ✓ Quality Maintenance reduces the cost of quality, as waste resulting from poor quality, rework, consumer complaints and the need for inspection are reduced. Defects become a failure of the organization’s systems, not the fault of the operator, and poor quality is no longer accepted as a normal occurrence. Everyone is responsible for maintaining optimal conditions and striving for zero defects.

Focused Improvement:

- Focused Improvement is the forth pillar of TPM. It provides a structured, team-based approach to drive elimination of specifically identified losses in any process.
- The pillar follows a structured set of steps aligned to the Plan, Do, Check, Act (PDCA) cycle, which can be implemented for improvement activities of any size or complexity in any organization.
- The pillar builds an understanding and analysis of the different loss types affecting an organization. The pillar operates at a strategic level, identifying the criteria for project selection and TPM deployment that will deliver the business objectives.
- The pillar develops the capabilities of teams to be self-sufficient in applying appropriate problem solving approaches. By building competencies and embedding behaviors, the pillar ensures that the workforce has the skills and motivation to eliminate loss from their processes, not only for selected projects but also for normal every day issues.

Benefits of the Pillar:

- ✓ As well as improving efficiency, reducing defects and improving safety performance due to eliminating losses, the Focused Improvement pillar ensures that the approach taken is consistent and repeatable to assure sustainability.

Early Equipment Management:

- Early Management is the fifth pillar of TPM and aims to implement new products and processes with vertical ramp up and minimized development lead time. It is usually deployed after the first four pillars as it builds on the learning captured from other pillar teams, incorporating improvements into the next generation of product and equipment design.
- There are two parts to the Early Management pillar: Early Equipment Management and Early Product Management. Both approaches focus on using the lessons from previous experiences to eliminate the potential for losses through the planning, development and

design stages.

- For Early Equipment Management, the goal is to introduce a loss and defect free process so that equipment downtime is minimal (zero breakdowns), and maintenance costs are all considered and optimized, from commissioning onwards.
- Early Product Management aims to shorten development lead times, with teams working on simultaneous activities so that vertical start up can be achieved with zero quality loss (zero defects).

Benefits of the Pillar:

- ✓ Effective Early Management implementation will deliver reduced product and process introduction lead times, improved Overall Equipment Effectiveness and the ability to deliver in volume at the right quality from production start-up. Cost savings will be delivered both during the introduction phase and throughout the equipment or product life cycle.

<u>Education and Training:</u>

- Training and Education is the sixth pillar of TPM. It ensures that staff are trained in the skills identified as essential both for their personal development and for the successful deployment of TPM in line with the organization's goals and objectives. Industry Forum Business Excellence Through Inspired People
- Initially the knowledge and skills required for carrying out each job are defined, in terms of both complexity of knowledge needed and the number of capable people required to support the business needs. A current state analysis assesses the current levels against the established requirements and a training plan is developed to close any gaps. This plan is implemented and evaluated to ensure that the activity generates the improved capabilities targeted.
- The pillar team then design, implement and improve a 'Skill Development System' to enable on-going development of all employees. As the TPM programme develops, the pillar will expand to cover broader roles and increasingly complex training needs.

Benefits of the Pillar:

- ✓ Increased skills and performance of all personnel throughout the organization is essential for the successful implementation of TPM. Without a strong Training and Education pillar, the impact of the first three pillars will not be sustainable.
- ✓ Untapped human potential creates substantial waste within an organization. Training and Education creates a corporate environment which is able to maximize the potential of all employees and respond positively to the changing business climate, technological advances and management innovation.

<u>Safety, Health and Environment:</u>

- Safety, Health and Environment (SHE) is the seventh pillar and implements a methodology to drive towards the achievement of zero accidents. It is important to note that this is not just safety related but covers zero accidents, zero overburden (physical and mental stress and strain on employees) and zero pollution.
- Although the SHE pillar is the eighth pillar of TPM, it should not be thought of as the last to be deployed. The implementation of SHE strategies occurs throughout the TPM

deployment process and SHE activities are never complete.

- SHE pillar activities aim to reactively eliminate the root causes of incidents that have occurred, to prevent reoccurrence, and proactively reduce the risk of future potential incidents by targeting near misses and potential hazards. The pillar team target three key areas: people's behaviors, machine conditions and the management system. All SHE pillar activities should be aligned to relevant external quality standards and certifications.

Benefits of the Pillar:

- ✓ The immediate benefits of implementing the SHE pillar are to prevent reoccurrence of lost time accidents and reduce the number of minor accidents as well as preventing environmental system failure. This has a direct financial saving in the cost of containment, investigation and compensation as well as reputational impact.

TPM in Administration:

- Office TPM is the final pillar and concentrates on all areas that provide administrative and support functions in the organization. The pillar applies the key TPM principles in eliminating waste and losses from these departments. The pillar ensures that all processes support the optimization of manufacturing processes and that they are completed at optimal cost.
- The initial preparation stage for the pillar ensures that the goals and objectives for each department are aligned to the organization's vision and mission. There are then five key activities that the Office TPM pillar undertakes within an appropriate timeframe.
- The Office TPM team implements office versions of Focused Improvement, Autonomous Maintenance and the Training and Education pillars to establish sustainable, performing processes. They deploy a flexible staffing policy to allow departments to manage peak workloads, without overstaffing, and a prioritized improvement program, by loss analysis, against the goals and objectives set in the preparatory activity phase.

Benefits of the Pillar:

- ✓ Office TPM benefits organizations by eliminating losses in the administrative systems across the whole organization and into the extended supply chain. This delivers cost reductions in the organization's overheads as well as supporting improvement and sustainability of the manufacturing process efficiency.
- ✓ The application of Office TPM also benefits the organization by developing support functions that react flexibility to changes in customer requirement and that ensure a strong brand image is maintained.

OEE (Overall Equipment Effectiveness):

OEE is a performance metric compiled from three data sources of the machine (or process) being measured. The three data sources are Availability, Performance and Quality.

• **Availability -** Compares the actual time a piece of equipment is actually available to produce parts in comparison to the planned available time.

• **Performance -** Compares the actual amount of product processed relative to the maximum amount that could be processed within the available production time.

• **Quality -** The proportion of the product from a process that is right first time with no scrap, rework or concession to accept outside process tolerances.

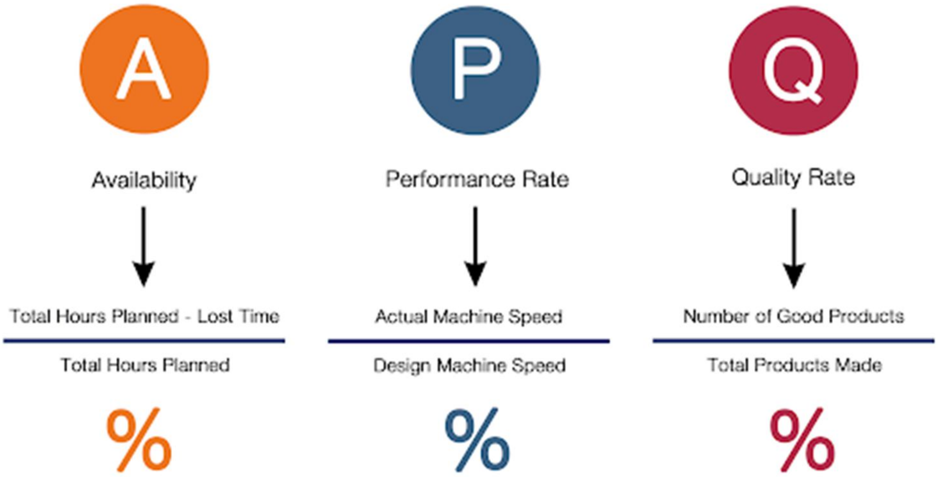


Fig: 7.2: OEE Parameters

Standard OEE Benchmarks:

- An OEE score of 100 percent is considered perfect production, meaning company only manufacturing quality parts as quickly as possible with no downtime.
- An OEE score of 85 percent is considered world class for discrete manufacturers and is a sought-after long-term goal.
- An OEE score of 60 percent is typical for discrete manufacturers and shows there is considerable room for improvement.
- An OEE score of 40 percent is considered low but not uncommon for manufacturers just starting to track and improve performance. In most cases, a low score can easily be improved through easy-to-apply measures.

Activity: Study the following research paper.

– Ahuja, I. P. S., & Kumar, P. (2009). A case study of total productive maintenance implementation at precision tube mills. Journal of Quality in Maintenance Engineering, 15(3), 241-258. (DOI:10.1108/13552510910983198)

– Mwanza, B. G., & Mbohwa, C. (2015). Design of a total productive maintenance model for effective implementation: Case study of a chemical manufacturing company. Procedia Manufacturing, 4, 461-470. (DOI:.1016/j.promfg.2015.11.063)

Quiz:

Q-1: What is the difference between TPM and TQM?

Q-2: What is the impact of TPM on the goals of a company and what are its objectives

Q-3: Explain eight pillars of TPM in detail.

Q-4: How does TPM impact overall equipment effectiveness (OEE)? What are your steps to increase the OEE of company?

Q-5: How does TPM differ from traditional maintenance practices?

Q-6: How does TPM impact employee morale?

Q-7: Identify one related research paper and discuss its work briefly.

Suggested Reference:

1. Ahuja, I. P. S., & Kumar, P. (2009). A case study of total productive maintenance implementation at precision tube mills. Journal of Quality in Maintenance Engineering, 15(3), 241-258. (https://doi.org/10.1108/13552510910983198)
2. Mwanza, B. G., & Mbohwa, C. (2015). Design of a total productive maintenance model for effective implementation: Case study of a chemical manufacturing company. Procedia Manufacturing, 4, 461-470. (https://doi.org/10.1016/j.promfg.2015.11.063)
3. Borris, S. (2006), Total productive maintenance, McGraw-Hill Publication (DOI: 10.1036/0071467335)
4. Total Quality Management by K C Arora, S K Kataria & Sons

References used by the students:

Rubric wise marks obtained:

Criteria	**%**	**10**	**9-8**	**7-6**	**5**
Knowledge	30	Correct answers 90% or more by student.	Correct answers between 70-89%.	Correct answers between 50-69%.	Correct answers less than 50%.
Quality of report	20	Proper formatting and well attempted quiz and case study with excellent reported work	Only formatting is improper (Location of figures/tables, use of pencil and scale). Good	A few required elements (labeling/ notations) are missing. Average	Several elements are missing (content in paragraph, labels, figures, tables). Poor report
Participation type	30	Participation 25% Excellent focused attention in the exercise.	Moderately focused attention on exercise.	Focused limited attention in the exercise.	Less Participation
Punctuality	20	Timely Submission	Submission late by one laboratory.	Submission late by two laboratories.	Submission late by more than two laboratories.
Criteria	**%**	**Level of Marks**	**Multiplication**	**Total**	**Remarks**
Knowledge	30		0.3 *_____		
Quality of report	20		0.2*_____		
Participation	30		0.3*_____		
Punctuality	20		0.2*______		
			Total Marks		

Sign of Faculty

Experiment No: 8
Quality Standards and their role

Date:

Relevant CO: Illustrate Total Productive maintenance and ISO. (CO3)

Objectives:

- To understand ISO standards
- Understanding of products and organizations in relation to different ISO standards

Task1: Discuss with example ISO 9000 series. Also narrate advantages and limitations of registration of firm or your Institute for ISO

Task 2: Elaborate significance and requirement of QS 9000 certification for automotive industries.

Task 3: Explain briefly about Gujarat Pollution Control Board ISO 14001 certified organization and its environmental clearance guidelines. What is ISO 14001

Task 4: Why and which types of firms need to go for ISO 14000 with its implementation benefits and barriers.

Task 5: Refer any one research article listed below and summarize it in detail.

References:

- McCornac, D. C., & Bich, T. T. H. (2006). The Implementation Of ISO9000 In Vietnam: Case Studies From The Footwear Industry. International Business & Economics Research Journal (IBER), 5(2). (DOI: doi.org/10.19030/iber.v5i2.3459)
- Mo, J. P., & Chan, A. M. (1997). Strategy for the successful implementation of ISO 9000 in small and medium manufacturers. The TQM magazine, 9(2), 135-145. (DOI: doi.org/10.1108/09544789710165581)
- Hibadullah, S. N., Habidin, N. F., Fuzi, N. M., Desa, A. F. N. C., & Zamri, F. I. M. (2013). ISO 14001 performance efforts and environmental performance in Malaysian automotive industry. Journal of Environmental Science, Computer Science and Engineering & Technology, 2(1), 129-138.

BOOK:

1. Jaju, S. B. (2011). Implementation of ISO 14000 in Luggage Manufacturing Industry: A Case Study. In Environmental Management in Practice. IntechOpen.
2. Hoyle, D. (2009). ISO 9000 Quality Systems Handbook-updated for the ISO 9001: 2008 standard. Routledge.
3. Quality Assurance and Total Quality Management (ISO 9000, QS 9000 ISO 14000) by K C Jain and A K Chitale, Khanna Publishers

References used by the students:

Rubric wise marks obtained:

Criteria	**%**	**10**	**9-8**	**7-6**	**5**
Knowledge	30	Correct answers 90% or more by student.	Correct answers between 70-89%.	Correct answers between 50-69%.	Correct answers less than 50%.
Quality of report	20	Proper formatting and well attempted quiz and case study with excellent reported work	Only formatting is improper (Location of figures/tables, use of pencil and scale). Good	A few required elements (labeling/ notations) are missing. Average	Several elements are missing (content in paragraph, labels, figures, tables). Poor report
Participation type	30	Participation 25% Excellent focused attention in the exercise.	Moderately focused attention on exercise.	Focused limited attention in the exercise.	Less Participation
Punctuality	20	Timely Submission	Submission late by one laboratory.	Submission late by two laboratories.	Submission late by more than two laboratories.
Criteria	**%**	**Level of Marks**	**Multiplication**	**Total**	**Remarks**
Knowledge	30		0.3 *_____		
Quality of report	20		0.2*_____		
Participation	30		0.3*_____		
Punctuality	20		0.2*______		
			Total Marks		

Sign of Faculty

Experiment No: 9

Problems on failure mechanism and reliability

Date:

Relevant CO: Utilize knowledge of contemporary trends in quality engineering and Reliability Engineering in industry. (CO4)

Objectives:

- To understand reliability and failure repair process
- To sense the need of reliability over product life cycle.

Quiz:

Q-1: Draw and explain Bath tub Curve. State the difference between reliability and quality.

Q-2: With a block diagram explain the reliability design process.

Q:3 What is the inspection and repair availability model? Explain a case for it.

Q-4 Ten parts were tested out of which five parts failed and were not repairable they are shown in table. Calculate Failure rate (ƛ) and Mean time to failure (MTTF).

Part 1	Part 2	Part 3	Part 4	Part 5
90	110	125	330	525

Q-5 Determine the system reliability (R), for a specified service period of 100 hours. Where component failure rate is 0.001 per hour

Q-6 Explain terms: Mean time to failure (MTTF), Failure rate (ƛ), and Mean time between failures (MTBF).

Q-7 Solve three additional numerical related to different aspects of reliability

Q-8 For a selected electric part its mean time between failures is 2000 hours and specified service period of 150 hours. Calculate the reliability of the part.

Q-9 What is reliability engineering and its significance from industrial aspect and how it differs with word quality

Q-10 Explain different kinds of measures of skewness

Q-11 Explain concept of reliability function

Suggested Reference:

1. Reliability Engineering by Kailash C. Kapur, Michael Pecht Wiley publications.
2. Reliability Engineering by Srinath L. S., Affiliated East West Press.

References used by the students:

Rubric wise marks obtained:

Criteria	%	10	9-8	7-6	5
Knowledge	30	Correct answers 90% or more by student.	Correct answers between 70-89%.	Correct answers between 50-69%.	Correct answers less than 50%.
Quality of report	20	Proper formatting and well attempted quiz and case study with excellent reported work	Only formatting is improper (Location of figures/tables, use of pencil and scale). Good	A few required elements (labeling/ notations) are missing. Average	Several elements are missing (content in paragraph, labels, figures, tables). Poor report
Participation type	30	Participation 25% Excellent focused attention in the exercise.	Moderately focused attention on exercise.	Focused limited attention in the exercise.	Less Participation
Punctuality	20	Timely Submission	Submission late by one laboratory.	Submission late by two laboratories.	Submission late by more than two laboratories.
Criteria	**%**	**Level of Marks**	**Multiplication**	**Total**	**Remarks**
Knowledge	30		0.3 *_____		
Quality of report	20		0.2*_____		
Participation	30		0.3*_____		
Punctuality	20		0.2*______		
			Total Marks		

Sign of Faculty

Experiment No: 10

Recent trends and World Class Manufacturing

Date:

Relevant CO: Utilize knowledge of contemporary trends in quality engineering and Reliability Engineering in industry. (CO4)

Objectives:

- To understand World Class Manufacturing, Agile manufacturing, Lean, Concurrent engineering and benchmarking.

World class manufacturing (WCM)

World class manufacturing is a collection of concepts, which set standard for production and manufacturing for another organization to follow. WCM has place great emphasis on being close to the customer. Customer prosperity goes much further and examines how much value is added to the customer by the use of your company's products & services. World class manufacturing was introduced in the automobile, electronic and steel industry.

World class manufacturers tend to implement best practices and also invent new practices as to stay above the rest in the manufacturing sector. The main parameters which determine world-class manufacturers are quality, cost effective, flexibility and innovation.

Fig: 10.1 WCM

World class manufacturers implement robust control techniques but there are five steps, which will make the system efficient. These five steps are as follows:

- **Reduction of set up time and in tuning of machinery:** It is important that organizations are able to cut back time in setting up machinery and also tune machinery before production.
- **Cellular Manufacturing:** It is important that production processes are divided into according to its nature, with similar nature combined together.
- **Reduce WIP material:** It is normal tendency of manufacturing organization to maintain high levels of WIP material. Increased WIP leads to more cost and decreased WIP induces more focus on production and fast movement of goods.

- **Postpone product mutation:** For to achieve a higher degree of customization many changes are made to final product. However, it is important that mutation conceived for the design stage implement only after final operation.
- **Removal the trivial many and focus on vital few:** It is important for organization to focus on production of products which are lined with forecast demand as to match customer expectation

Principles of World Class Manufacturing

There are three main principles, which drive world-class manufacturing.

- Implementation of just in time and lean management leads to reduction in wastage thereby reduction in cost.
- Implementation of total quality management leads to reduction of defects and encourages zero tolerance towards defects.
- Implementation of total preventive maintenance leads to any stoppage of production through mechanical failure.

Eight dimension of WCM

1) Waste(Muda) elimination
2) Work environment(5's)
3) JIT/supply chain management
4) Equipment effectiveness/TPM
5) Customer driven
6) Quality first. Six sigma/SQM and best practices
7) Liason team force and skill development
8) Information system/BPR, technology and cash flow

Agile manufacturing (AM)

- Agile manufacturing is a term applied to an organization that has created the processes, tools, and training to enable it to respond quickly to customer needs and market changes while still controlling costs and quality.
- Agile manufacturing is the science of a business system that integrates management, technology and workforce, making the system to flexible and engages for a manufacturer to switch over from one product to another product in cost effective manner within the framework of the system.
- Agile manufacturing allows companies to adapt to changing global circumstances or the requirements of customers, staying ahead of the competition and remaining at the forefront of customers' minds. Agile manufacturing meets the desires of consumers for new and customized products, choice, and fast delivery times.
- Agile manufacturing includes planning, finance, and process design, tooling, machines and machinery. Layout, materials and inventory cost. Specification, prime constraint, marketing and sales service support.
- To approach agile manufacturing requires that the company already be world

class and using lean manufacturing methods. Agile manufacturing deals with the things we can control.

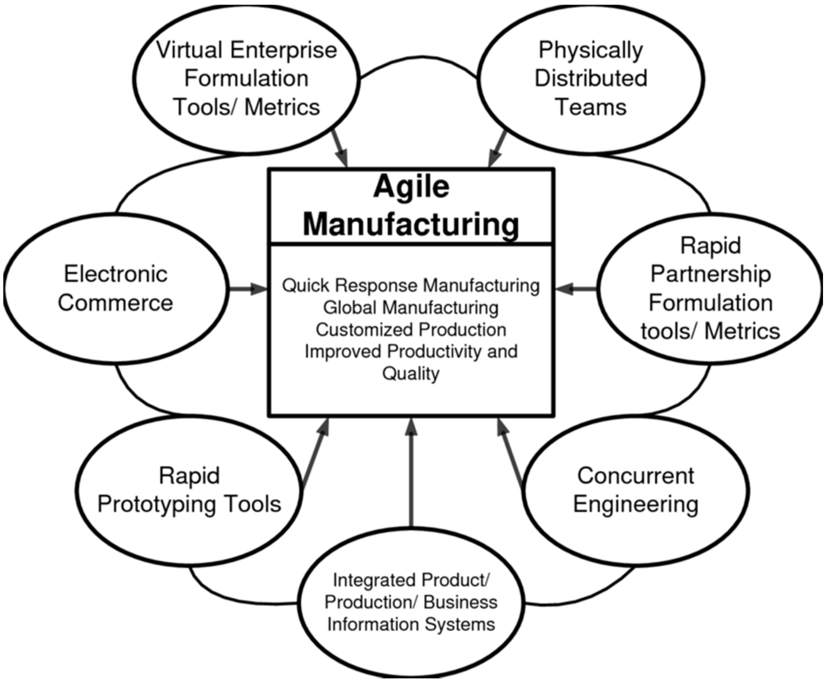


Fig: 10.2 : Agile Manufacturing

Key Factors of Agile Manufacturing

There are 5 key factors to consider when thinking of agile manufacturing: customer focused product design, technology, supply chain cooperation, employee training, and full company involvement.

1. Customer Focused Product Design

Consumers expect more personalized attention than ever before. This extends not only to rapid service but also to the products they order. An agile organization will stay on top of market demand and design the production process so that desired product variations are accounted for in the production planning.

2. Technologies

Quick response to market demand is difficult without an integrated technology environment. Information flow needs to be accurate, in real-time, and shared across all departments. This enables all areas of an agile manufacturing organization to fulfill orders correctly and efficiently. Everyone involved, from sales teams and customer service agents to line workers, needs to be on top of reliable production and market information. This information, of course, must be supported with the ability to act upon it quickly.

3. Supply Chain Cooperation

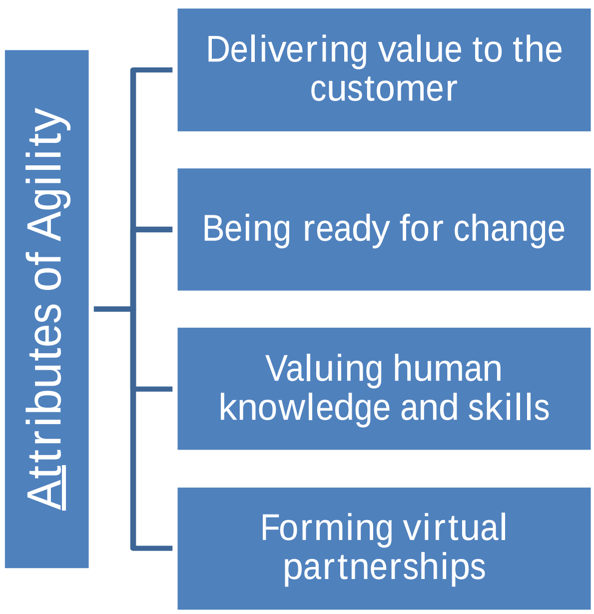
Agile methodologies involve both internal teams and external alliances. Suppliers can only respond quickly when armed with adequate production flow information, and shippers need to know what to expect for rapid delivery to end-users. It is helpful to involve new alliances and supply chain partners with some part of the product build-out or design to ensure adequate collaboration at each step. In sum, your entire supply chain must be viewed as a single entity and be aligned with your customer demand.

4. Employee Training

Employee training for agile manufacturing involves learning basic information on new production practices in addition to education in a new, agile, and customer-driven format. Expecting employees to understand the rapid changes and adaptations they will be involved in requires intensive training and an acknowledgement that a cultural change is occurring. Your team will then have the skills required to quickly solve problems in the events of unexpected disruptions.

5. Full Company Involvement

An agile transition will not work if it is relegated to the team level. Company structure needs to be part of the transformation to becoming agile. The changeover usually works better if an operation is introducing a new plant or expanding an older one. That way, the focus can be on bringing the entire new area up to agile standards. Requesting workers handle operations as they did previously while expecting them to concentrate on setting up an agile manufacturing module is doomed to fail.



<u>Advantages of Agile Manufacturing:</u>

1) Lead time reduction up to 38 %
2) Inventory reduction up to 40 %
3) Production floor space utilization increased by 27%
4) Reduction of management layers up to 70 %
5) Capacity to make variety products increases.

<u>Comparing Agile manufacturing with lean manufacturing</u>**;**

- Agile manufacturing is seen as the next step after lean in the evolution of production methodology. The key difference between the two is like between a thin and athletic person, agile being the latter. One can be neither, one or both. In manufacturing theory being both is often referred to as agile. When companies have to decide what to be, they have to look at the customer order cycle (COC-The time the customers are willing to wait) and lead time for getting supplies. If the supplier has a short lead time, lean production is possible. If the customer order cycle is short, agile production is beneficial.

- This concept is closely related to lean manufacturing, in which the goal is to reduce waste as much as possible. In lean manufacturing, the company aims to cut all costs which are not directly related to the production of a product for the consumer. Agile manufacturing can include this this concept, but it also adds an additional dimension, the idea that customer demand need to be met rapidly and effectively. In situations where companies integrate both approaches , they are sometimes said to be using " lean and agile manufacturing"
- Companies which utilize an agile manufacturing approach tend to have very strong networks with suppliers and related companies, along with numerous cooperative teams which work within the company to deliver products effectively. They can retool facilities quickly, negotiate, new agreements with suppliers and other partners in response to changing market forces, and take other steps to meet customer demands. This means that the company can increase production on products with a high consumer demand, as well as redesign products to respond to issues which have emerged on the open market.

Concurrent Engineering:

Concurrent engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers from the outset, to consider all elements of the product life cycle from conception to disposal, including quality, cost, schedule, and user requirements.

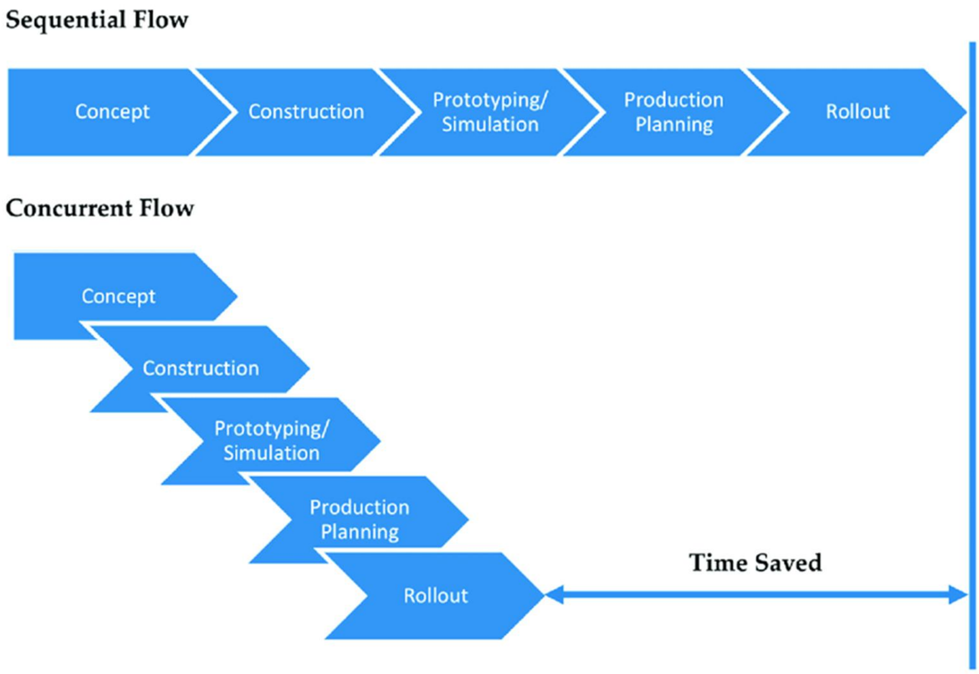


Fig: 10.3: Concurrent Engineering

- Concurrent engineering, also known as simultaneous engineering, is a method of designing and developing products, in which the different stages run simultaneously, rather than consecutively. It decreases product development time and also the time to market, leading to improved productivity and reduced costs.
- Concurrent Engineering is a long term business strategy, with long term benefits to

business. Though initial implementation can be challenging, the competitive advantage means it is beneficial in the long term. It removes the need to have multiple design reworks, by creating an environment for designing a product right the first time round

.

Why concurrent engineering?

- ✓ Increasing product variety and technical complexity that prolong the product development process and make it more difficult to predict the impact of design decisions on the functionality and performance of the final product.
- ✓ Increasing global competitive pressure that results from the emerging concept of reengineering.
- ✓ The need for rapid response to fast-changing consumer demand.
- ✓ The need for shorter product life cycle.
- ✓ Large organizations with several departments working on developing numerous products at the same time.
- ✓ New and innovative technologies emerging at a very high rate, thus causing the new product to be technological obsolete within a short period.

Seven steps to implementation of Concurrent Engineering:

1. Develop a strategy by top management;
2. Assessment of organization’s existing condition by using a particular assessment tools as benchmarking, questionnaires and performance metrics;
3. Create a supported company to increase awareness to CE method and provide related CE implementing training;
4. Priorities improvements based on result from assessment in step 2;
5. Plan the change by involving every person in charge, setting milestones/targets, and analyzing requires resources in CE project;
6. Implement improved situation
7. Support implementation.

These are just a few supportive tools that can be used in a concurrent engineering environment.

- Project management software
- Product data management & product lifecycle management suites
- Quality Function Deployment (QFD)
- 3D CAD and rapid prototyping technologies, such as additive manufacturing
- Suitable FEA tools
- Evaluation tools such as DFM, DFA, DFMA and DOE
- Failure mode analysis tools such as FMEA

Advantages of concurrent engineering

- ✓ It encourages multi-disciplinary collaboration
- ✓ Reduces product cycle time
- ✓ Reduces cost
- ✓ Increases quality by supporting the entire project cycle – enhanced quality.

- ✓ Increases productivity by stopping mistakes in their tracks
- ✓ It gives a competitive edge over the competitors

Disadvantages of concurrent engineering

- ✓ Complex to manage
- ✓ It relies on everyone working together; hence communication is critical
- ✓ Room for mistakes is small as it impacts all the departments or disciplines involved

Benchmarking:

Benchmarking is defined as the process of measuring products, services, and processes against those of organizations known to be leaders in one or more aspects of their operations.

Benchmarking is the process of improving performance by continuously identifying, understanding, and adapting outstanding practices and processes found inside and outside an organization (company, public organization, University, College, etc.).

Benchmarking focuses on the improvement of any given business process by exploiting "best practices" rather than merely measuring the best performance. Best practices are the cause of best performance. Companies studying best practices have the greatest opportunity for gaining a strategic, operational, and financial advantage.

The systematic discipline of benchmarking is focused on identifying, studying, analyzing, and adapting best practices and implementing the results. To consistently get the most value from the benchmarking process, senior management may discover the need for a significant culture change. That change, however, unleashes bench marking's full potential to generate large paybacks and strategic advantage.

The benchmarking process involves comparing one's firm performance on a set of measurable parameters of strategic importance against that of firms' known to have achieved best performance on those indicators. Development of benchmarks is an iterative and ongoing process that is likely to involve sharing information with other organizations working with them towards an agreeable metrology.

There are, in general, four types of benchmarking:

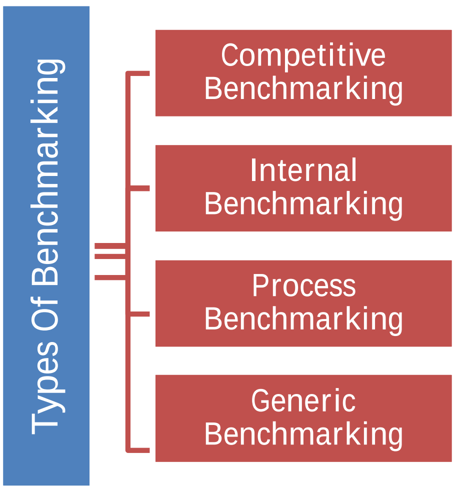


Fig: 10.4 Types of Benchmarking

1. COMPETITIVE BENCHMARKING :

Benchmarking is performed versus competitors and data analysis is done as to what causes the superior performance of the competitor. It can be, in some respects, easier than other types of benchmarking and in some respects more difficult. It is easier in the sense that many exogenic variables affecting company performance may be the same between the source and the recipient organization, since we are talking about companies of the same sector. On the other hand it is more difficult because, due to the competitive nature, data recuperation will not be straightforward. Difficulties of this type may be overcome if the two organizations have for e.g. different geographical markets.

2. INTERNAL BENCHMARKING :

This process can be applied in organizations having multiple units (for e.g. multinationals, companies with sale offices around the country, with multiple factory locations within the same country).

3. PROCESS BENCHMARKING :

Here we look at processes, which may be similar, but in different organizations, producing different products, for e.g. Airline industry & hospital industry looking at the process of catering their 'clients'.

4. GENERIC BENCHMARKING :

We would look here at the technological aspects, the implementation and deployment of technology. How else other organizations do it? Hence the source organizations may be of same industry or from another industry.

Benchmarking Procedure Considerations

Before an organization can achieve the full benefits of benchmarking, its own processes must be clearly understood and under control.

Benchmarking studies require significant investments of manpower and time, so management must champion the process all the way through, including being ready and willing to make changes based on what is learned.

Too broad a scope dooms the project to failure. A subject that is not critical to the organization's success won't return enough benefits to make the study worthwhile.

Inadequate resources can also doom a benchmarking study by underestimating the effort involved or inadequate planning. The better you prepare, the more efficient your study will be.

Plan

1. Define a tightly focused subject of the benchmarking study. Choose an issue critical to the organization's success.
2. Form a cross-functional team. During Step 1 and 2, management's goals and support for the study must be firmly established.
3. Study your own process. Know how the work is done and measurements of the output.
4. Identify partner organizations that may have best practices.

Collect

5. Collect information directly from partner organizations. Collect both process descriptions and numeric data, using questionnaires, telephone interviews, and/or site visits.

Analyze

6. Compare the collected data, both numeric and descriptive.
7. Determine gaps between your performance measurements and those of your partners.
8. Determine the differences in practices that cause the gaps.

Adapt

9. Develop goals for your organization's process.
10. Develop action plans to achieve those goals.
11. Implement and monitor plans.

Activity: Study the following research paper.

- Tang, S., Ng, T., Chong, W., & Chen, K. (2016). Case study on lean manufacturing system implementation in batch printing industry Malaysia. In MATEC Web of Conferences (Vol. 70, p. 05002). EDP Sciences.(https://doi.org/10.1051/matecconf/20167005002)
- The evolution of world class manufacturing toward Industry 4.0: A case study in the automotive industry. Ifac-Papersonline, 52(10), 188-194. (https://doi.org/10.1016/j.ifacol.2019.10.021)
- Vazquez-Bustelo, D., & Avella, L. (2006). Agile manufacturing: Industrial case studies in Spain. Technovation, 26(10), 1147-1161. (https://doi.org/10.1016/j.technovation.2005.11.006)
- Canciglieri, O., De Sampaio, R. J. B., Kovalchuk, J. P. B., & De Souza, T. M. (2010, July). A case study of concurrent engineering application on the development of parts for the White Goods industry in Brazil. In The 40th International Conference on Computers & Indutrial Engineering (pp. 1-6). IEEE (DOI: 10.1109/ICCIE.2010.5668327)
- Singh, B., Grover, S., & Singh, V. (2015). An assessment model for benchmarking in manufacturing industries. International Journal of Hybrid Information Technology, 8(12), 241-252 (http://dx.doi.org/10.14257/ijhit.2015.8.12.18)

Quiz:

Q-1: How does lean manufacturing work?
Q-2: What is world-class manufacturing and how has WCM evolved?
Q-3: How does agile manufacturing work?
Q-4: Differentiate between Agile manufacturing and lean manufacturing.
Q-5: What are the four types of benchmarking? How it is useful in industries?
Q-6: What is the most challenging part in doing benchmarking?
Q-7: Why do companies adopt concurrent engineering methods?

Suggested Reference:

1. Tang, S., Ng, T., Chong, W., & Chen, K. (2016). Case study on lean manufacturing system implementation in batch printing industry Malaysia. In MATEC Web of Conferences (Vol. 70, p. 05002). EDP Sciences.(https://doi.org/10.1051/matecconf/20167005002)
2. The evolution of world class manufacturing toward Industry 4.0: A case study in the automotive industry. Ifac-Papersonline, 52(10), 188-194. (https://doi.org/10.1016/j.ifacol.2019.10.021)
3. Vazquez-Bustelo, D., & Avella, L. (2006). Agile manufacturing: Industrial case studies in Spain. Technovation, 26(10), 1147-1161. (https://doi.org/10.1016/j.technovation.2005.11.006)
4. Canciglieri, O., De Sampaio, R. J. B., Kovalchuk, J. P. B., & De Souza, T. M. (2010, July). A case study of concurrent engineering application on the development of parts for the White Goods industry in Brazil. In The 40th International Conference on Computers &

Indutrial Engineering (pp. 1-6). IEEE (DOI: 10.1109/ICCIE.2010.5668327)

5. Singh, B., Grover, S., & Singh, V. (2015). An assessment model for benchmarking in manufacturing industries. International Journal of Hybrid Information Technology, 8(12), 241-252 (http://dx.doi.org/10.14257/ijhit.2015.8.12.18)
6. Total Quality Management by K C Arora, S K Kataria & Sons
7. Total Quality Management: Poornima M. Charantimath, Pearson education(Singapore) Pte. Ltd.

References used by the students:

Rubric wise marks obtained:

Criteria	**%**	**10**	**9-8**	**7-6**	**5**
Knowledge	30	Correct answers 90% or more by student.	Correct answers between 70-89%.	Correct answers between 50-69%.	Correct answers less than 50%.
Quality of report	20	Proper formatting and well attempted quiz and case study with excellent reported work	Only formatting is improper (Location of figures/tables, use of pencil and scale). Good	A few required elements (labeling/ notations) are missing. Average	Several elements are missing (content in paragraph, labels, figures, tables). Poor report
Participation type	30	Participation 25% Excellent focused attention in the exercise.	Moderately focused attention on exercise.	Focused limited attention in the exercise.	Less Participation
Punctuality	20	Timely Submission	Submission late by one laboratory.	Submission late by two laboratories.	Submission late by more than two laboratories.
Criteria	**%**	**Level of Marks**	**Multiplication**	**Total**	**Remarks**
Knowledge	30		0.3 *_____		
Quality of report	20		0.2*_____		
Participation	30		0.3*_____		
Punctuality	20		0.2*______		
			Total Marks		

Sign of Faculty

Experiment No: 11

Discuss your internship as industrial case study and analyse it with supportive similar other study

Date:

Relevant CO: Interpret Quality and Total quality management (CO1), Make use of design of experiments, concepts of just in time and quality management (CO2), Illustrate Total Productive maintenance and ISO (CO3) and Utilize knowledge of contemporary trends in quality engineering and Reliability Engineering in Industry (CO4)

Objectives:

- Overall actual industrial understanding of quality, and reliability
- Hands-on experience of the subject

Open ended exercise: Discuss your internship details (taken in 6th semester) or any industry visited so far and develop tasks as shown below. Also identify work as industrial case study or research paper that supports your findings.

Task1: Develop an activity based on your internship OR any industrial visit.

Step1: **Name the company as ABC**, describe organization hierarchical structure. Draw the line diagram of the plant/firm and departments as per your understanding. Enlist maximum possible technical details in relation with products, processes and overall execution. Also include type of firm, its production type etc.

Step2: Highlight the importance of QC and R&D was there or not? If yes describe inspection and quality department work in detail, types of quality control tools that were used and what else can be adopted. Incorporate line diagram of the department if possible and details of machines and activities in brief. Also suggest possible changes or improvement scopes as per your learning and perspective. If not then what will be your suggestions.

Task 2: Student should select any of the related topics or as assigned by faculty and will make a powerpoint presentation related to the concept, its applications as witnessed in any of the industry. Describe brief what is covered in presentation

References used by the students:

Rubric wise marks obtained:

Criteria	**%**	**10**	**9-8**	**7-6**	**5**
Knowledge	30	Correct answers 90% or more by student.	Correct answers between 70-89%.	Correct answers between 50-69%.	Correct answers less than 50%.
Quality of report	20	Proper formatting and well attempted quiz and case study with excellent reported work	Only formatting is improper (Location of figures/tables, use of pencil and scale). Good	A few required elements (labeling/ notations) are missing. Average	Several elements are missing (content in paragraph, labels, figures, tables). Poor report
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Punctuality	20	Timely Submission	Submission late by one laboratory.	Submission late by two laboratories.	Submission late by more than two laboratories.
Criteria	**%**	**Level of Marks**	**Multiplication**	**Total**	**Remarks**
Knowledge	30		0.3 *_____		
Quality of report	20		0.2*_____		
Participation	30		0.3*_____		
Punctuality	20		0.2*______		
			Total Marks		

Sign of Faculty