Failure Mode Effect Analysis and Total Productive Maintenance: A Review

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Abstract-The goal of quality and reliability systems is the same-to achieve customer satisfaction. Quality and reliability are synonymous. A system cannot be reliable if it does not have high quality. Likewise, a system cannot be of high quality if it is not reliable. The quality performance of a firm is often assessed by the reliability of the firm's equipment or machinery. If a system is unreliable, it is unpredictable and if it is unpredictable, it is not of high quality. FMEA is a one of the most important quality management Techniques. Total Productive Maintenance is useful technique to increase the productivity of plant and equipment with a modest investment in maintenance. The paper reviews various approaches of Failure Mode Effect Analysis and Total Productive Maintenance has been developed so far and discussion about use of FMEA-TPM in integrated approach.

Keywords-FMEA, TPM, Integrated, Modified, Service, OEE.

I. INTRODUCTION

Failure Mode and Effect Analysis (FMEA) were first developed as a formal design methodology in the 1960s by the aerospace industry with their obvious reliability and safety requirements. Later, its use spread to other industries, such as the automotive, oil and natural gas. FMEA aims to identify and prioritize possible imperfections in products and processes. FMEA analyses

- Potential failure modes of product or machine,
- Potential effects of failure,
- Potential causes for failure (like Material defects, Design deficiencies,
- Processing and manufacturing deficiencies, and Service condition etc.)
- Assesses current process controls, and
- Determines a risk priority factor.

FMEA is an essential function in design, from concept through development. Quality and reliability of products and manufacturing processes are critical to the performance of the final products. They are also important indices for meeting customer satisfaction. In order to fulfill customer requirement for quality and reliability, some actions for assuring the quality and reliability of products or processes should be taken by all engineers involved. One of the most powerful methods available for measuring the reliability of products or process is FMEA. Customers are placing increased demands on companies for high quality, reliable products. The increasing capabilities and functionality of many products are making it more difficult for manufacturers to maintain the quality and reliability. Traditionally, reliability has been achieved through extensive testing and use of techniques such as probabilistic reliability modeling. These are techniques done in the late stages of development. The challenge is to design in quality and reliability early in the development cycle. The cause and effect diagram is used to explore all the potential or real causes (or inputs) that result in a single effect (or output). Causes are arranged according to their level of importance, resulting in a depiction of relationships and hierarchy of events. This can help you search for root causes, identify areas where there may be problems, and compare the relative importance of different causes. There are several types of FMEA's; some are used much more often than others. FMEA's should always be done whenever failures would mean potential harm or injury to the user of the end item being designed. FMEA is a reliability procedure which documents all possible failures in a system design within specified ground rules. It determines, by failure mode analysis, the effect of each failure on system operation and identifies single failure points, which are critical to mission success or crew safety [1].
In general FMEA is a systemized group of activities designed to:

- recognize and evaluate the potential failure of a product/process and its effects,
- identify actions , which could eliminate or reduce the chance of potential failure occurring,
- document process.

The purpose of the FMEA is to take actions to eliminate or reduce failures, starting with the highest-priority ones. It may be used to evaluate risk management priorities for mitigating known threat-vulnerabilities. In FMEA, failures are prioritized according to three dimensions: 1) How serious their consequences are, 2) How frequently they occur, 3) How easily they can be detected. Good FMEA methodology allows for the identification and documentation of potential failures of a system and their resulting effects. It also allows for the assessment of the potential failure to determine actions that would reduce severity, reduce occurrence, and increase detection. The composite risk score for each unit operation step is the product of its three individual component ratings: Severity (S), Occurrence (O) and Detection (D). This composite risk is called a risk priority number (RPN). This number is then used to rank order the various concerns and failure modes associated with a given design as previously identified in the FMEA. *RPN = (S) x (O) x (D).* The RPN is a measure of design risk. The RPN is also used to rank order the concerns in processes (e.g., in Pareto fashion). The RPN will be between "1" and "1,000." For higher RPNs the team must undertake efforts to reduce this calculated risk through corrective action(s).

Total Productive Maintenance (TPM) is a unique Japanese philosophy, which has been developed based on the productive maintenance concepts and methodologies. This concept was first introduced by M/s Nippon Denso Co. Ltd. of Japan, a supplier of M/s Toyota Motor Company, Japan in the year 1971. Total productive maintenance is an innovative approach to maintenance that optimizes equipment effectiveness, eliminates breakdowns and promotes autonomous maintenance by operators through day-to-day activities involving total workforce. Nakajima (1989), a major contributor of TPM, has defined TPM as an innovative approach to maintenance that optimizes equipment effectiveness, eliminates breakdowns, and promotes autonomous maintenance by operators through day-to-day activities involving the total workforce

In this stage eight activities are carried which are called eight pillars in the development of TPM activity. Of these four activities are for establishing the system for production efficiency, one for initial control system of new products and equipment, one for improving the efficiency of administration and are for control of safety, sanitation as working environment.

Eight Pillars of TPM

1. 5S: TPM starts with 5S. Problems cannot be clearly seen when the work place is unorganized. Cleaning and organizing the workplace helps the team to uncover problems. Making problems visible is the first step of improvement. The meaning of 5S is SEIRI - Sort out, SEITON – Organize, SEISO - Shine the workplace, SEIKETSU – Standardization, SHITSUKE - Self discipline.

2. Autonomous Maintenance : This pillar is geared towards developing operators to be able to take care of small maintenance tasks, thus freeing up the skilled maintenance people to spend time on more value added activity and technical repairs. The operators are responsible for upkeep of their equipment to prevent it from deteriorating.

3. Continuous Improvement (KAIZEN): Kai" means change, and "Zen" means good (for the better). Basically kaizen is for small improvements, but carried out on a continual basis and involve all people in the organization. Kaizen is opposite to big spectacular innovations. Kaizen requires no or little investment. The principle behind is that "a very large number of small improvements are more effective in an organizational environment than a few improvements of large value. This pillar is aimed at reducing losses in the workplace that affect our efficiencies. By using a detailed and thorough procedure we eliminate losses in a systematic method using various Kaizen tools. These activities are not limited to production areas and can be implemented in administrative areas as well.

4. Planned Maintenance: It is aimed to have trouble free machines and equipments producing defect free products for total customer satisfaction. This breaks maintenance down into 4 "families" or groups such as Preventive Maintenance , Breakdown Maintenance , Corrective Maintenance , Maintenance Prevention

5. Quality Maintenance: It is aimed towards customer delight through highest quality through defect free manufacturing. Focus is on eliminating non-conformances in a systematic manner, much like Focused Improvement. We gain understanding of what parts of the equipment affect product quality and begin to eliminate current quality concerns, then move to potential quality concerns.

6. Education & Training: It is aimed to have multi-skilled revitalized employees whose morale is high and who has eager to come to work and perform all required functions effectively and independently. Education is given to operators to upgrade their skill.

7. Office TPM: Office TPM should be started after activating four other pillars of TPM (JH, KK, QM, PM). Office TPM must be followed to improve productivity, efficiency in the administrative functions and identify and eliminate losses. This includes analyzing processes and procedures towards increased office automation. Office TPM addresses twelve major losses. They are Processing losses.

8. Safety, Hygiene and Environment Control: In this area focus is on to create a safe workplace and a surrounding area that is not damaged by our process or procedures. This pillar will play an active role in each of the other pillars on a regular basis. A committee is constituted for this pillar which comprises representative of officers as well as workers. The committee is headed by Senior vice President (Technical). Utmost importance to Safety is given in the plant. Manager (Safety) is looking after functions related to safety. To create awareness among employees various competitions like safety slogans, Quiz, Drama, Posters, etc. related to safety can be organized at regular intervals [2].

Overall Equipment Effectiveness (OEE) is used as a measure when evaluating the result of TPM.

- OEE = Availability (A) × Performance Efficiency (P) × Rate of Quality (Q)
  where
- Availability (A) = Operating Time / Planned Production Time
- Operating Time = Planned Production Time – Down Time
- Planned Production Time= Shift Length – Breaks

- Performance Efficiency (P)= Ideal Cycle Time / (Operating Time / Total Pieces)
- Ideal Cycle Time = Shift Length / Scheduled Number of Products
- Quality Rate (Q) = Good Pieces / Total Pieces
- Good Pieces = Total Pieces – Reject Pieces

Kathleen E. Mckone (1998) described the basic elements of TPM programs, categorized the relevant research literature using a practitioner's framework for autonomous and planned maintenance activities, and identified the current gaps between practitioner needs and academic research in the area of TPM and offers suggestions to close the gaps. F. Ireland (2001) focused on a study of total productive maintenance (TPM) in three companies. The companies implemented TPM because of the business difficulties they faced. In all three companies senior management had supported TPM and set up suitable organizational structures to facilitate its implementation. The companies had followed Nakajima's seven steps of autonomous maintenance, although different TPM pillars had been adopted, with the common ones being improvements, education and training, safety, and quality maintenance. The main differences in TPM implementation related to the use of ABC machine classification system and the role of facilitators. I.P.S. Ahuja (2006) developed an understanding of contributions of total productive maintenance (TPM) initiatives towards building core competencies in Indian manufacturing industry. Large numbers of manufacturing organizations have been extensively surveyed to ascertain contributions made by TPM initiatives in the Indian manufacturing industries towards realizing core competencies & involved working out the correlations between various TPM implementation dimensions and core competencies, and employ various statistical tools for extracting significant factors contributing effectively towards realization of core competencies. I.P.S. Ahuja and J.S. Khamba (2007) identified maintenance-related losses for ascertaining and addressing the performance losses, and affecting improvements in the manufacturing performance in an organization through strategic total productive maintenance (TPM) initiatives. In his study TPM initiatives in the steel manufacturing plant have been elaborated to ascertain the tangible and intangible benefits accrued as a result of successful TPM implementation. The approach has been directed toward justification of TPM implementation for its support to competitive manufacturing in the context of Indian manufacturing industries. I.P.S. Ahuja (2008) focused on systematic identification of obstacles in TPM implementation and working out success factors towards improving manufacturing performance in Indian industry through strategic TPM initiatives. The study highlighted the strong potential of TPM implementation initiatives in affecting organizational performance improvements & revealed that implementing TPM is by no means an easy task, which is heavily burdened by organizational, cultural, behavioral, technological, operational, financial, and departmental barriers. The study has been conducted in Indian manufacturing organizations to formulate the critical success factors and enablers for overcoming obstacles to successful TPM implementation with regard to its preparedness to face global challenges. The study stresses the need for improving the synergy between the maintenance function and other organizational quality improvement initiatives in the organizations, to establish maintenance as a competitive strategy for meeting the challenges of a highly competitive environment. The study highlighted the difficulties faced by Indian manufacturing organizations in their attempt to implement TPM initiatives in order to improve organizational efficiency. K. C. Ng, G. G. G. Goh, U. C. Eze (2011) highlighted the importance of proactive maintenance of the equipment in optimum condition at all times for the successful deployment of TPM programs in manufacturing organizations. It can also be observed that the 'soft' or human-oriented aspects of TPM implementation play a crucial role in the success of its implementation and hence should require the adequate attention of the management. Among these critical success factors are top management involvement, training and education, benchmarking, effective communication, cultural change and following established TPM procedures. Narender & A.K.Gupta (2012) reviewed of the TPM programme for an Indian service sector. Through the review of TPM in Indian service sector, the practical aspects within and beyond basic TPM theory, difficulties in the adoption of TPM and the problems encountered during the implementation are discussed and analyzed. Moreover, the critical success factors for achieving TPM in Indian service sector are also discussed. The efficient maintenance of the production and other plant machinery is crucial in determining the success of the manufacturing process. Despite time and money spent on the development/production of the advanced plant and its equipment, there has not been enough attention to defining comprehensive maintenance strategies, practices and policies. However, there are indications that the transition process from reactive (breakdown) maintenance to preventive maintenance is already taking place.

II. LITERATURE REVIEW

Failure Mode Effect Analysis -From the past literature survey, it is evident that some research on FMEA have been carried out by previous researchers but still a lot of applied research in the above field is required so as to explore the successful utilizations of the FMEA technique in the area of manufacturing and design. The survey carried in following field such as Process Failure Mode Effect Analysis, Design Failure Mode Effect Analysis, Fussy Logic and Design Failure Mode Effect Analysis, Failure Mode Effect Analysis in medical, Failure Mode Effect Analysis and Optimization, Modified Failure Mode Effect Analysis, Integrated Failure Mode Effect Analysis, Failure Mode Effect Analysis in Service and Failure Mode Effect Analysis and Reliability.

Process Failure Mode Effect Analysis-PFMEA is the basis of process reliability research in manufacturing. With the development of equipment reliability designing in our country, the reliability problem in producing process has become a weak aspect in improving reliability of equipment. In the design process, PFMEA is the important basic technology of improving equipment productive reliability. The PFMEA technique evaluates the potential failure of a product or process and its effects, identifies what actions could be taken to eliminate or minimize the failure from occurring and documents the whole procedure. It is used from the initial planning stages of designing and processing a product through to the end of its life. K.G. Johnson , M.K. Khanb (2003) described a study made into the application of PFMEA in a sample of suppliers to an automotive manufacturing company in the UK. The objectives of the research were to study the concerns and inhibitors that PFMEA users have, establish how the effectiveness could be determined, and evaluate PFMEA use as a problem prevention technique and to recommend best practice. The research methodology included the use of interviews, workshops and questionnaires involving 150 quality approved suppliers. Conclusions were drawn to show that the PFMEA technique has its limitations, caused by a number of issues. Recommendations for overcoming these limitations of the PFMEA process are presented. George Pantazopoulos and George Tsinopoulos (2005) introduced the use of this technique in a critical process in the metal forming industry. Risk reassessment and further preventive action planning could lead to effective risk minimization. The application of a FMEA reveals the hidden process weaknesses, leading to the quantification of failure related indicators/failure risks and the creation of a prioritization matrix for further improvement actions. A FMEA is applied to the brass disk annealing process with the goal of optimizing the operational performance by decreasing the RPN and increasing the process capability. In order to facilitate the application of a FMEA, the failures are divided into two main categories: Failures allocated to the energy supplied system, Failures allocated to the method affected by human factors. Mei Rong (2008) proposed some solutions to the shortcomings of the conventional approach. Advanced HF-PFMEA integrates several important concepts that distinguish it from conventional HF-FMEA, including: (1) suggest a method to break down task process according to the sequence and logicality of task process, (2) use Hazard and Operability study (HAZOP) to analyze human operational errors. The operational errors can be identified by determining guidewords and process parameters. For each action performed, all potential human errors are identified. Each error is then evaluated to identify positive and negative contributing factors, barriers, and controls. The aim of his works is to give risk reduction measures to minimize the risk of human process. Zhaoyang ZENG, Jianguo ZHANG (2009) focused on embedding PFMEA (Process Failure Mode Effect Analysis) module in the system of CAPP (Computer Aided Process Planning), and achieved the integrated technology of Reliability design with CAPP. It introduced the functional instruction, flow chart and main module of the CAPP software designed on dependence. The corresponding software package was developed to verify the application of producing foundry goods.

Design Failure Mode Effect Analysis-The information input to design FMEA consists of customer inputs and specifications. Based on customer requirements, the potential failure modes are formed. All the possible functional failures in product design must be caught at the development of the design FMEA report. A well-trained and balanced design FMEA team must be established to initiate the FMEA process and to embed reliability concerns in the product design process.

Sheng-Hsien (Gary) Teng (1995) developed an approach to integrate FMEA, product design, and process control to one complete closed loop to establish an overall quality control plan. First discussed the FMEA procedure. Then, the procedure will be separated into two domains – the product design domain and the process control domain. Design FMEA and process FMEA will be demonstrated, and the integration among design, control, and reliability analysis for a product illustrated. Robert B. Stone (2004) developed the function- failure design method (FFDM), has been to allow designers to perform failure mode and effect analysis (FMEA) during conceptual design & explored two approaches to populating a knowledge base with actual failure occurrence information from Bell 206 helicopters. The FFDM can offer substantial improvements to the design process since it enhances failure analysis thus giving it the ability to reduce the number of necessary redesigns. P C Teoh (2004) proposed `knowledge fragment' reasoning concept. FMEA is introduced in the conceptual design stage so as to minimize the risks of costly failure. The method enables new knowledge to be formed using the limited available information in the conceptual design stage. A prototype has been created to evaluate the proposed method. Two design cases and three process cases for two-way radio design and manufacture have been evaluated using the prototype software. The case studies show that the method is able to provide reliable results with limited information. Kyoung-Won Noh (2010) proposed module-based failure propagation (MFP) model based on the function behavior state scheme. The MFP model consists of function decomposition tree model, configuration flow graph model, function rule, and failure rule. This study describes how to build the MFP model and introduces how to carry out FMEA with the proposed MFP model. To show the benefit of the proposed MFP model, a FMEA case study on a car air purifier is performed. Zaifang Zhang and Xuening Chu (2010) proposed a design for supporting conceptual design of product and maintenance (P&M). The approach uses an improved quality function deployment (QFD) tool to translate customer requirements into concept specifications. An information exchange mechanism is developed to exploit the interrelationships between P&M. In the mechanism, a failure mode and effects analysis (FMEA) tool is used to identify and analyse failure modes and their effects on the product concept. Then maintenance concepts are generated based on the results of QFD and FMEA. The proposed approach is applied in a conceptual design case of a horizontal directional drilling machine with its maintenance.

Fussy Logic and Design Failure Mode Effect Analysis-Failure Mode and Effect Analysis (FMEA) is a popular problem prevention methodology. It utilizes a Risk Priority Number (RPN) model to evaluate the risk associated to each failure mode. The conventional RPN model is simple, but, its accuracy is argued. A fuzzy RPN model is proposed as an alternative to the conventional RPN. The fuzzy RPN model allows the relation between the RPN score and Severity, Occurrence and Detect ratings to be of non-linear relationship, and it may be a more realistic representation. John B. Bowles (1995) described a new technique, based on fuzzy logic, for prioritizing failures for corrective actions in a Failure Mode, Effects and Criticality Analysis (FMECA). Two fuzzy logic based approaches for assessing criticality are presented. The first is based on the numerical rankings used in a conventional Risk Priority Number (RPN) calculation and uses crisp inputs gathered from the user or extracted from a reliability analysis. The second, which can be used early in the design process when less detailed information is available, allows fuzzy inputs and also illustrates the direct use of the linguistic rankings defined for the RPN calculations. C. ENRIQUE PELEZ (1996) explored the application of Fuzzy Cognitive Maps (FCM) to Failure Modes and Effects Analysis (FMEA). FMEAs are used in reliability and safety evaluations of complex systems to determine the effects of component failures on the system operation. FCMs used a digraph to show cause and effect relationships between concepts; thus, they can represent the causal relationships needed for the FMEA and provide a new strategy for predicting failure effects in a complex system. Anand Pillay (2001) proposed a new approach, which utilizes the fuzzy rules base and grey relation theory is used & developed a method that does not require a utility function to define the probability of occurrence (Sf), severity (S) and detectability (Sd) considered for the analysis and to avoid the use of the traditional RPN. This is achieved by using information gathered from experts and integrating them in a formal way to reflect a subjective method of ranking risk. K. Xu (2001) presents a fuzzy-logic-based method for FMEA to address interdependencies among various failure modes with uncertain and imprecise information are very difficult to be incorporated for failure analysis & presented a fuzzy-logic-based method for FMEA to address this issue. A platform for a fuzzy expert assessment is integrated with the proposed system to overcome the potential difficulty in sharing information among experts from various disciplines. The FMEA of diesel engine's turbocharger system is presented to illustrate the feasibility of such techniques. Kwai-Sang Chin (2006) proposed a framework of a fuzzy FMEA (failure modes and effects analysis) based evaluation approach for new product concepts. Based on the proposed approach and methodologies, a prototype system named EPDS-1, which can assist inexperienced users to perform FMEA analysis for quality and reliability improvement, alternative design evaluation, materials selection, and cost assessment, thus helping to enhance robustness of new products at the conceptual design stage. Liang-Hsuan Chen (2008) proposed fuzzy nonlinear programming models based on Kano’s concept to determine the fulfillment levels of parts characteristics (PCs) with the aim of achieving the determined contribution levels of design requirements (DRs) in phase one for customer satisfaction. In addition, to deal with the design risk, & incorporates failure modes and effects analysis (FMEA) into QFD processes, and treats it as the constraint factor in the models. To cope with the vague nature of product development processes, fuzzy approaches are used for both FMEA and QFD. The applicability of the proposed models in practice is demonstrated with a numerical example. Ying-Ming Wang (2009) treated the risk factors O, S and D as fuzzy variables and evaluated using fuzzy linguistic terms and fuzzy ratings & proposed fuzzy risk priority numbers (FRPNs) for prioritization of failure modes. The FRPNs are defined as fuzzy weighted geometric means of the fuzzy ratings for O, S and D, and can be computed using alpha-level sets and linear programming models. For ranking purpose, the FRPNs are defuzzified using centroid defuzzification method, in which a new centroid defuzzification formula based on alpha-level sets is derived. A numerical example is provided to illustrate the potential applications of the proposed fuzzy FMEA and the detailed computational process of the FRPNs. Zaifang Zhang (2010) used the fuzzy methods and linear programming methods have been as an effective solution for the calculations of fuzzy RPNs & integrated a fuzzy-RPNs-based method weighted least square method, the method of imprecision and partial ranking methods is proposed to generate more accurate fuzzy RPNs and ensures to be robust against the uncertainty. A design example of new horizontal directional drilling machine is used for illustrating the application of the proposed approach. Ahmet Can Kutlu (2012) presented fuzzy approach to use linguistic variables for determining S, O, and D, is considered for FMEA by applying fuzzy ‘technique for order preference by similarity to ideal solution’ (TOPSIS) integrated with fuzzy ‘analytical hierarchy process’ (AHP). Fuzzy TOPSIS based FAHP is utilized to get the scores of PFMs, which are ranked to prioritize the failure modes. The results are used to find out the most important and risky PFM that would be handled at first glance. The hypothetical case study demonstrated the applicability of the model in FMEA under fuzzy environment. Daniele Regazzoni (2010) disclosed an innovative step by step method based on TRIZ tools used according to the general approach suggested by FMEA. The aim of the proposed method consists in building an improved risk management model for design and to enhance the capability of anticipating problems and technical solutions to reduce failure occurrence. The method adopts tools used to model the system, such as functionality, Su-Fields models, resource evaluation and tools dedicated to problem solving such as standard solutions. The resulting method allows a better definition of the system decomposition and functioning and provides a sharp definition of the events and failures potentially occurring into the system, which is not provided by standard FMEA. Kai Meng Tay (2009) A fuzzy RPN model is proposed as an alternative to the conventional RPN. The fuzzy RPN model allows the relation between the RPN score and Severity, Occurrence and Detect ratings to be of non-linear relationship, and it may be a more realistic representation. The efficiency of the fuzzy RPN model in order to allow valid and meaningful comparisons among different failure modes in FMEA to be made is investigated. It is suggested that the fuzzy RPN should be subjected to certain theoretical properties of a length function e.g. monotonicity, sub-additivity and etc. In this paper, focus is on the monotonicity property. The monotonicity property for the fuzzy RPN is firstly defined, and a sufficient condition for a FIS to be monotone is applied to the fuzzy RPN model. This is an easy and reliable guideline to construct the fuzzy RPN in practice.

Case studies relating to semiconductor industry are then presented. Zhaojun Yang (2010) described a new fuzzy FMEA model integrating with fuzzy linguistic scale method. The model proposed a risk space diagram to explicit the relationship of S,O and D. On the basis of the risk-space diagram, risk priority number is calculated by weighted Euclidean Distance formula and centroid defuzzification based on Alpha-level. This study is used to analysis a type of CNC lathe. Compared with the criticality ranking about another similar type of CNC lathe, the risk ranking of FMEA model revealed that the method is basically same with the actual situation. The results indicated that the fuzzy FMEA used in CNC lathe is a reasonable method corresponding to the manufacturing, and it is a validity foundation for constructing reliability design model or supporting control plan of manufacturing. Manu Augustine (2011) proposed a structured framework for the development and use of cognitive map based system models capable of capturing all types of failure modes, including interaction failures. The applicability of the proposed framework is demonstrated with the example of an electric water heater.

Failure Mode Effect Analysis in medical-Today, manufacturing operates as a global network, which has created more awareness of the quality of products and services. A systematic and rational way of managing quality assurance is currently lacking. This can cause serious problems in sectors such as the medical industry, as product failure may not only cause time delays, but also create risks for the health and safety of patients and users. Esra Bas (2011) developed a general framework for child injury prevention and a multi-objective, multi-dimensional mixed 0-1 knapsack model to determine the optimal time to introduce preventive measures against child injuries. The model maximizes the prevention of injuries with the highest risks for each age period by combining preventive measures and supervision as well as satisfying budget limits and supervision time constraints. The risk factors for each injury, variable, and time period were based on risk priority numbers (RPNs) obtained from failure mode and effects analysis (FMEA) methodology, and these risk factors were incorporated into the model as objective function parameters. S.L. Chan (2011) proposed a quality assurance approach that incorporates risk analysis (based on ISO14971) and failure analysis (based on FMEA) into the product design phase to assure product quality in the short term and facilitate global manufacturing practices in the long run. The proposed approach includes a Markov model to predict product failure from a customer perspective, which serves as a checkpoint for feedback to provide a basis for quality assurance. A medical equipment firm is used as a test-bed to illustrate how the proposed approach works and to verify its effectiveness. Mohammad D. AL-Tahat (2012) used Ordinal Logistic Regression Modeling (OLRM) to predict and to investigate the relationship(s) between the different types of failures encountered in tableting tools of pharmaceutical industry and relevant tablet-and punch attributes. Failure Mode and Effects Analysis (FMEA) has been applied to relate main types of failure that occur in pharmaceutical punch sets to their root causes both qualitatively and quantitatively (through OLR modeling). Rakesh.R (2013) provided the use of Failure Mode and Effects Analysis (FMEA) for improving the reliability of sub systems in order to ensure the productivity which in turn improves the bottom line of a manufacturing industry. Thus the various possible causes of failure and their effects along with the prevention are discussed in this work. Severity values, Occurrence number, Detection and Risk Priority Number (RPN) are some parameters, which need to be determined. These are the steps taken during the design phase of the equipment life cycle to ensure that reliability requirements have been properly allocated and that a process for continuous improvement exists. The FMEA technique is applied on an automatic plastic welding machine used for the production of blood bags in a life care manufacturing company in south India. The preventions suggested in this study can considerably decrease the loss of production hours in the industry due to the breakdown of the machine

Failure Mode Effect Analysis and Optimization-XU Yuarrming (2005) used combination of case based reasoning (CBR) and genetic algorithm (GA) is considered in the problem of failure mode identification in aeronautical component failure analysis. Several implementation issues such as matching attributes selection, similarity measure calculation, weights learning and training evaluation policies are car efully studied. The testing applications illustrate that an accuracy of 74.67% can be achieved with 75 balanced distributed failure cases covering 3 failure modes, and that the resulting learning weight vector can be well applied to the other 2 failure modes, achieving 73.3% of recognition accuracy. I t is also proved that its popularizing capability is good to the recognition of even more mixed failure modes. Y. Zare Mehrjerdi (2012) proposed Multiple Objective Goal Programming Model of Fuzzy QFD and FMEA model demonstrated the process of development of the equivalent deterministic form of chance constrained programming for the QFD and FMEA combined systems. The final model presented is a linear multi-objective goal programming problem that can be solved by a linear goal programming program.

Integrated Failure Mode Effect Analysis-One of the major limitations of FMEA, which has not been pointed in any investigation, is that severity rates are determined only with respect to organization's point of view, not according to its customers. For customer satisfaction/dissatisfaction the FMEA has been integrated with other different approaches. The integrated FMEA links quality control tools together and turns data into information, so the FMEA report is no longer a text file only. It is a living document that helps design and process engineers do their jobs better. Arash Shahin (2003) proposed a new approach to enhance FMEA capabilities through its integration with Kano model. Which evolves the current approaches for determination of severity and "risk priority number" (RPN) through classifying severities according to customers' perceptions. It supports the nonlinear relationship between frequency and severity of failure. Also a new index called "correction ratio" (Cr) is proposed to assess the corrective actions in FMEA. The findings of a short case study highlight the gap between managers and customers in prioritizing a set of failures and the difference between RPN and Cr prioritizations, caused by target failure frequencies. The proposed approach enables managers/designers to prevent failures at early stages of design, based on customers who have not experienced their products/services yet. Seung J. Rhee (2003) introduced a new methodology, Life Cost-Based FMEA, which measures risk in terms of cost. Life Cost-Based FMEA is useful for comparing and selecting design alternatives that can reduce the overall life cycle cost of a particular system. Next, a Monte Carlo simulation is applied to the Cost-Based FMEA to account for the uncertainties in: detection time, fixing time, occurrence, delay time, down time, and model complex scenarios. Life Cost-Based FMEA can also provide a fair comparison between competing designs of subsystems. B. Almannai, R. Greenough , J. Kay (2008) described an integrated approach developed for supporting management in addressing technology, organization, and people at the earliest stages of manufacturing automation decision-making. The approach used both the quality function deployment (QFD) technique and the failure mode and effects analysis (FMEA) technique. The principal concepts of both applications are merged together to form a decision tool; QFD in its ability to identify the most suitable manufacturing automation alternative and FMEA in its ability to identify the associated risk with that option to be addressed in the manufacturing system design and implementation phases & presented the results of a practical evaluation conducted in industry. V. Ebrahimipour (2009) proposed an ontology based on the standard ISO-15926 has been used in an effort to improve the representation of knowledge that is used and produced during Failure Mode and Effect Analysis (FMEA). Traditionally, the information that is used and produced during the FMEA studies is registered in text format. The reusability of this knowledge during design or operations is limited due to difficulties in finding and analyzing information. The basic ontology has been extended by protégé tool so that engineers can use more informative queries (instead of text based) to find relevant information during the safety analyses. S. Gary Teng (2009) proposed an integrated FMEA approach, to implement the procedure in a supply chain, and the common problems occurred in its implementation in automotive industry under a collaborative environment & provided guidelines for manufacturing industry in correcting the problems in FMEA applications, so companies can adopt their FMEA process into a collaborative supply chain environment. He also demonstrated a Microsoft EXCEL-based tool that can ease the FMEA process in a collaborative environment for determining sampling size, reliability and confidence level for tests in design verification and control plan as a part of integrated FMEA process. M. Ilangkumaran (2009) utilized the strength of hazard and operability (HAZOP) study and failure mode and effect analysis (FMEA) to identify and prioritize the hidden potential failures present in the system. Fuzzy linguistics approach has been applied to enhance the performance. Risk priority number and fuzzy weighted geometric mean of the risk factors are used to improve the performance of the risk evaluation. Alaa Hassan , AliSiadat , Jean-Yves Dantan , Patrick Martin (2010) presented an approach to develop a quality/cost-based conceptual process planning (QCCPP) & aimed to determine key process resources with estimation of manufacturing cost, taking into account the risk cost associated to the process plan. It can serve as a useful methodology to support the decision making during the initial planning stage of the product development cycle. Quality function deployment (QFD) method is used to select the process alternatives by incorporating a capability function for process elements called a composite process capability index (CCP). The quality characteristics and the process elements in QFD method have been taken as input to complete process failure mode and effects analysis (FMEA) table. To estimate manufacturing cost the activity-based costing (ABC) method is used . Then, an extended technique of classical FMEA method is employed to estimate the cost of risks associated to the studied process plan, this technique is called cost-based FMEA. For each resource combination, the output data is gathered in a selection table that helps for detailed process planning in order to improve product quality/cost ratio & case study is presented to illustrate this approach. Rajiv Kumar Sharma (2010) used Root cause analysis (RCA), failure mode effect analysis (FMEA) and fuzzy methodology (FM) to build an integrated framework, to facilitate the reliability/system analysts in maintenance planning. The factors contributing to system unreliability were analyzed using RCA and FMEA. The uncertainty related to performance of system is modeled using fuzzy synthesis of information. The in-depth analysis of system is carried out using RCA and FMEA. The discrepancies associated with the traditional procedure of risk ranking in FMEA are modeled using decision making system based on fuzzy methodology. Ben Marriott and Jose Arturo Garza-Reyes, Horacio Soriano-Meier, Jiju Antony (2012) reviewed some of the most commonly used prioritisation methods and the theory and logic behind the proposed prioritization methodology & presented an integrated methodology of two commonly used approaches in industry, Process Activity Mapping (PAM) and Failure Mode and Effect Analysis (FMEA), to prioritise improvements. This methodology can help, in particular, organizations embarked in the manufacture of low volume-high integrity products to take better decisions and align the focus of improvement efforts with their overall performance and strategic objectives. Chee-Cheng Chen (2013) developed a new approach to integrate the RCA and FMEA techniques to establish an APM system that meets a company's goal of reducing manufacturing costs and promoting employee and equipment productivity. The major contribution of this study is constructing potential equipment failure modes and their risk priority number through RCA and FMEA integration transformed into a selection of items and their APM maintenance frequencies. A strategy for deploying employee technical capability upgrade through effective training is developed.

Modified Failure Mode Effect Analysis-FMEA (Failure Mode Effect Analysis) is a widely used reliability design and analysis method. It depends on the analyzer's experience and skills greatly, so the result of FMEA to large-scale complex systems is usually not satisfactory. It is getting more difficult to apply FMEA analysis to large-scale integrated systems with highly complicated structures and logical relations. G. Q. Huang (2000) proposed to employ the World Wide Web (WWW, web) technology to provide

FMEA services on the internet/intranets & discussed the design, development and initial evaluation of a prototype web-based FMEA system on the internet/intranet. Web-based FMEA provides better support for teamwork. Different functions of diverse disciplines which are geographically distributed can make their individual contributions simultaneously. Users may use different web browsers to connect to the FMEA web server at the same time to make simultaneous contributions from different points of view. Resulting web-based FMEA systems require no installation or maintenance but offer remote and simultaneous access and therefore better teamwork. Ningcong Xiao , Hong-Zhong Huang , Yanfeng Li , Liping He , Tongdan Jin (2001) introduced a useful method to simultaneously analyze multiple failures for complex systems proposed minimum cut set based method for assessing the impact of multiple failure modes Traditionally, failure mode and effects analysis (FMEA) only considers the impact of single failure on the system. For large and complex systems, since multiple failures of components exist, assessing multiple failure modes with all possible combinations is impractical. The definition of RPN is extended by multiplying it with a weight parameter, which characterize the importance of the failure causes within the system. P.C. Teoh (2004) proposed the reuse of FMEA knowledge through a knowledge modelling approach. An attempt is made to shift FMEA activities to the conceptual design stage. An object-oriented approach has been used to create an FMEA model. Functional diagrams have been used for the conceptual model. The FMEA model is assisted by functional reasoning techniques to enable automatic FMEA generation from historical data. The reasoning technique also provides a means for the creation of new knowledge. The automatic generation replaces the traditional brainstorming process for FMEA report creation. Failure report is used as the data source for the FMEA generation. The proposed method has been evaluated with prototype software and case studies. Zhao Tingdi (2004) formed an intelligent FMEA framework that is an intelligent failure effect inference mechanism based on the target system model as well as using expert experience and considering failure modes input and output relationship between products in the system. This framework is comprised of three parts, failure mode analyzer, failure effect analyzer and FMEA report creator. Failure effect analysis based on system models & two system modeling methods, system hierarchical model based on expert knowledge and fault input/output relationship net(FIORN) model which describes the relationship among products belonging to the same level in the system. The latter based on failures' relationship and it could analyses correlated failures and common cause failures. Inference mechanism is presented based on these two models. Lastly, a prototype software iFMEA(intelligent FMEA) is developed. Intelligent FMEA technique is used in analysis of an aircraft's main gear system through which detail steps of intelligent FMEA method are described. Darren A. Kees (2006) presented the systematic enhancement of a flexibility assessment tool referred to as CMEA, Change Modes and Effects Analysis. CMEA provides the basic ability to assess the flexibility of a product, with analogous features to the well-known Failure Modes and Effects Analysis. His enhancements extend the method to provide for intuitive and more repeatable measures of flexibility. He then used the enhanced CMEA to investigate a variety of consumer products with the goal of inductively deriving product flexibility principles. Concrete applications are shown for these principles from the domain of power yard tools, such as hedge trimmers, weed trimmers, and leaf blowers. Also, the applications are used to demonstrate the value of the CMEA enhancements. Bimal P. Nepal (2007) presented a general framework for failure modes and effects analysis (FMEA) to capture and analyze component interaction failures. The advantage of the proposed methodology is that it identifies and analyzes the system failure modes due to the interaction between the components. An example is presented to demonstrate the application of the proposed framework for specific product architecture (PA) that captures interaction failures between different modules. However, the proposed framework is generic and can also be used in other types of PA. Lars Grunske (2007) proposed a method for FMEA which makes use of probabilistic fault injection and probabilistic model checking. Based on this approach safety engineers are able to formally identify if a failure mode occurs with a probability higher than its tolerable hazard rate. This work complements existing research which uses (standard) model checking to automate the FMEA process by formalising the calculation of hazard violations. The method may be used with any sufficiently powerful probabilistic modelling language which has tool support for model checking. Mei Rong,Tingdi Zhao,Yang Yu (2008) proposed some solutions to the shortcomings of the conventional approach. Advanced HF-PFMEA integrates several important concepts that distinguish it from conventional HF-FMEA, including: (1) suggest a method to break down task process according to the sequence and logicality of task process, (2) use Hazard and Operability study (HAZOP) to analyze human operational errors. The operational errors can be identified by determining guidewords and process parameters. The task decomposition method describes the specific details of task process in hierarchical structure to find the key operations. The human errors identification method utilizing the concept of deviations from process parameters could determine all possible errors. Advanced HF-PFMEA makes the analysis more systematically and exactly. Nitin Upadhyay (2010) developed Concurrent Failure Mode and Effect Analysis (CFMEA) of Component Based Software System (CBSS) using a graph theoretic approach & proposed approach is an improvement over the present practiced procedures. Using the approach reliability evaluation of CBSS can be done effectively and extensively at the early design stage. The important feature of the proposed approach is that it takes into account structural and functional interactive complexity of CBSS concurrently. A digraph model and matrix approach is used to provide in depth analysis and evaluation of failure mode and effects by developing failure index. High failure index represents low reliability of CBSS. Hua He, Mingyou Ying, Luning Zhang and Jingxian Chen (2010) addressed an important practical issue in manufacturing enterprise technology management: how to structure a practical technology base. Inspired by the FMEA, a popular tool for reliability analysis, it is suggested in his study that the application of FMEA can be extended to form a technology breakdown system (TBS), which enables us to well structure a technology base to form an intact platform supporting design, manufacturing and service of products and to devise a way to deliver the technology in a useable form. In order to manage mass information during conducting FMEA and TBS, a feasible and practical three-tier model of a technology management information system (TMIS) has been proposed. Michael H. Wang (2011) proposed the adoption of quality cost factors that are used to replace the ambiguous factors used in the traditional FMEA calculation. In addition, a Graphical-User-Interface (GUI) has been developed which can present the FMEA outcome in a cause-effect relationship figure rather than the traditional FMEA table-form format. Michael H. Wang (2011) proposed the adoption of quality cost factors that are used to replace the ambiguous factors used in the traditional FMEA calculation. The internal failure cost plays two important roles: (1) being one of three factors in calculation risk priority number (RPN), which is used to prioritize the potential projects and (2) providing financial information to decision makers for determining the economical corrective actions. The fishbone diagram is modified to visually present a failure with its causes and effects including eight components of the internal failure cost. In addition, a Graphical-User-Interface (GUI) has been developed which can present the FMEA outcome in a cause-effect relationship figure rather than the traditional FMEA table-form format.

Failure Mode Effect Analysis in Service-Service FMEA (SFMEA) points out the failure modes caused by deficiencies of field service after sale, for example, serviceability, spare parts availability and service manpower availability. The service failures occur when a service does not adequately protect against risks of injury, fail to perform intended function safely, fail to minimize avoidable consequences in the event of an accident, or fails to deliver the expected service. FIORENZO Franceschiniy And MAURIZIO Galettoy (2001) presented a method for carrying out the calculus of the risk priority of failures in Failure Mode and Effect Analysis (FMEA). The novelty of the method consists of new management of data provided by the design team, normally given on qualitative scales, without necessitating an arbitrary and artificial numerical conversion. The practical effects of these issues are shown in an application example of a design of a cooling fan assembly. Zigmund Bluvband, Pavel Grabov, Oren Nakar (2004) described a simple graphical tool to improve the effectiveness of prioritization in FMEA. Evaluation of the adequacy of correction actions proposed to improve product/process/service, and the prioritization of these actions, can be supported by implementing the procedure proposed here, which is based on the evaluation of correction action feasibility. The procedure supports evaluation of both the feasibility of a corrective action implementation and impact of the action taken on failure mode. Ioannis S. Arvanitoyannis And Theodoros H. Varzakas (2008) carried out analysis to compare ISO 22000 analysis with HACCP (Hazard Analysis and Critical Control Point) over salmon processing and packaging. The FMEA model was applied for risk assessment of salmon manufacturing in conjunction with ISO 22000. Preliminary Hazard Analysis was used to analyze and predict the occurring failure modes in a food chain system. Critical Control points were identified and implemented in the cause and effect diagram. The validity of conclusions derived from risk assessment and FMEA. H. Arabian-Hoseynabadi (2009) applied Failure Modes and Effects Analysis (FMEA) method to a wind turbine (WT) system using a proprietary software reliability analysis tool. Comparison is made between the quantitative results of an FMEA and reliability field data from real wind turbine systems and their assemblies. The main system studied was an existing design 2 MW wind turbine with a Doubly Fed Induction Generator (DFIG), which was then compared with a hypothetical wind turbine system using the Brushless Doubly Fed Generator (BDFG) of the same rating. Vinay Sharma (2009) used FMEA to improve the reliability of a rotor support system of a modern aircraft engine. The procedure carried out as specified by MIL-STD-1629A procedure for carrying out failure mode, effects and criticality analysis. Kadir Cicek (2010) used failure modes and effects analysis (FMEA) to adapt innovative marine technologies integrated with the operational aspects in order to prevent crankcase explosion failure onboard ships. The main objectives were to improve the machinery system reliability and to enhance operational safety concepts on board ship. The research outcomes have potential to contribute the ongoing efforts of marine equipment manufacturers/classification societies/ship operators. Alina Crişan (2011) proposed a possible approach to curricular design in Higher Education from an interdisciplinary perspective, by interweaving techniques, instruments and methods used in the competitive design of products with the dedicated methods of education sciences. Baiqiao Huang (2011) introduced the severity and the alterability into the risk matrix model to get the Borda ordered values of this risk matrix model as the decision reference of the implementing priorities of the improvement measures. The Borda ordered value that considers the failure effect and the implementing difficulties of the improvement measures comprehensively makes the decision reference more sufficient and makes the failure modes in the same severity level be distinguished due to the different Borda ordered values. This proposed approach is applied to evaluate the results of the FMEA and guide the developers to determine the implementing priorities of the improvement measures according the Borda ordered values. S.L. Chan, W.H. Ip & W.J. Zhang (2011) proposed a quality assurance approach that incorporates risk analysis (based on ISO14971) and failure analysis (based on FMEA) into the product design phase to assure product quality in the short term and facilitate global manufacturing practices in the long run. He included a Markov model to predict product failure from a customer perspective, serves as a checkpoint for feedback to provide a basis for quality assurance. A medical equipment firm is used as a test-bed to illustrate how the proposed approach works and to verify its effectiveness. I. Alfred Ebenezer, S. R. Devadasan, C. G. Sreenivasa & R. Murugesh (2011) investigated the method of applying a technique called 'total failure mode and effects analysis' (TFMEA) in tea industry. TFMEA is a simple and an effective technique when compared with 'Failure Mode and Effects Analysis' which is widely used in the TQM field. TFMEA is devoid of any complex computations and procedures and therefore it facilitates illiterate labourers of the tea industry to participate in the endeavor of achieving continuous quality improvement in tea manufacturing. Despite its simplicity, tactical steps are required to be followed to gain the acceptance of TFMEA program among the labourers and managerial personnel of tea manufacturing companies. Mahdi Bahrami , Danial Hadizadeh Bazzazb, Mojtaba Sajjadi (2012) proposed use of Failure Modes and Effects Analysis (FMEA) technique due to innovation in implementation and management of projects. FMEA technique is a systematic tools based on team working which usually can be used for identify, prevent, eliminate or control of potential errors causes in a system/ process/project. He described use of FMEA in the implementation and management of projects in order to systematically improvement of processes and reduces project costs.

Failure Mode Effect Analysis and Reliability-Failure Mode Effect Analysis (FMEA) is one of the well known risk-assessment methodologies. FMEA, first used in 1960’s in the Aerospace industry, is now recognized as a fundamental tool in the Reliability Engineering field. M. Braglia, G. Fantoni, M. Frosolini (2007) provided a structured methodology for performing build-in reliability (BIR) investigation during a new product development cycle. The methodology in this paper represents an extension of the Quality Functional Deployment/House of Quality (QFD/HoQ) concepts to reliability studies. It is able to translate the reliability requisites of customers into functional requirements for the product in a structured manner based on a Failure Mode and Effect Analysis (FMEA). Besides, it then allows it to build a completely new operative tool, named House of Reliability (HoR) that enhances standard analyses, introducing the most significant correlations among failure modes. Using the results from HoR, a cost-worth analysis can be easily performed, making it possible to analyze and to evaluate the economical consequences of a failure. M. Kostina, T. Karaulova , J. Sahno , M. Maleki (2012) developed a reliability assessment method with an extension of the existing ones and pooling them to a common framework & the system must identify the most unreliable parts of a production process and suggest the most efficient ways for the reliability improvement. FMEA is in the centre of the proposed framework,a reliability analysis type, the most widely used in enterprises. The current research suggests extending the FMEA by introducing a classification of faults. In this procedure, Bayesian Belief Network is employed to analyze faults. BBN provide a method of modeling process losses and measuring the effectiveness of recommendations used for process reliability improvement.

Total Productive Maintenance

Total Productive Maintenance-From the past literature survey, the literature on classification of Total Productive Maintenance has been so far limited. The review carried in Overall Equipment Effectiveness, Integrated TPM, 5-s, Service and Quality.

Total Productive Maintenance and Overall Equipment Effectiveness-Nowadays, consumers expect manufacturers to provide excellent quality, reliable delivery and competitive pricing. This demands that the manufacturer’s machines and processes are highly reliable. In order to possess highly reliable machines to make sure smooth manufacturing process, many organizations have implemented Total Productive Maintenance (TPM) as the enabling tool to maximize the effectiveness of equipment by setting and maintaining the optimum relationship between people and their machines. Overall Equipment Effectiveness (OEE) is used as a measure when evaluating the result of TPM. F.-K. Wang, W. Lee (2001) focused on the application of total productive maintenance (TPM). The continuous improvement concepts such as total quality management, just-in-time and total productive maintenance have been widely recognized as a strategic weapon and successfully implemented in many organizations. A random effect non-linear regression model called the Time Constant Model was used to formulate a prediction model for the learning rate in terms of company size, sales, ISO 9000 certification and TPM award year. A two-stage analysis was employed to estimate the parameters. Using the approach of this study, one can determine the appropriate time for checking the performance of implementing total productive maintenance. By comparing the expected overall equipment effectiveness (OEE), one can improve the maintenance policy and monitor the progress of OEE. Ohwoon Kwon and Hongchul Lee (2004) presented the new quantitative calculation methodology model for estimating the quantitative monetary managerial effects such as contribution profit and reduced cost as a result of total productive maintenance (TPM) activities to measure what degree of contribution to the managerial profits. This newly presented model is expected to contribute to the maturity of TPM activities by grasping the monetary quantitative managerial effects periodically. This model can be adapted to all processing types and/or plant type manufacturing equipment that overall equipment efficiency (OEE) can be calculated. Anil S. Badiger,R. Gandhinathan (2008) proposed a method to evaluate OEE by including a factor known as usability, in the OEE calculation method. Further, an approach is developed to evaluate the earning capacity of addressing the six big losses, with incremental improvement in OEE, as an extension to the maturity of OEE. Overall Equipment Effectiveness (OEE) is a proven approach to increase overall performance of equipment. Osama Taisir R.Almeanazel (2010) review the goals and benefits of implementing Total Productive Maintenance, and it will also focusing on calculating the overall equipment effectiveness in one of Steel Company in Jordan, and it also discuss what called the big six losses in any industry (the quality, availability and speed). A case study taken from Steel Company in Jordan, the data taken along fifteen working days and teams formed in period of two months to find out the benefit of formation a multidiscipline team from different department to eliminate any boundaries between the departments and make the maintenance process more effectively, labors on the production line also included in way to adopt the autonomous maintenance operations (daily maintenance). As a result the company achieved 99% in quality factor of overall equipment effectiveness equation and 76% in availability where in performance it got 72%. Set of techniques like Single minute exchange die, computer maintenance management system, and production planning were suggested to the industry after calculating the OEE to improve their maintenance procedures and improve the productivity. P Sharma (2010) studied workings of the selected machines were carefully in an industry. Data for past one year have been analyzed. The analysis has revealed that there are 98% good components, 2% rework losses, where the nine most common causes were identified for the machine stoppages. The OEE was 65% and the six big losses represent 35% loss of the product time. Based on the findings, it was recommended to implement a TPM to improve the OEE of the plant. Trinath Sahoo (2010) proposed a concept of E-Diagnostics to improve Overall Equipment Effectiveness (OEE) of Process Plant Equipments. The e-Diagnostics helps increase the availability of production, reduce the mean time to repair and provide significant reduction in field service resource and cost. Many plant operators have come to recognize the economic significance of e- monitoring, especially in regard to machines whose central importance could stop production of a whole plant on failure. Abdul Talib Bon (2011) found out the relationship between TPM implementation and OEE result. Comparison between before and after the implementation of TPM is carried out to see the difference that TPM can bring to an organization. Elements that constitute the OEE equation will be analyzed in order to identify which one that affects OEE result. After identifying, improvement will be made on that element so that OEE result will be improved ultimately. The approach used in this paper is case study and the instruments used to collect data are observation and interview. Microsoft Excel is used to analyze data obtained and calculate OEE. Hence, TPM is a useful tool in helping firm to achieve optimal manufacturing process. By being able to achieve this level of maintenance, an organization will be able to reap competitive advantages brought by TPM, thus, producing quality products that manage to satisfy customers and subsequently generating greater profits. Abdul Talib Bon, Lim Ping Ping (2011) proposed to find out the difference between before and after the TPM implementation to OEE result. Comparison between before and after the implementation of TPM is carried out to see the difference that TPM can bring to an organization. Elements that constitute the OEE equation will be analyzed in order to identify which one that affects OEE result. After identifying, improvement will be made on that element so that OEE result will be improved ultimately. He used experimental approach and the instruments used to collect data are observation and interview. Microsoft Excel is used to analyze data obtained and calculate OEE. Hence, TPM is a useful tool in helping firm to achieve optimal manufacturing process. By being able to achieve this level of maintenance, an organization will be able to reap competitive advantages brought by TPM, thus, producing quality products that manage to satisfy customers and subsequently generating greater profits. Annamalai Sivakumar (2011) provided an overview of the various processes in textile fabric industry. From the analysis of data taken during the past three years, the company has noted that it has not achieved the targeted productivity. A systematic methodology is presented and analysed by software for improvement productivity at the factory level. Metrics of overall equipment effectiveness (OEE) is introduced and developed a structured robust framework for improvement of quality and productivity. Panagiotis H. Tsarouhas (2012) investigated the relationship between the factory management and the operation of the limoncello production line. Overall equipment effectiveness (OEE) is a well-accepted measure of performance in industry. The analysis of failure and repair data of the line over a period of 8 months was carried out. Descriptive statistics at machine and at line level were computed. In addition, the components availability (A), performance efficiency (PE), and quality rate (QR) of the OEE were calculated. Failure and repair data analysis identify the critical points of the production process that need immediate action to improve the operation of the line. After observing the results the components PE and QR should be improved immediately to optimize the productivity and the efficiency of the line. It can also be utilized in the beverage industry sector by the machinery manufacturers and the manufacturers of bottled products to improve the design and operation management of the bottling production lines. Ranteshwar Singh, Ashish M Gohil, Dhaval B Shah, Sanjay Desai (2012) shared an experience of implementing Total Productive Maintenance and investigated for a company manufacturing automotive component. Concept is implemented in the machine shop having CNC turning centers of different capacity. Overall Equipment Effectiveness is used as the measure of success of TPM implementation. The losses associated with equipment effectiveness are identified. All the pillars of TPM are implemented in a phased manner eliminating the losses and thus improving the utilization of CNC machines. Hemant Singh Rajput (2012) studied selected machines carefully in an industry. Data for past have been analyzed and results achieved are quite encouraging in terms of motivated employees, improvement in overall equipment effectiveness (OEE) and reduction in no. of accidents on shop floor. The analysis has revealed that there are 98% good components, 2% rework losses, where the nine most common causes were identified for the machine stoppages. The OEE was 67% and the six big losses represent 35% loss of the product time. Based on the findings, it was recommended to implement a TPM to improve the OEE of the plant. Rajiv Kumar Sharma (2013) developed an integrated model based on Six Sigma and TPM framework focusing on adding performance indicators. The goals of the study were achieved by utilizing various tools such as brainstorming sessions, pareto analysis fish-bone diagrams, histograms, FMEA, box plots, control charts and process capability plots for analysis'. While implementation of such twin framework requires greater management commitment in terms of training, resources and integration, they are also expected to provide higher levels of equipment and plant performance as evident from the results. The results show significant improvement in OEE level (Before 50, 54 and after 76, 83 for M/C –I and M/c-II), reduction in rework (from 22% to 10%), reduction in maintenance versus operation cost (from 30% to 10%) and reduction in defect rate (from 24.82% to 5%) and average outgoing quality level (from 30% to 5%). The substantial improvement in sigma level from 2.16 and 2.64 to 4.01 and 4.12 for M/C –I and M/C-II resulted in financial savings of approximately $2m per annum.

Integrated Total Productive Maintenance-A major challenge facing maintenance people nowadays is not only to learn what these techniques are, but to decide which are worthwhile and which are not for a particular asset. If we make the right choices, it is possible to improve asset performance and at the same time, even reduce the cost of maintenance. If we make the wrong choices, new problems are created while existing problems only get worse. The control of production processes is the subject of several disciplines. Although these disciplines are traditionally separated (both in science and in business practice), their goals have a great deal of overlap. Their common goal is to achieve optimal product quality, little downtime, and cost reduction, by controlling variations in the process. However, single or separated parallel applications may be not fully effective. So it is necessary to have integrated approach of TPM. K.Y. Kutucuoglu (2001) focused at the role of performance measurement systems (PMS) in maintenance, with particular reference to developing a new PMS using the quality function deployment (QFD) technique. First performance measurement is presented, in which the key factors for an effective PMS are identified. Second, common PMSs for maintenance are examined. Then, based on the principles of an effective PMS a discussion on PMSs is presented, when applied to the maintenance function. Next, a framework is developed to embrace these key facets, which is followed by a discussion of its practical implications, in the light of its application within a SME. Kristy O. Cua, Kathleen E. McKone, Roger G. Schroeder (2001) investigated the practices of the three programs Total Quality Management (TQM), Just-in-Time (JIT) and Total Productive Maintenance (TPM) simultaneously. This is done by specifying a common set of human and strategic practices that are shared by all three programs. This leaves a set of basic techniques that are unique to each of the three programs. This study provides a foundation for examining TQM, JIT, and TPM within a single framework. Werner A.J. Schippers (2001) discussed how controls from disciplines such as SPC, TPM and APC can be seen as a coherent set of efforts directed to the technical control of production processes & introduced an integrated process control (IPC) model. The control of production processes is the subject of several disciplines, such as statistical process control (SPC), total productive maintenance (TPM), and automated process control (APC). The model provides a structure to get an overview of the functions of controls and their interrelations. It shows that there is no one best way to control a process: the optimal set of controls depends on the situation. The main contingencies are briefly addressed. The possibilities to use the model for prescribing, describing and improving control are illustrated. S. A. BRAHy and W.-K. CHONGy (2004) focused on gaining insights into the impact of TPM on the performance of the organization. There is support for a positive correlation between TPM and business performance. There is also a positive correlation between TPM and business performance shown by all the six general constructs of corporate planning, top management leadership, human resource focus, process focus, total quality management focus and information system focus, and the three specific constructs of TPM strategies, TPM teams and TPM process focus. Clearly, this indicates the need for TPM to be an integrated effort for the entire organization. In addition, experienced and large TPM firms fare better in terms of business performance while there are no differences in the performance of manufacturing and services. V.R. Pramod, S.R. Devadasan, S. Muthu, V.P. Jagathyraj, G. Dhakshina Moorthy (2006) provided maintenance engineering community with a model named “Maintenance quality function deployment” (MQFD) for nourishing the synergy of quality function deployment (QFD) and total productive maintenance (TPM) and enhanced maintenance quality of products and equipment. The principles of QFD and TPM were studied. MQFD model was designed by coupling these two principles. The practical implementation feasibility of MQFD model was checked in an automobile service station. M.C. Eti , S.O.T. Ogaji , S.D. Probert (2006) presented methodology for the development of PM using the modern approaches of FMEA, root-cause analysis, and fault-tree analysis. Applying PM leads to a cost reduction in maintenance and less overall energy expenditure. Implementation of PM is preferable to the present reactive maintenance procedures (still prevalent in Nigeria). Pule A. Kholopane , Leon Pretorius, Alwyn Strauss (2007) focuses on the effect of an integrated human resource strategy on Total Productive Manufacturing (TPM) and assesses how the combination of the two can increase a firm's productivity. Some results of a South African manufacturing case study company in a unique environment are presented. The main conclusion reached in this study was that when innovative human resources practices are applied properly, they will promote total machine system efficiency and hence increase the productivity of the company. Overall Equipment Effectiveness (OEE) improved as a result of the committed TPM activities as interventions N.K.K.Prasanna, Shakti Akula, Tushar N. Desai (2011) presented a method of integration of various maintenance methodologies to arrive at an integrated maintenance strategy with a case study of a vertical integrally geared high speed pump & many maintenance management concepts, such as Reliability Centered Maintenance (RCM), Total Productive Maintenance (TPM), Total Quality Management (TQM). Incorporation of integrated maintenance strategy has significantly increased the reliability and uptime of the asset. Suzaituladwini Hashim (2012) examined the relationship of TPM practices and KE practices in Malaysian automotive industry. A conceptual model using Structural Equation Modeling (SEM) has been proposed. This model will be used to study the relationship between TPM practices and KE practices for Malaysian automotive industry. Based on the proposed conceptual model and reviewed, research hypotheses are being developed. Kanwarpreet Singh and Inderpreet Singh Ahuja (2012) evaluated the combined TQM–TPM strategic factors to determine the critical success factors in environmental uncertainty using analytical hierarchy process. The study decision criteria include TQM, TPM and transfusion of TQM–TPM, whereas the competitive advantages taken are strategic business performance, quality, production, cost, employee safety and morale. The research findings are applicable to manufacturing organizations, suggesting them the adoption of flexibility of TQM–TPM as a major competitive advantage with a higher uncertainty and delivery with a lower uncertainty. It is evident that using the quality tools/approaches like TQM–TPM can bring in commendable reforms and improvements in terms of realization of manufacturing excellence in the manufacturing organizations. Ahmad, M.F. , Zakuan, N.b , Jusoh, A. and Takala, J. d (2012) proposed a relationship between TQM practices and business performance with mediators of Statistical Process Control (SPC), Lean Production (LP) and Total Productive Maintenance (TPM) based on extensive review of the literature. The main contribution is to identify the relationships among TQM, TPM, SPC and Lean Production practices as a conceptual model. This proposed conceptual model will help the academicians and industry players to have better understanding on the relationship between the practices and step by step implementation to improve business performance. The structural equation modeling (SEM) techniques are used to examine the relationships of the practices. A. P. Kedar R. R. Lakhe V. S. Deshpande P. V. Washimkar M.V.Wakhare (2008) reviewed in brief the theoretical aspect of TQM, TPM, Six Sigma, BPR, Lean and ISO series of standards which highlights similarity, differences and potentiality of these approaches to improve organizational performance. All the approaches can be useful if handled carefully. Care has to be taken in deciding which would be more suitable for any organization depending on cost of implementation in terms of time and money involved. Mandeep Kaur, Kanwarpreet Singh and Inderpreet Singh Ahuja (2012) evaluated the contributions of synergic implementation of total quality management (TQM) and total productive maintenance (TPM) paradigms towards improving business performance in the Indian manufacturing industry. In his study, a large number of manufacturing organizations have been extensively surveyed, to ascertain contributions made by TQM-TPM paradigms in the Indian manufacturing organizations towards realizing business performance improvements. The correlations between various organizational initiatives towards TQM-TPM implementation and business performance improvements have been evaluated and validated by employing various statistical tools. Adnan Hj. Bakria, Abdul Rahman Abdul Rahimb, Noordin Mohd. Yusofc, Ramli (2012) Studied on the literature related to the application of TPM in the manufacturing industry. The significance role of TPM as an important complementary to lean production is observed. The available literature investigates the relation of TPM and lean production quite in a broad a lack of comprehensive research available to integrate the TPM element into lean production. The outcomes from this review is hope justify the needs of further research in the area of TPM integration with lean production, aimed at strengthening its philosophy towards more realistic applications.

Total Productive Maintenance and 5-S-TPM starts with 5S. 5S can be called as foundation stone of TPM implementation. It is a Japanese way of housekeeping. Problems cannot be recognized is the work place is unorganized. Cleaning and organizing the workplace helps us to pop up the problems. Making problems visible and seen to the people gives an opportunity of improvement. If this 5S is not taken up seriously, then it leads to 5D i.e. Delays, Defects, Dissatisfied customers, Declining profits and Demoralized employees. 5S is a principle institutionalized in Japan and has left rather considerable results in industrial and service sectors. These results are briefly known as incidents prevention, delays reduction, and productivity enhancement in work environment. The ultimate goal of 5S is to prevent losses. Shamsuddin Ahmed, Masjuki Hj. Hassan and Zahari Taha (2005) presented a generic model on using the total productive maintenance (TPM) concept in conjunction with ecology oriented manufacturing (EOM) and 5S focusing on their joint strengths in attaining organizational goals in furtherance to the equipment maintenance objectives. A systematic implementation-framework coupled with the standard tools, techniques and practices has been designed. The framework was applied in a large semiconductor manufacturing company. A well conceived TPM implementation not only improve the equipment efficiency and effectiveness but also brings appreciable improvements in other areas. M. Moradi, M. R. Abdollahzadeh, A. Vakili (2011) explicated relations between 5S and pillars of Total Productive Maintenance (TPM). In order to evaluate performance and effectiveness of 5S benefited from a checklist by which status of implementation and execution of 5S in a foodstuff production factory in Iran has been studied. Furthermore, effects of this implementation on development and maturity of TPM is evaluated. Ashok Kumar Sharma (2012) described the maintenance (Total Productive Maintenance) as strategy to improve manufacturing performance. Further, 5S as the base of Total Productive Maintenance (TPM) and overall equipment effectiveness (OEE) as a measure of effectiveness have also been discussed. This system consists of various resources like labour, materials, tools, plant and equipment, and others, used for production. The desired production output is achieved through high equipment availability, which is influenced by equipment reliability and maintainability. Maintenance function is therefore vital for sustainable performance of any manufacturing plant, since, a proper maintenance plan improve the equipment availability and reliability.

Total Productive Maintenance in Service-Nowadays, consumers expect manufacturers to provide excellent quality, reliable delivery and competitive pricing. This demands that the manufacturer's machines and processes are highly reliable. In order to possess highly reliable machines to make sure smooth manufacturing process, many organizations have implemented Total Productive Maintenance (TPM) as the enabling tool to maximize the effectiveness of equipment by setting and maintaining the optimum relationship between people and their machines. TPM is a useful tool in helping firm to achieve optimal manufacturing process. By being able to achieve this level of maintenance, an organization will be able to reap competitive advantages brought by TPM, thus, producing quality products that manage to satisfy customers and subsequently generating greater profits**.** Melesse Workneh Wakjira (2012) evaluated the contributions of total productive maintenance (TPM) initiatives towards improving manufacturing performance in Ethiopian malt manufacturing industry. The correlations between various TPM implementation dimensions and manufacturing performance improvements have been evaluated and validated by employing overall equipment effectiveness (OEE) in boiler plant. The study highlights the strong potential of TPM implementation initiatives in affecting organizational performance improvements. The achievements of Ethiopian manufacturing organizations through proactive TPM initiatives have been evaluated and critical TPM success factors identified for enhancing the effectiveness of TPM implementation programs in the Ethiopian context. Islam H. Afefy (2013) focused on a study of total productive maintenance and evaluating overall equipment effectiveness. The calculation of the overall equipment effectiveness in Salt Company (Emisal) in Egypt is carried out. The big six losses in any industry (quality, availability and speed) are also presented. The data were collected through reviewing the technical documents available in Emisal Company. Based on these results, global maintenance management, and production planning were suggested to improve their maintenance procedures and improve the productivity. Also, the company needs to work hard to improve their inspection system start from the raw materials inventory to the work in process finished with finish goods inventory. Ir.K.Batumalay (2008) studied the state of Overall Equipment Effectiveness (OEE) through Total Productive Maintenance (TPM) practices across the Malaysian industries. A theoretical framework is developed to determine the predominant TPM pillars that influence the OEE. Based on this theoretical framework, a survey-based research on a sample size of 70 Malaysian industries is applied to this study. The outcome of this survey is analyzed using SPSS. The analysis show that the predominant TPM pillars indeed has a considerable impact on the OEE. S. Fore (2010) focused on improving the maintenance in a manufacturing set up using an innovative maintenance regime mix to improve overall equipment effectiveness. Interviews, reviewing documentation and historical records, direct and participatory observation were used as data collection methods during the research. Usually production is based on the total kilowatt of motors produced per day. The target kilowatt at 91% availability is 75 Kilo watts a day. Reduced demand and lack of raw materials particularly imported items are adversely affecting the manufacturing operations. The company had to reset its targets from the usual figure of 250 Kilowatt per day to mere 75 per day due to lower availability of machines as result of breakdowns as well as lack of raw materials. Manu Dogra (2011) presented detail implementation of TPM in the cold rolling plant is discussed. Results achieved are quite encouraging in terms of motivated employees, improvement in overall equipment effectiveness (OEE) and reduction in no. of accidents on shop floor. It is seen that during all data analysis (OEE, Maintenance cost, Number of accidents etc.) the results are improving effectively only after a years' time of implementation. It is clear that employees need a time to adopt TPM system in the organization. Hence Management has to be patience enough to motivate the employees and watch for the results with passage of time. Autonomous maintenance concept has helped to reduce the mechanical maintenance cost which is showing a down trend continuously and lead to saving of Rs.100 per metric ton (MT) of production and further contributed for the increase in profitability of the system, side by side this concept has helped in imbibing the ownership concept about the equipment in the production operators. This has in turn leaded to equipment competent operators. Suzaituladwini Hashim (2012) identified the TPM constructs and innovation performance measures for Malaysian automotive industry and also to develop research model of the TPM and innovation performance measures relationship for Malaysian automotive industry. A conceptual model based on previous studies has been proposed &sampling method by using structured questionnaire. The population of this study comprised in Malaysian automotive industry. Questionnaires will distribute to respondents from the listing of automotive industry obtained from Malaysian Automotive Component Parts Association (MACPMA), Proton Vendors Association (PVA), and Kelab Vendor Perodua. To analyze the data, one statistical technique was adopted. Structural equation modelling techniques was utilize to perform the require statistical analysis of the data from the survey. Exploratory factor analysis, reliability analysis and confirmatory factor analysis to test for construct validity, reliability, and measurements loading were performed. Having analyzed the measurement model, the structural model was then tested and confirmed. The statistical Package for the Social Sciences (SPSS) version 17 was used to analyze the preliminary data and provide descriptive analyses about thesis sample such as means, standard deviations, and frequencies. Structural Equation Modelling (SEM using AMOS 6.0) will use to test the measurement model. Jagtar Singh (2013) reviewed all the Total Productive Maintenance (TPM) Pillars, TPM Implementation methodology and the contribution of TPM towards improving manufacturing performance. It also focused on calculating the Overall Equipment Effectiveness (OEE) in one of the two wheeler automobile Industry in India. The relationship between various TPM implementation dimensions and manufacturing performance improvements have been evaluated by applying OEE. The study established that focused TPM implementation over a reasonable time period can strategically contribute towards realization of significant manufacturing performance enhancements. Set of various techniques like Single Minute Exchange Die (SMED), computer maintenance management system, production planning were suggested to the industry after calculating the overall equipment effectiveness to improve their maintenance procedures and improve the productivity. T. Carannante , R. H. Haigh & D. S. Morris (1996) studied the nature of TPM and its merits and application in the foundry industries of the UK and Japan, and proposes a generic model to facilitate its wider implementation & proposed a generic model to facilitate TPM wider implementation.

Total Productive Maintenance and Quality-RODNEY Mcadam & Anne-Marie Duffner (1996) discussed in detail how TPM can be effectively implemented within an organization that has an established Total Quality programme in place. The relationship between total quality management and TPM is investigated with regard to improving the synergy between the initiatives and the effectiveness of each respectively. The benefits of applying TPM are shown and an implementation strategy is described. Case study data on Harris Ireland Ltd (part of the Harris Corporation) are analyzed and discussed in detail. The data include questionnaire and interview data. Comparison is also made with TPM implementation in NEC Semiconductor Ireland Ltd and Short Bros plc (part of the Bombardier Aerospace Group). The strategy to maximize the effectiveness of equipment currently in use through total employee involvement is being pursued through employee involvement, teamwork and training. Christian N. Madu (1999) developed a framework that establishes the link between quality, reliability, and maintainability. The aim of this framework is to get corporate attention to focus on reliability issues and also, to establish the link between reliability, company's bottom line, and corporate survival. A greater focus on ``total reliability management (TRM)" will help firms to improve their productivity and efficiency while reducing cost and increasing their competitiveness. The popular tools for quality such as the quality function deployment (QFD) and problem solving techniques such as the Fishbone diagram can be instrumental in designing and producing highly reliable systems. M.C. Eti , S.O.T. Ogaji , S.D. Probert (2004) explored the ways in which Nigerian manufacturing industries can implement TPM as a strategy and culture for improving its performance and suggests self-auditing and bench-marking as desirable prerequisites before TPM implementation. Nigerian industrial managers must move away from traditional reactive maintenance procedures to implementing more proactive maintenance processes. Ma Lixin, Dong Shicheng, Gong Yunqi , Yu Guiwen (2011) focused on the application of TPM in companies, and a new facility management mode that positively propels the improvement of comprehensive efficiency and enterprise vitality was proposed. Practice in many enterprises has been proved that TPM adheres to people-oriented and enhances full participation awareness, which radically changed obsolete equipment management mode and shaped full participation and active atmosphere in enterprises. R. Wudhikarn (2011) presented methodology is to calculate losses following overall equipment effectiveness (OEE) consisting of opportunity and production cost losses and also from cost of quality (COQ) approaches. This method eliminates some of OEE's weaknesses and expands scope from overall equipment cost loss (OECL). The proposed calculating methodology is demonstrated by applying to a real manufacturer of equipment. This newly improved model can prioritize problematic equipment more appropriately than OEE and OECL. This research has the objective of improving indicators for evaluating losses of equipment. It also proposes a newly developed computing methodology for estimating the quantitative losses in monetary unit.

III. DISCUSSION

A FMEA is an analytical quality planning tool dedicated to the identification of the main potential failure modes and their associated effects at the product, service, process, and/or design stages. Its effective use could lead to numerous reductions (improvements) in:

• Internal defects (during and after the manufacturing process)
• Customer complaints
• Failures in the field

In addition, successful application of a FMEA could lead to improved customer satisfaction and services produced by reliable manufacturing processes. In order to survive every industry has to improve productivity by utilizing resources like machinery, men, and material as optimally as possible. Every manufacturing industry facing huge losses/wastage occurs in the manufacturing shop floor. This waste is due to operators, maintenance personal, process, tooling problems and non-availability of components in time etc. Other forms of waste includes idle machines, idle manpower, break down machine, rejected parts etc. are all examples of waste. The quality related waste are of significant importance as they matter the company in terms of time, material and the hard earned reputation of the company. There are also other invisible wastes like operating the machines below the rated speed, start up loss, break down of the machines and bottle necks in process. Zero oriented concepts such as zero tolerance for waste, defects, break down and zero accidents are becoming a pre-requisite in the manufacturing and assembly industry. In this situation, a revolutionary concept of Total Productive Maintenance (TPM) has been adopted in many industries across the world to address the above said problem.

TPM is an innovative approach to maintenance that optimizes equipment effectiveness, eliminates breakdowns and promotes autonomous operator maintenance through day-to-day activities involving the total workforce. TPM can be considered the science of machinery health. TPM is productive maintenance carried out by all employees through small group activities. TPM covers three areas: equipment, people, and the workplace. One of the main aims of TPM is to increase productivity of plant and equipment in such a way as to achieve maximum productivity with only a modest investment in maintenance.

Therefore by FMEA-TPM helps in improving quality, reliability and productivity

IV. CONCLUSION

Quality and reliability of products and manufacturing processes are critical to the performance of the final products. They are also important indices for meeting customer satisfaction. In order to fulfill customer's requirements for quality and reliability, some actions for assuring the quality and reliability of products or processes should be taken by all the persons involved. One of the most powerful methods available for measuring the reliability of products or process is FMEA. Probably the greatest criticism of the FMEA has been its limited use in improving designs. Customers are placing increased demands on companies for high quality and reliable products. FMEA provides an easy tool to determine which risk has the greatest concern and therefore an action is needed to prevent a problem before it arises. The development of these specifications will ensure the product will meet the defined requirements. Before starting the actual FMEA, a worksheet needs to be created, which contains the important information about the system, such as the revision date or the names of the components. On this worksheet all the items or functions of the subject should be listed in a logical manner.

The initial output of an FMEA is the prioritization of failure modes based on their risk priority numbers and this alone does not eliminate the failure mode. Additional action that might be outside the FMEA is needed.

Quality and Maintenance of manufacturing systems are closely related functions of any organization. Over a period of time the concept have emerged which is Total Productive Maintenance (TPM to achieve World Class Manufacturing system. Total productive maintenance (TPM) is increasingly being seen as a suitable initiative technique for effectively involving the workforce in manufacturing based organizations to produce increased productivity and add new impetus to quality efforts. TPM is a useful tool in helping firm to achieve optimal manufacturing process. By being able to achieve this level of maintenance, an organization will be able to reap competitive advantages brought by TPM, thus, producing quality products that manage to satisfy customers and subsequently generating greater profits. By preventing equipment break-down, improving the quality of the equipment and by standardizing the equipment (results in less variance, so better quality), the quality of the products increases

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