Ford fmea handbook 4.2 pdf

The systematic technique for identifying potential failure modes in a system and its causes and effects Analysis of the mode of failure and effects (FMEA; often written with plural failure modes) is the process of reviewing as many components, assemblies and subsystems as possible to identify potential modes of failure in a system and their causes and effects. For each component, the error modes and resulting effects on the rest of the system are recorded in a specific FMEA worksheet. There are many variants of such worksheets. An FMEA can be a qualitative analysis, [1] but it can be put on a quantitative basis when mathematical models of the failure rate[2] are combined with a statistical database of the error report. It was one of the first highly structured, systematic techniques for the analysis of failure. It was developed by reliability engineers in the late 1950s to study the problems that could arise as caused by malfunctions of military systems. An FMEA is often the first step in a system reliability study. There are a few different types of FMEA analyses, such as: Functional design process Sometimes FMEA is extended to FMEA (failure mode, effects and criticality analysis) to indicate that criticality analysis is performed too. FMEA is an inductive reasoning (logic forward) single point of analysis of failure and is a basic task in reliability engineering, safety engineering and quality engineering. A successful FMEA activity helps identify potential modes of failure based on experience with similar products and processes or on the basis of common physics of the logic of failure. It is widely used in the development and manufacturing industries at different stages of the product lifecycle. The effects analysis refers to the study of the consequences of these malfunctions at different levels of the system. Functional analyses are required as input to determine the correct failure modes at all system levels for both functional fMEA and FMEA(hardware) for both functional and FMEA. An FMEA is used to structure mitigation to reduce risk based on reduced severity of failure effect (mod) or decrease in probability of failure or both. The FMEA is, in principle, a complete inductive analysis (logic before), but the probability of failure can only be estimated or reduced by understanding the failure mechanism. Therefore, the FMEA may include information on the causes of failure (deductive analysis) to reduce the possibility of occurrence by eliminating identified causes (root). Introduction EMF(C)A is a design tool used to systematically analyze postulated component errors and to identify the resulting effects on system operations. The analysis is characterized as consisting of two sub-analyses, the first being the modes of failure and effect analysis (FMEA), and the second, the analysis of criticism (CA). [3] The successful development of an FMEA requires the analyst to include all significant error modes for each element or part that contributes to the system. FMEA can be performed on the system, subsystem, assembly, assembly, or at the piece level. FMECA should be a living document during the development of a hardware design. It should be programmed and completed at the same time as the design. If completed in a timely manner, the FMECA can help guide design decisions. The usefulness of the FMECA as a design tool and in the decision-making process depends on the effectiveness and appropriateness with which design problems are identified. The news is probably the most important consideration. In the extreme case, the FMECA would have a reduced value for the design decision-making process if the analysis is carried out after the hardware is built. While the FMECA identifies all modes of part failure, its primary benefit is the early identification of all critical and catastrophic subsystems or system failure modes so that they can be eliminated or minimized by modifying the project at the earliest in the development effort; therefore, the EMFA should be carried out at system level as soon as preliminary design information is available and extended to the lower levels as the design of the details progresses. Note: For more complete scenario modelling, a different type of reliability analysis, e.g. fault tree analysis (ALS), may be considered; a deductive analysis (reverse logic) that can handle several malfunctions within the article and/or external to the element, including maintenance and logistics. It starts at the higher functional level/system. An ALS can use FMEA records in basic error mode or a summary of the effect as one of its entries (basic events). Interface hazard analysis, human error analysis, and more can be added for completion in scenario modeling. Functional failure mode and effect analysis Analysis Analysis must always begin by enumerating the functions that the design must perform. Functions are the starting point of a well-made FMEA, and using functions as a base provides the best efficiency of an FMEA. After all, a design is just a possible solution to perform functions that need to be met. In this way, an FMEA can be done on concept design, as well as detail models, on hardware, as well as software, and no matter how complex the design. When performing an FMECA, it is first considered that the interface hardware (or software) works in accordance with the specifications. After that, it can be extended by using one of the 5 possible ways to failure an interface hardware function as a cause of failure for the design element under review. This provides the ability to make the design robust for function failure elsewhere in the system. In addition, each partial error is considered to be the only failure in the system (e.g. it is a single fault analysis). In addition to the FMEA carried out on the systems to assess the impact of lower-level failures on the functioning of the system, several other FMEAs are carried out. Particular attention is paid to interfaces between systems and, in fact, to all functional interfaces. The purpose of these EMAs is to ensure that and/or functional damage does not propagate in the interface as a result of malfunctions at one of the interface units. These analyses shall be carried out at the part level for circuits that interact directly with the other units. FMEA can be achieved without a CA, but a CA requires that the FMEA has previously identified critical system-wide errors. When both steps are performed, the total process is called an EMPECA. Basic rules The basic rules of each FMEA include a set of procedures selected for projects; the assumptions on which the analysis is based; hardware that has been included and excluded from the analysis and the justification of exclusions. The basic rules also describe the level of qualification of the analysis (i.e. the level in the hierarchy of the part to the subsystem, the subsystem system, etc.), the basic hardware status and the success criteria of the system and mission. Every effort should be made to define all the basic rules before the start of the FMEA; however, the basic rules may be extended and clarified as the analysis continues. A typical set of basic rules (hypotheses) follows:[4] There is only one error mode at a time. All entries (including software commands) of the analyzed item are also present at nominal values. All consumables are present in sufficient quantities. Nominal power is available Major benefits derived from a properly implemented FBECA effort are as follows: It provides a documented method for selecting a design with a high probability of operation and successful safety. A documented uniform method of assessing potential failure mechanisms, malfunction modes and their impact on the functioning of the system, resulting in a list of failure modes classified according to the severity of their impact on the system and the likelihood of their occurrence. Early identification of single fault points (FPS) and system interface issues, which may be essential for mission success and/or safety. They also provide a method of verifying that switching between redundant elements is not endangered by single postulated errors. An effective method of assessing the effect of the proposed changes to the design and/or operational procedures on the success and safety of the mission. A basis for in-flight troubleshooting procedures and for locating performance monitoring and fault detection devices. Criteria for early test planning. From the list above, early identification of FPS, introduction to the troubleshooting procedure and location of performance monitoring/fault detection devices are probably the most important benefits of FMECA. In addition, the EMFCA procedures are simple and allow an orderly evaluation of the project. The history procedures for carrying out the FBECA have been described in the military procedures of the U.S. armed forces MIL-P-1629[5] (1949); revised in 1980 as MIL-STD-1629A. [6] Until the early 1960s, contractors for the U.S. National Aeronautics and Space Administration (NASA) were using variations of the FMEA or FMEA under a variety of Name. [7] NASA programs using the FMEA variants included Apollo, Viking, Voyager, Magellan, Galileo, and Skylab. [10] [11] The civil aviation industry was an early adopter of the FMEA, with the Auto Engineers Society (SAE, an organization covering aviation and other transport beyond automobiles, despite its name) publishing ARP926 in 1967. [12] After two revisions, the recommended practice of the aerospace industry ARP926 was replaced by ARP4761, which is now widely used in civil aviation. In the 1970s, the use of FMEA and related techniques spread to other industries. In 1971, NASA prepared a report for the U.S. Geological Survey recommending the use of FMEA in assessing offshore oil exploration. [13] A 1973 report by the U.S. Environmental Protection Agency described the application of FMEA to wastewater treatment plants. [14] FMEA as an application for HACCP on the Apollo Space Program has moved into the food industry in general. [15] The automotive industry began using FMEA until the mid-1970s. [16] Ford Motor Company introduced FMEA to the automotive industry for safety and regulation after the Pinto business. Ford applied the same process approach (PFMEA) to take into account potential process-induced failures prior to the launch of production. In 1993, Automotive Industry Action Group (AIAG) first published an FMEA standard for the automotive industry. [17] It is now in its fourth edition. [18] SAE first published standard J1739 in 1994. [19] This standard is also now in its fourth edition. [20] In 2019, both descriptions of the method were replaced with the new AIAG/VDA FMEA manual. It is a harmonisation of the former FMEA standards of AIAG, VDA, SAE and other descriptions of methods. [21] [22] [23] Although initially developed by the military, the FMEA methodology is now widely used in a variety of industries, including semiconductor processing, food services, plastics, software and healthcare. [24] Toyota has taken this step forward with its Design Review Based on Failure Mode (DRBFM) approach. The method is now supported by the American Quality Society, which provides detailed guidance on how to apply the method. [25] Standard Procedures for Analysis of Effects and Effects (FMEA) and Failure, Effects and Criticality (FMECA) identify product failure mechanisms but cannot model them without specialized software. This limits their applicability to provide significant input to critical procedures, such as virtual qualification, root cause analysis, accelerated testing programs and remaining life assessment. In order to overcome the deficiencies of the FMEA and the FMECa, the modes of failure, mechanisms and effect analysis (FMMEA) were often used. The following basic terms cover some basic FMEA terminology. [26] Priority of Action (AP) AP the former risk matrix and RPN in the AIAG / VDA FMEA 2019 manual. It shall make a statement on the need for further improvement measures. Failure Loss of a function in accordance with Failure mode The specific mode or mode by which a failure occurs in respect of the failure of the part, component, function, equipment, subsystem or system under investigation. Depending on the type of FMEA performed, the failure mode can be described at different levels of detail. Part of the FMEA part will focus on detailed ways of failure of parts or components (such as fully fractured or deformed bone or open, short or intermittent locked electrical contact). A functional FMEA will focus on functional failure modes. These can be general (such as No Function, Over Function, Under Function, Intermit Function, or Unintended Function) or more detailed and specific to the equipment analyzed. A PFMEA will focus on process failure modes (such as inserting a wrong drill). Cause of failure and/or mechanism Defects in requirements, design, process, quality control, handling or partial application, which are the cause or sequence of causes that initiate a process (mechanism) that leads to a mode of failure within a certain time. An error mode can have several causes. For example; fatigue or corrosion of a structural beam or corrosion in the event of fretting in an electrical contact is a defect mechanism and in itself (probably) not a mode of failure. The associated failure mode (final condition) is a complete structural beam fracture or an open electrical contact. The original cause could have been improper application of the corrosion protection layer (paint) and/or (abnormally) vibration input from another (possibly failed) system. Effect of failure Immediate consequences of an error on the functioning, or generally on the needs for the client/user that should be met by the function, but now is not, or not fully met levels of indentation (material invoice or functional breakdown) An identifier for the system level and therefore the complexity of the element. Complexity increases as levels are closer to one. Local Effect Error Effect, this is how the item analyzed applies. The next top-level effect The error effect so applies to the next higher indentation level. Final effect Effect error at the highest indentation level or at the total system. Detection Means of detection of failure mode by the maintenance person, operator or built-in detection system, including the estimated period of longing (if applicable) Probability of occurrence of failure. Risk Priority Number (RPN) Severity (event) × Probability (of event that occurred) × Detection (Probability that the event will not be detected before the user is aware of it) Severity Consequences of an error mode. Severity takes into account the most serious consequence a malfunction, due to the degree of injury, damage to the property, damage to the system and/or time wasted to repair the malfunction. Comments/mitigation/actions Additional information, including proposed mitigation or actions used to reduce a risk or to justify a level of risk or scenario. Example of FMEA Worksheet Example FMEA Worksheet FMEA Ref. Potential Potential Error Item Cause(s) /mechanism Mission Phase Local Effects of Failure Next Senior Effect Level End Effect System (P) Probability (Estimate) (S) Severity (D) Detection (Indications for Operator, Maintenance) Detection Sleeping Period Risk Level P * S (+D) Actions for Further Investigations /Evidence Mitigation / Requirements 1.1.1.1 Brake Collector Ref. Designer 2b, Channel A, O-ring internal leaks from Channel A to B a) O-ring Compression Set (Creep) failure b) surface damage during assembly landing Low pressure to main brake hose No left brake braking severely deceleration of the aircraft on the ground and lateral drift. Partial loss of runway position control. Collision risk (C) Occasionally (V) Catastrophic (this is the worst case) (1) Flight computer and maintenance computer will indicate left main brake, low pressure Built-in test interval is 1 minute Unacceptable check period and probability of failure Requires redundant independent hydraulic brake channels and/or Requires redundant sealing and classifyring O as critical part Class 1 Probability (P) It is necessary to analyze the cause of a failure mode and the probability of occurrence. This can be done through analysis, calculations/FEM, looking at similar elements or processes and modes of failure that have been documented to them in the past. A cause of failure is seen as a weakness of design. All potential causes of a failure mode must be identified and documented. This should be technically. Examples of causes are: Human errors in handling, Manufacturing-induced defects, Fatigue, Creep, Abrasive wear, erroneous algorithms, excessive voltage or improper operating conditions or use (depending on the basic rules used). An error mode can give a classification of probabilities with a defined number of levels. Rating Sense A Extremely unlikely (Virtually impossible or not known events on similar products or processes, with many hours of operation) B Distance (relatively few failures) C occasional (occasional failures) D reasonable possible (repeated failures) E frequent (failure is almost inevitable) For a piece of the FMEA part, the quantitative probability can be calculated from the results of a reliability prediction analysis and the failure mode ratios from a distribution catalog failure mode, would be RAC FMD-97. [27] This method allows a quantitative ALS to use FMEA results to verify that undesirable events meet acceptable levels of risk. Severity (S) Determination of severity for worst adverse end-effect scenario (status). It is convenient to write these effects down in terms of what the user might see or experience in terms of functional failures. Examples of these final effects are: loss of x function, degraded performance, inverted functions, too late operation, irregular operation, etc. Each end effect is given a severity number (S) from, say, I (no effect) to V (catastrophic), based on cost and/or loss of life or quality of life. These numbers prioritize (along with probability and detectability). A typical classification is given below. Other classifications are possible. See also hazard analysis. Rating Meaning I No relevant effect on reliability or safety II Very minor, no damage, no injury, only leads to a maintenance action (only observed by discriminatory customers) III Minor, reduced damage, slight damage (affects very little of the system, observed by the average client) IV Critical (causes a loss of primary function; Loss of all safety margins, 1 failure away from a catastrophe, serious damage, serious damage, maximum 1 possible death) V Catastrophic (product becomes inoperative; failure can lead to complete unsafe operation and possible multiple deaths) Detection (D) Means or method by which a malfunction is detected, isolated from the operator and/or maintenance and the time required. This is important for maintenance control (system availability) and is particularly important for several failure scenarios. This may involve latent failure modes (e.g. no direct system effect, while a redundant system/item automatically retrieves or when failure is problematic only during specific mission or system states) or latent failures (e.g. damage mechanisms failure, would be a growing metal crack, but not a critical length). It should be clarified how the failure is or the cause can be discovered by an operator under normal operating conditions of the system or whether it can be discovered by the maintenance crew by a particular diagnostic action or by automatic testing incorporated into the system. A period of sleepiness and/or latency may be introduced. Rating Meaning 1 Certain - the fault will be caught in the test - for example, Poka-Yoke 2 Almost certain 3 High 4 Moderate 5 Low 6 Defect is undetected by Dormance operators or maintainers or the average latency period the average time during which a failure mode can be undetected can be introduced if known. For example: Seconds, auto detected by computer maintenance 8 hours, detected by turn-around inspection 2 months, detected by the scheduled maintenance block X 2 years, detected by the task of overhaul x Indication Whether the undetected failure allows the system to remain in a safe/working state, a second failure situation should be explored to determine whether or not an indication will be obvious to all operators and what corrective measures can or should take. Indications for the operator should be described as follows: Normal. An indication that is evident to an operator when the system or equipment is operating normally. Abnormal. An indication that is evident to an operator when the system has failed or failed. Incorrect. An incorrect indication for an operator due to or failure of an indicator (e.g. instruments, detection devices, visual or audible warning devices, etc.). EFFECTATION OF DETECTION ACOPERS ANALYSIS FOR TEST AND MONITORING PROCEDURES (From ARP4761): This type of analysis is useful to determine how effective the different testing processes are when detecting Defects. The method used to do so involves an examination of the applicable malfunction modes to determine whether their effects are detected or not and to determine the percentage of the failure rate applicable to the malfunction modes that are detected. The possibility that the detection means fail latently should be taken into account in the analysis of the coating as a limiting factor (i.e. the coverage cannot be more reliable than the availability of the detection means). The inclusion of detection coverage in the FMEA can lead to each individual failure that would have been an effect category that is now a separate effect category due to the detection coverage possibilities. Another way to include detection coverage is for the ALS to conservatively assume that no holes in the coating due to latent failure of the detection method affect the detection of all defects attributed to the fault concern category. The FMEA may be reviewed if necessary in cases where this conservative assumption does not allow the requirements for the probability of peak event to be met. After these three basic steps, the level of risk can be provided. Risk level (P×S) and (D) Risk is the combination of probability and severity of the final effect, where probability and severity include the effect on non-detectability (sleeping time). This can influence the probability of the final effect of failure or the worst effect of severity. The exact calculation can not be easy in all cases, would be those in which several scenarios (with multiple events) are possible and detectability / dormancy plays a crucial role (as for redundant systems). In this case, analysis of the fault shaft and/or event trees may be necessary to determine the exact probability and risk levels. Preliminary risk levels can be selected on the basis of a risk matrix, such as the one shown below, on the basis of mil. Str. [28] The higher the level of risk, the more justification and mitigation is needed to provide evidence and reduce the risk to an acceptable level. A high risk should be indicated for high-level management, which is responsible for final decision-making. SeverityProbability I II III IV IV VI A Low Low Low Low Moderate High B Low Low Low Low High Unacceptable C Low Moderate Lyustabil D Moderate Moderate Lyacceptable Unacceptable Moderate Unacceptable Moderate Unacceptable After this step FMEA became like an FMEA. The FMEA calendar should be updated whenever: A new cycle begins (new product/process) Changes are made to operating conditions A change is made in the design New regulations are instituted Customer feedback indicates a problem Uses Development of system requirements that minimizethe the likelihood of failures. projects and testing systems to ensure that faults have been eliminated or that the risk is reduced to an acceptable level. Development and evaluation of diagnostic systems To help choose design (compromise analysis). Catalyst advantages for teamwork and exchange of ideas between Collect information to reduce future failures, capture engineering knowledge Early identification and elimination of potential failure modes Accentuate problem prevention Improve company image and competitiveness Improve production efficiency Improve quality, Reliability and Safety of a Product/Process Increase User Satisfaction Maximize Profit Minimize Delayed Changes and Associated Costs Reduce Impact on The Company's Profit Margin Reduce System Development Time and Cost Reduce the possibility of the same type of failure in the future Reduce warranty limitation potential While FMEA identifies significant hazards in a system, its results may not be comprehensive and the approach has limitations. [29] [30] [31] In the context of healthcare, FMEA and other risk assessment methods, including SWIFT (Structured What If Technique) and retrospective approaches, have been shown to have limited validity when used in isolation. The challenges of delimitation and organisational boundaries appear to be a major factor in this lack of validity. [29] If used as a top-down tool, FMEA can only identify major modes of failure in a system. Fault tree analysis (FTA) is more suitable for top-down analysis. When used as a bottom-up FMEA tool can enhance or complete the FTA and identify several causes and modes of failure resulting in upper-level symptoms. It is not in a position to discover complex modes of failure involving multiple failures within a subsystem or to report the expected failure intervals of certain modes of failure to the upper-level subsystem or system. [citation required] In addition, multiplication of severity, occurrence and detection rankings can lead to rank reversals, if a less serious failure mode receives a higher RPN than a more serious mode of failure. [32] The reason for this is that rankings are ordinal scale numbers, and multiplication is not defined for ordinal numbers. The ordinal ranking says only that one ranking is better or worse than another, but not by how much. For example, a 2 ranking may not be twice as severe as a ranking of 1, or an 8 may not be twice as severe as a 4, but multiplication treats them as it would. See Measurement Level for further discussion. Various solutions to this problem have been proposed, for example, the use of fuzzy logic as an alternative to the classic RPN model. [33] [34] [35] The FMEA worksheet is difficult to produce, difficult to understand and read, and difficult to maintain. Using neural network techniques to cluster and view failure modes have been suggested since 2010. [36] [37] [38] An alternative approach is to combine the with a set of bow tie charts. Charts provide a view of cause and effect chains, while the FMEA table provides detailed information about specific events. [39] Functional types: Before design solutions are provided (or only at a high level), functions can be evaluated based on potential functional failure effects. General general conditions requirements) may be proposed to limit the consequences of functional failures or to limit the likelihood of occurrence in this early development. It is based on a functional breakdown of a system. This type can also be used for software evaluation. Concept Design / Hardware: analysis of systems or subsystems in the early stages of the design concept to analyze malfunction mechanisms and lower-level functional failures, especially at various conceptual solutions in detail. It can be used in compromise studies. Detailed design / Hardware: analysis of products before production. These are the most detailed (in MIL 1629 called Piece-Part or FMEA Hardware) and used to identify any possible hardware (or other) failure mode up to the lowest part level. It should be based on hardware breakdown (e.g. BoM = Bill of Material). Any effect of failure Severity, failure prevention (mitigation), detection of failure and diagnosis can be fully analyzed in this FMEA. Process: analysis of manufacturing and assembly processes. Both quality and reliability may be affected by process errors. The input for this FMEA is, among other things, a process of work/load Breakdown. See also Design Review Based on How Failure Eight Disciplines Solving Problems Cause Failure Mode Failure, Effects, and CriticalIty Analysis (FMECA) – Systematic Technique for Analysis of Failure Ways of Failure, Effects, and Diagnostic Analysis (FMEDA) Failure Rate Fault Tree Analysis - Failure Analysis System Used in Safety Engineering and Reliability Engineering Hazard Analysis and Critical Control Points - Preventive Systematic Approach food safety High availability – systems with high up-time, a.k.a. always on List of material analysis methods – Wikipedia article list List of materials-testing resources Process decision chart Engineering reliability – Engineering sub-discipline of systems that emphasize reliability in lifecycle management of a product or a risk assessment system - Estimation of the risk associated with exposure to a specific set of hazards Expert Subject - An authority in a particular field or subject Taguchi methods - Statistical methods to improve the quality of manufactured products References ^ System Reliability Theory : Models, Statistical Methods, and Applications, Marvin Rausand & Arnljot Hoylan, Wiley Series in probability and statistics —second edition 2004, page 88 ^ Tay K. 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