Idea Paper: A Failure Analysis Matrix

1. Problem Statement and Goal

Introduction

Failure Modes and Effects Analysis (FMEA) is a tool for identifying, analyzing and prioritizing potential failures. FMEA provides a framework for a detailed cause and effect analysis (Russomanno, Bonnell, and Bowles, 1994). FMEA requires a team to thoroughly examine and quantify the relationships among failure modes, effects, causes, current controls, and recommended actions. At General Electric (GE), FMEA is documented in an Excel spreadsheet. By multiplying the values for severity, occurrence, and detection, the team obtains a risk priority number (RPN). These risk priority numbers help the team to select the recommended actions with the most impact.

An FMEA worksheet has multiple rows with fixed column headings. The FMEA worksheet is often arranged in 16 columns, 11 for the FMEA Process and 5 for the Action Results (McDermott, Mikulak, and Beauregard, 1996, p. 29). The FMEA Process columns normally include Item and Function; Potential Failure Mode; Potential Effect(s) of Failure; Severity; Potential Cause(s) of Failure; Occurrence; Current Controls; Detection; RPN; Recommended Action; and Responsibility and Target Completion Date. The Action Results columns include Action Taken, Severity, Occurrence, Detection, and RPN. Kukkal, Bowles, and Bonnell (1993) stated that failure effects at one level of a system need to be propagated as failure modes to the next higher level. Bull et al. (1996) noted that an FMEA is often quite long. Thus, an FMEA is at least 16 columns wide, is often several levels deep, and is sometimes dozens or hundreds of pages long.

Problem Statement

The author is a Senior Project Manager in the Information Management function at GE Industrial Systems. As the author's team struggles to improve its processes, it has become apparent that FMEA, as implemented in Excel, is so cumbersome that using the FMEA process is a daunting task. There are many-to-many relationships among failure modes, effects, causes, current controls, and recommended actions. Almost any significant FMEA application soon bogs down in confusion due to large amounts of repetitive and redundant data. The information overload obscures the relationships among the relevant objects and attributes (failure modes, effects, causes, current controls, recommended actions, severity, occurrence, and detection), adding to the confusion. The author's team has found that elements of FMEA such as detection and failure modes are not intuitive. (See Raskin, 1994, for the definitive analysis of intuitiveness.)

Goal

The goal of this dissertation is the creation of a usable and useful model for prioritizing solutions to potential failures in information systems. Sincell et al. (1998) pointed out that many benefits of FMEA can be obtained by alternative methods. Hindson, Cook, and Kochhar (1997) stated that many benefits of FMEA can be obtained without formally using the tool. The dissertation's new model will be called a failure analysis matrix (FAM).

Research Questions

One section of the dissertation will review the FMEA literature to understand FMEA issues. Another section will examine the usability literature on scrolling. The author will test the hypothesis that a FAM with a few variable column headings is a usable and useful alternative to an FMEA with many fixed column headings.

2. Relevance and Significance

Historical Overview

In the years following World War II, Juran, Deming, and others developed statistical tools and methods to improve the quality of manufactured products. These concepts developed into today's body of knowledge surrounding manufacturing quality. Total Quality Management (TQM) is perhaps the most prevalent doctrine. See Moriguti (1997) for an extensive examination of TQM for software development.

There is a sect of the Total Quality movement called Six Sigma. The Six Sigma paradigm consists of a number of tools and methods as well as changes to business process and business culture. Hendricks and Kelbaugh (1998) reported that Six Sigma is in use at Motorola, Texas Instruments, Eastman Kodak, Allied Signal, and GE.

A good way to manufacture high-quality products is to design in the quality starting at the product conception stage. GE calls the methods in this area Design for Six Sigma (DFSS) (Scobbo, 1998). Designers of manufactured products most commonly use DFSS.

GE Industrial Systems is one of GE's 11 major strategic business units. GE Industrial Systems is primarily a manufacturing business. It started to apply DFSS techniques to the development of information systems in 1998.

FMEA is one of the tools in DFSS. In the 1960's, FMEA became a widely used reliability and safety technique in the aerospace, automotive, electronic, and nuclear industries (Russomanno et al., 1994). See Banerjee (1995) for an insightful look at how teams should use FMEA in software development.

Theory and Research Literature

Yang and Kapur (1997) noted that FMEA typically oversimplifies a system into two binary states, success and failure. They argued that the customer's view includes a time-oriented continuous degradation of the state of the product. They also pointed out that FMEA does not consider variation in performance and failure times. Price and Taylor (1998) noted that FMEA is not conducive to the analysis of multiple simultaneous failures.

The FMEA method is too simplistic to prioritize changes to complex systems without complicated extensions to the method (Vandenbrande, 1998, and Bowles, 1998). Gilchrist (1993) noted that, because FMEA was developed without a formal model, the FMEA method lacks rigor.

Several recent articles proposed changes to the FMEA model. The RPN in FMEA is usually calculated as the product of the severity, occurrence, and detection ratings (McDermott et al., 1996). Vandenbrande (1998) suggested that the RPN be modified to factor in contribution, the extent to which the element contributes to the overall impact. Gilchrist (1993) suggested that FMEA be modified to consider expected costs in prioritizing failures. Luke (1995) proposed that proxies such as software complexity and historical failure rate be substituted for occurrence.

Bowles (1998) described how failure modes that have identical consequences can be grouped under a single identifying Fault (equivalent) Identifier Number (FIN). The use of FIN's can reduce redundancy and inconsistency in FMEA.

Price et al. (1995) and Pugh and Snooke (1996) discussed a qualitative knowledge-based system for FMEA. Price (1996) extended their work to include a facility for iterative analysis of electrical systems. Recent research has included the use of a qualitative expert system to facilitate FMEA for multiple failures in electrical circuit designs (Price and Taylor, 1998).

Montgomery and Marko (1997) presented their research on quantitative FMEA automation. Montgomery et al. (1996) described a pilot program to link tools for qualitative and quantitative FMEA automation in the automotive industry.

Peláez and Bowles (1996) presented the use of fuzzy cognitive maps for FMEA. A cognitive map shows concepts as nodes in a directed graph with arrows that describe the relations between the concepts. A fuzzy cognitive map additionally describes the degree of relationship between concepts.

Summary of Knowns and Unknowns

Several recent articles proposed changes to the FMEA model. See Vandenbrande (1998), Gilchrist (1993), and Luke (1995).

Most of the recent FMEA research has applied various artificial intelligence technologies. The applications of artificial intelligence to FMEA fall into three main categories: qualitative, quantitative, and fuzzy. Montgomery et al. (1996) noted that qualitative simulation is used in the early (architectural) stages of design whereas quantitative simulation is used later.

Peláez and Bowles (1996) noted that effective FMEA automation has been an elusive goal for some time. The scope of meaningful FMEA automation has been limited to specific proprietary or academic application domains where substantial time and effort have been invested. Commercially available FMEA software packages do little more than reduce clerical effort. See Russomanno et al. (1994) and Montgomery et al. (1996). There has been no published research on the usability of FMEA software.

Banerjee (1995, p. 222) stated that FMEA requires teamwork and the pooled knowledge of all team members. This suggests the need to investigate groupware. However, Chen et al. (1998) noted that information visualization deficiencies tend to limit the usability of electronic meeting groupware due to information overload and vocabulary inconsistencies. There has been nothing published on a groupware approach to FMEA automation.

There is very little information published on the usability of FMEA for information systems. Although Banerjee (1995), Moriguti (1997, pp. 70-78), and Luke (1995) described the use of FMEA in software development, almost all FMEA research has been directed toward manufactured products rather than information systems. Binder (1997) argued that Six Sigma tools developed for manufacturing are not suitable for software.

Significance

McDermott et al. (1996, p. 28) noted that the FMEA worksheet is easiest to work with on 11 inch by 17 inch paper. The FMEA worksheet, when computerized, does not fit well on a computer screen; much scrolling is necessary. The work of Plaisant et al. (1997) demonstrated the need to avoid scrolling for usability.

This dissertation will significantly advance knowledge and improve professional practice by providing a usable and useful alternative to FMEA for information systems.

3. Barriers and Issues

Montgomery et al. (1996) noted that entries in the FMEA worksheet are voluminous and, as a result, very terse. They pointed out that these numerous brief entries make FMEA reports difficult to produce, difficult to understand, and difficult to maintain.

Several authors have reported problems in using the FMEA process. Price et al. (1995, p. 90) and Peláez and Bowles (1996, p. 180) have reported on the difficulties in preparing the FMEA. Bull et al. (1996) stated that the length of time involved in FMEA analysis is prohibitive. They pointed out that a manual FMEA is an unwieldy document. Montgomery et al. (1996) noted that the traditional brainstorming process for FMEA is tedious, time-consuming, and error-prone. They also pointed out that FMEA often suffers from inconsistency and incompleteness. Sincell et al. (1998, p. 54) noted that the FMEA process is laborious and sometimes opaque. Russomanno et al. (1994) stated that FMEA users suffer from poor understanding of FMEA and inadequate FMEA training. They also noted that FMEA expertise tends to be concentrated in the hands of relatively few specialists.

This dissertation will require an interdisciplinary synthesis of concepts from quality management, information systems development, problem solving, and usability engineering. It will require integration of leading-edge practices in industry with the latest research from academia. This dissertation will require difficult trade-offs to maximize the usability, power, and rigor of FAM.

4. Approach

Here is a sequential list of the major steps to complete this dissertation.

1. Create the first draft of the FAM in Excel. FAM will probably list up to five or seven top failures or potential failures as column headings. Each row will likely show an alternative solution that would address one or more failures. The cell at the intersection of a failure and an alternative solution could hold a number indicating the estimated correlation between the alternative solution and the failure. The FAM might also include a row for the expected cost of the failures and possibly a column for the estimated cost of the alternative solutions. The FAM will probably include a calculated priority column that might consider the expected cost for each failure affected by the alternative solution and the estimated cost of the solution. The priority column would be used to help select among the alternative solutions. There may also be a calculated coverage row that totals the correlations for each failure.

2. Take an information systems FMEA and re-enter it into FAM.

3. Create the second draft of the FAM, complete with the information systems data from the FMEA.

4. Test FAM at GE Industrial Systems and validate usability and usefulness. The usability and usefulness evaluation will include observation of test subjects using the FAM and a survey of the test subjects.

5. If necessary, modify FAM and test the updated FAM, again validating usability and usefulness.

6. Accept or reject the dissertation's hypothesis.

5. Resources

The author leads the GE Industrial Systems team responsible for Speedi-WIN™. Speedi-WIN is the quotation and order entry tool for thousands of GE Industrial Systems sales engineers and customers. More than twenty programmers and analysts work on the Speedi-WIN team. Speedi-WIN is a personal computer-based system consisting of millions of lines of code developed over almost two decades in Visual Basic, Clipper, C, and COBOL.

Each year, the Speedi-WIN team completes dozens of projects packaged into two or more releases.

Team members on several of these projects will test the FAM.

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