

A Tool for Ensuring Consistent Occurrence Ranking in FMEAs

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ABSTRACT

In the automotive industry, FMEA occurrence ranking is made to a standard such as SAE J1739. The SAE J1739 standard, as does other comparative standards, provides numerical probability criteria to aid ranking. Problems arise when the part or system under analysis is new, and there is no field data to estimate the probability of failure occurrence. Attempts to use qualitative verbal criteria or to go by the “feel” often result in inconsistency or large variability across and within FMEA projects. This paper presents a case study in which this problem was solved by the development of a tool that enables consistent – and efficient – FMEA occurrence rankings. The tool takes input from the user in the form of multiple-choice answers and calculates the final solution. The focus of this paper is the process and thinking behind the creation of this methodology – rather than justification of the tool itself – in the hopes that other automotive enterprises tackling the same issue may find ways to develop their own solutions.

INTRODUCTION

The failure mode and effects analysis (FMEA) is a qualitative risk analysis [7, 8]. As is the case for all analyses of this nature, the FMEA is sensitive to human subjectivity [7]. When developing an FMEA for a complex system, it is a common practice to first analyze the system as a whole then break it into various key parts for which more detailed FMEAs are developed [8]. This is often necessary in order to reach the level of detail that is required. An FMEA project, therefore, can have multiple FMEA teams undertaking analyses of subassemblies and components simultaneously.

When more than one FMEA project is running at the same time, it can become a challenge to maintain consistency across project teams. This makes it mandatory to have a set of analysis standards and guidelines available to all teams. In the American automotive industry, SAE J1739 is the default standard for FMEAs. This is the standard according to which the AIAG FMEA workbook is written [4]. Many automotive companies develop their own internal FMEA guidelines based on these external standards. For example, at

TRW Automotive's Steering & Suspension, the severity (S), occurrence (O), and detection (D) ranking criteria provided by the J1739 are translated into the specifics of TRW's products. Having key elements of FMEA, such as the S-O-D rankings, clearly defined and interpreted for specific product lines upfront helps streamline team discussion and promotes rapid consensus.

One element of an FMEA that can cause difficulty is occurrence ranking, especially if the product under analysis is new. The probability of failure occurrence could be estimated using field data – or laboratory data if available in substantial amount. When the product under analysis is very new, however, neither may be available. Lacking field or extensive laboratory test data, it is difficult to equate occurrence probability to that provided by an external guideline, such as J1739. TRW Steering & Suspension was not immune to this problem as it is engaged in research and development of new products. To counter this problem, qualitative verbal criteria were developed to define each of the ten occurrence levels. Even so, occurrence ranking showed more inconsistency and wider range of disagreement among FMEA participants than the project teams found acceptable.

This paper is a real-life case study that presents how one TRW group coped with this challenge. It is presented in the hopes that it will provide useful insight to other FMEA analysts in the automotive community facing similar challenges.

PROBLEM DEFINITION

The scope of this case study is limited to design failure modes and effects analysis (DFMEA). The same principles used to solve the problem, however, should work just as well in other types of FMEA, for example, process failure modes and effects analysis (PFMEA).

SAE J1739

The SAE J1739 standard, in Section 3.2.15, defines probability of occurrence for DFMEA as

“... the likelihood that a specific cause/mechanism will occur during the design life. The likelihood of occurrence ranking number has a relative meaning rather than an absolute value.” [8]

Further, in Section 3.2.15 the standard states

“Estimate the likelihood of occurrence of potential failure cause/mechanism on a ‘1’ to ‘10’ scale. In determining this estimate, questions such as the following should be considered . . . ” [8]

In the same section, the standard goes on to list the following factors as being key for occurrence ranking determination: service history, field experience, similarity of product to those in the field, degrees of product

changes from previous applications and/or operating environment, existence of engineering analysis and preventive controls [8].

Finally, the standard advocates (also in Section 3.2.15) that

“A consistent occurrence ranking system should be used to ensure continuity. The occurrence ranking number is a relative rating within the scope of the FMEA and may not reflect the actual likelihood of occurrence.” [8]

The standard, in Section 3.2.15.1, provides the guideline for ranking occurrence probability as shown in Table 1 below.

Probability of Failure	Likely Failure Rates over Design Life	Ranking
Very High: Persistent failures	≥ 100 per thousand vehicles/items	10
	50 per thousand vehicles/items	9
High: Frequent failures	20 per thousand vehicles/items	8
	10 per thousand vehicles/items	7
Moderate: Occasional failures	5 per thousand vehicles/items	6
	2 per thousand vehicles/items	5
	1 per thousand vehicles/items	4
Low: Relatively few failures	0.5 per thousand vehicles/items	3
	0.1 per thousand vehicles/items	2
Remote: Failure is unlikely	≤ 0.01 per thousand vehicles/items	1

Table 1: Suggested DFMEA Occurrence Evaluation Criteria adapted from Table 2 in J1739

As stated earlier, however, reasonably accurate numerical probability estimates are seldom available for parts or features that have had little field usage. For that reason, occurrence ranking criteria such as shown in Table 1 do not work well on a new product that is in early stage of development. To cope with this challenge, the TRW Steering group first developed verbal criteria associated with each occurrence rank. For example,

- Occurrence ranking 10 is defined as “History of many failures with previous similar design and used in environment extremely harsh or unknown OR New concepts with no past design experience and no analytical methods available to evaluate”
- Occurrence ranking 5 is defined as “Part/assembly similar to previous design with only fair reliability

record used in a slightly harsher environment OR Application of existing concept and materials, which have had good field results, to new design”

- Occurrence ranking 1 is defined as “Carry-over part/assembly with good reliability record used in current environment OR Replication of existing concept, design, and materials that have had broad field experience rated good.”

For the sake of brevity, the remainder of the verbal criteria is not shown. The basic idea, however, should be clear: The more similar the part or feature is to an already proven-out predecessor, the lower the probability of failure occurrence should be. This is in line with the intent of J1739 as referenced earlier.

PROBLEM

Despite the effort to define criteria for each occurrence level, inconsistencies and variability were still observed in FMEA work – across, and sometimes within, projects. In particular, the FMEAs that were scrutinized not just by TRW players but its suppliers and customers became the most difficult to manage. Not only were differences among these three parties noted, depending on the day of the week or time of the day, variability within groups was also observed.

What it amounts to is that there is always ambiguity or uncertainty in even the simplest of communications. Any verbal criteria are subject to more than one interpretation; it simply comes with the territory [6]. Added to that, FMEA participants may not necessarily be native speakers of the same language. This was definitely the case for the FMEA project that prompted the development of the methodology introduced in this paper. The project involved several key suppliers from around the world. The degree of fuzziness that is always present in one language can be amplified when it is translated into other languages.

Improvement of the verbiage in the work instructions was agreed upon and was expected to improve the situation – to some extent. In addition to this effort, however, the team felt that it needed a better methodology to more consistently rank FMEA occurrence.

DEVELOPMENT OF A SOLUTION

In this section, steps taken by the team to develop a solution are explored. The main intent here, again, is to present the thought process by which the new methodology was created – rather than the validity of the end product. The tool works for TRW Steering team. It may work for other automotive enterprises with customization – it is up to individual readers to decide. The focus here is to offer insight in the hopes that it will help those tackling the same problem find ways to develop their own solutions.

BASIC PREMISES

Design FMEA (DFMEA) occurrence ranking is about failure probability estimation. What, then, are the factors that affect such a probability?

A part or feature that is either same or very similar to one already proven out in the field probably is expected to have a lower failure probability than a brand new design with little field experience. Field experience implies existence of reliability data. The longer the part is in the field, the more data accumulates.

Product reliability information can also come from laboratory testing and engineering analyses. A product that is in early stage of development naturally does not

have as much information available for it as a product that is further along in its development cycle.

In the context of DFMEA occurrence ranking – in which ranks are scaled from 1 to 10 – there is little room for argument that a part or feature having a high degree of similarity to one that has performed successfully in the field for years is expected to fail far less frequently than a new design for which very little prove-out data exists. The FMEA team is likely to rate the former as “low occurrence,” approaching or at 1; whereas the latter case would be rated as “high occurrence,” approaching or at 10. Not only is this intuitive but is also the essence of the J1739 guideline, as provided under Section 3.2.15 of the standard [8].

STARTING POINT

The basic premises explored in the previous section lead to the following three statements:

1. Every part or feature has a predecessor
2. The probability of failure occurrence is affected by the degree of similarity of the part or feature to its predecessor
3. Occurrence ranking is also affected by the amount of reliability data that exists on both the part or feature and its predecessor

Statements 1 and 2 directly relate to Tatsuhiko Yoshimura's GD³ philosophy [9]. One of the key elements of GD³ is that a design predecessor is the starting and anchor point of product robustness assessment. If nothing changes from the predecessor to the current design, then the failure rate of the current design should be the same as that of its predecessor! On the other hand, any differences between the two can potentially affect probability of part failure occurrence. Goel and Itabashi-Campbell also explored reliability assessment methods from the same line of thinking [3].

Statements 2 and 3 can be viewed as directly equating to “reliability” and “confidence,” respectively, in conventional reliability engineering language. Information gained in statement 2 enables evaluation of reliability level whereas statement 3 implies adequateness of data points to gain confidence in the estimate.

Statement 2 warrants further exploration. Changes from predecessor to current designs are not contained just in physical part configuration. Differences between the two can be in any or all of the following areas:

- a. Design
- b. Application
- c. Interfaces with external systems
- d. Environment
- e. Unintended use