Proceedings of the 9th Annual World Conference of the
Society for Industrial and Systems Engineering,
2020 SISE Virtual Conference
September 17-18, 2020

A New Approach to Represent the Risk and Its Temporal Course in a FMEA

A Aichele, A Lorenzoni, and O Mannuß

Fraunhofer Institute for Manufacturing Engineering and Automation (IPA)
Stuttgart, Germany

Corresponding author's Email: andreas.aichele@ipa.fraunhofer.de

Author Note: Andreas Aichele is a research associate at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in the Sustainable Production and Quality Department. He works in the field of technical risk analysis and process optimization with a focus on quality issues. As FMEA moderator and Six Sigma Black Belt he is active in both areas, in research as well as in operational application.

Abstract: Due to global competition and the resulting strong competitive pressure, undesirable developments and quality problems are severely punished and should therefore be avoided. In order to minimize such risks and to be able to survive in competition, risk management is therefore practised. Some of these risks relate to the technical risks of products. These risks can be examined with the help of Failure Mode and Effect Analysis (FMEA). The results of this investigation must be communicated to superiors and those responsible, as they may have to make necessary decisions on how to deal with the risks further. In addition to the presentation of the risks at the time of analysis, it is also important to describe the further treatment of the risks and their further development. For this reason, the paper examines the different possibilities of risk representation of FMEA and shows a new approach for an improved representation of the chronological course of risks.

Keywords: Failure Mode and Effect Analysis, FMEA

1. Introduction

An essential characteristic of successful companies in order to survive in today's global competition is speed in the market (Schober & Lindow, 2012). This means for companies to react as quickly as possible to new trends and situations (Kamiske & Brauer, 2011). The consequences of these conditions for companies' products are ever shorter and faster product life cycles with ever-faster development times (Specht, Beckmann, & Amelingmeyer, 2002). Parallel to this, the complexity of products is increasing, as more functions are integrated and the number of variants is growing explosively due to the increasing individualization of products (Eversheim & Schuh, 2005; Wiendahl, 2014). Shorter development times and increasing complexity lead to an increased risk of erroneous developments and quality problems (Zentis, 2011). In global competition, however, undesirable developments and quality problems in particular are severely punished and should therefore be avoided wherever possible (Kamiske & Brauer, 2011). In order to minimize risks, risk management is therefore carried out to meet the requirements of global competition.

2. Research Issue

The risks can occur in various areas, such as deadline risks, political risks or technical risks. A widely used method to support the management of technical risks is Failure Mode and Effects Analysis (FMEA) (Hans-Georg Köglmayr, Andreas Jilinski, Veronika Pauer, Oliver Saur, & Andrea Ströhle, 2011). It is a team-oriented, systematic and qualitative method of analysis. The method addresses following objectives (Automotive Industry Action Group, 2019):

- Assessment of potential technical risks due to a defect in the product itself or in the manufacturing process.
- Investigation of causes and consequences of such errors.
- Documentation of current and future planned actions for risk mitigation.

The broad application of the method in the (automotive) industry is based on the naming or requirement in standards and guidelines (International Automotive Task Force & Verband der Automobilindustrie, 2016; International Organization for Standardization, 2015). Another point is its standardized description (Automotive Industry Action Group, 2019). As in risk management in general, it is also important for FMEA to communicate the results of the risk management process (Automotive

Industry Action Group, 2019; Verband der Automobilindustrie e.V. [VDA], 2003-2007). An essential part in the communication of risks is the representation of the risk assessment, which is the subject of this paper.

The challenge in communication, and thus also in the presentation of results of the risk management process, lies in the truthful, accurate and comprehensible transmission of the relevant information (International Organization for Standardization, 2018). Due to the challenges in communication and the special features of FMEA (a large number of risks are considered), the following requirements result for the representation of the risk assessment of an FMEA:

- It represents the risk, consisting of the risk level and risk relevance of the individual risks.
- It summarizes in a compact overview the large number of risks considered.
- It shows a change in risk development over time, which results from the treatment of risks already carried out in the FMEA.

3. State of the Art

In the section below a representation and explanation follows why existing visualizations of FMEA-results only insufficiently meet the requirements mentioned above and why a new form of representation is necessary. However, there is a short introduction into the FMEA method according to Automotive Industry Action Group (2019) in advance to provide the necessary background for a better understanding of the paper.

As mentioned above, FMEA is a systematic analysis method for managing technical risks of products or manufacturing processes. The method includes seven steps. Steps 5 and 6 are important for the presentation of the risk assessment, because in these two steps you assess the risk initially and after potential optimization actions. The risk for each potential error is assessed with three factors (significance S, probability of occurrence O and probability of detection D), each with a rating of one to ten. One means a low risk, ten a high risk. If the evaluation of the factors results in a significantly greater risk, you have to plan optimization actions. Based on these optimization actions, which you implement at various points in the future, you evaluate the individual errors again with regard to the risk and replace the previous evaluation. You repeat the optimization until the risk of each error has reached an acceptable level.

There are two approaches to express the risk of a single potential error simply by one value instead of the three factors S, O and D: The Risk Priority Number (RPN) and the Action Priority (AP). The RPN is the multiplication of the three original ratings S, O, and D of the error. The RPN can take a value from 1 to 1,000 due to the possible rating of 1 to 10 of each factor. The disadvantage of this information compression from three to one factor is a less differentiated view of the risk assessment, because all three factors are equally weighted. (Automotive Industry Action Group, 2019)

Action priority was developed as an alternative to the RPN. With this approach, a scheme is initially defined before the FMEA is performed which combination of S, O and D results in a "high", "medium" or "low" priority. This classification should support the further planning of optimization measures and by defining the scheme, an individual consideration can be given to the weighting of the single factors S, O or D. By reducing the 1,000 possible combinations of S, O and D (10x10x10) to the three priorities mentioned above, however, no differentiated risk assessment is possible and the requirement to include the presentation of "risk level and risk relevance" as set out above cannot be met. Therefore, the AP, like the RPN, is not suitable for the presentation of the risk assessment of an FMEA.

An existing representation option for the origin ratings S, O and E are the so-called risk matrices. A matrix of two of the three factors S, O and E is constructed and you enter the quantity of errors with this combination according to the combination in the matrix. The usual realization in Software[1] offers the possibility to display two different action states of the risk evaluation (one before the “/” and one behind). For example, you can select the initial status of actions and the last status of actions as data basis. This possibility represents in a certain way a temporal change, but neither the choice of a concrete date is possible, nor you cannot represent more than two action states at the same time. This representation option is therefore only conditionally suitable with regard to represent the time course. As additional disadvantage, you can only view two factors simultaneously.

[1] For example, in the Software APIS IQ-FMEA

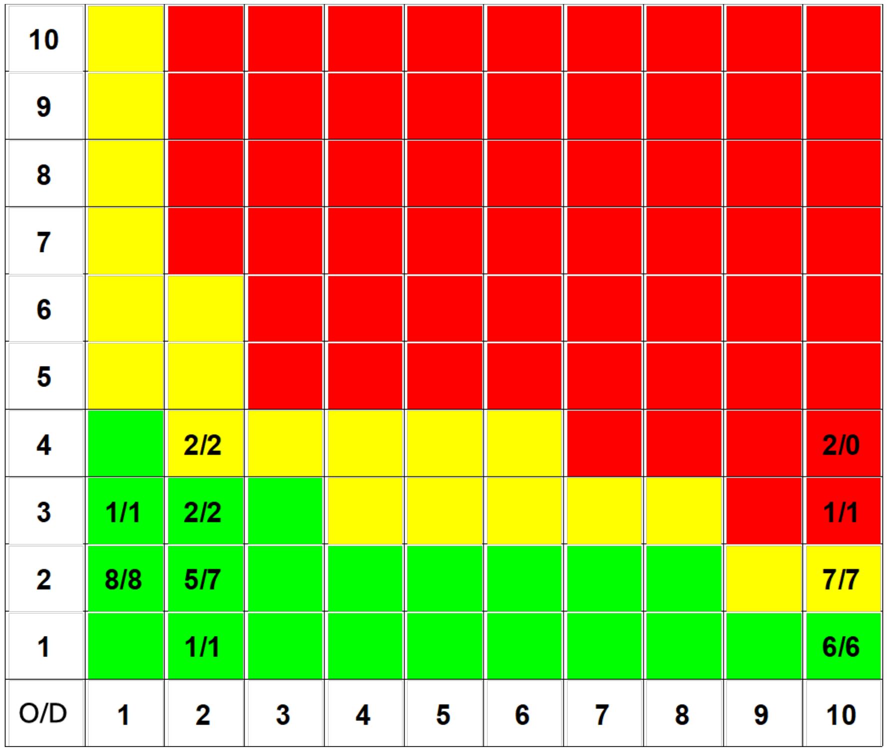

Figure 1. Risk matrix depending on detection (D) and occurrence (O)

Based on the approaches presented, it is evident that the previous representation of the risk assessment of the FMEA is only suitable to a limited extent compared to the requirements mentioned above. Particularly the existing approaches do not address the points "change in risk development over time" and "mapping of risk level and risk relevance". The following chapter therefore presents an approach that also addresses these requirements.

4. Results

The approach presented here is based on the OxD-Matrix presented in the previous chapter (Figure 1). Due to the requirements mentioned above (see chapter 2) and the disadvantages of the existing approaches (see chapter 3), two essential points have to be developed:

1. The representation of the temporal course
2. The consideration of all three evaluation factors

These two points are elaborated in the following subchapters.

4.1 Representation of the temporal course

Figure 1 has the disadvantage of being able to represent only two points in time of the risk assessment. Implementing a separate diagram for each point in time to represent the risk can compensate this disadvantage. Standardized points in time in the context of a product development project would be for example the milestones ‘concept draft’, ‘design freeze’, ‘prototype construction’ and ‘tests’. This approach makes it possible to show the chronological course of the risk assessment. In other project types, other milestones are available and you can use them as well.

ISBN: 97819384961-9-6

4.2 Integration of all three evaluation factors

As explained in the previous chapter, only two of the three risk assessments S, O and D can be represented in the approach shown in Figure 1. To supplement the third risk assessment, additional diagrams can be added to the representation analogous to the representation of the time course. This would mean that in a diagram a matrix of two factors, for example O and D, is shown at a point in time for a fixed value of the third factor, in the example the significance S. For each further value of S a separate diagram would have to be provided for each time to illustrate the evaluation of all risk factors. If one would like to represent the risk for each possible S-value from one to ten and the four milestones exemplarily specified in the previous section, a representation of the risk results by 40 diagrams. A clear representation in common formats is thus not possible and it is not possible to speak of a compact overview of the risks. Even if the graphs are reduced by grouping S-values into ranges of values (for example S = 10, 9 → range 1; S = 8, 7, 6, 5 → range 2; S = 4, 3, 2, 1 → range 3), no compact overview is created. Imagine therefore the schematic Figure 2 with the actual size per diagram analogous to Figure 1.

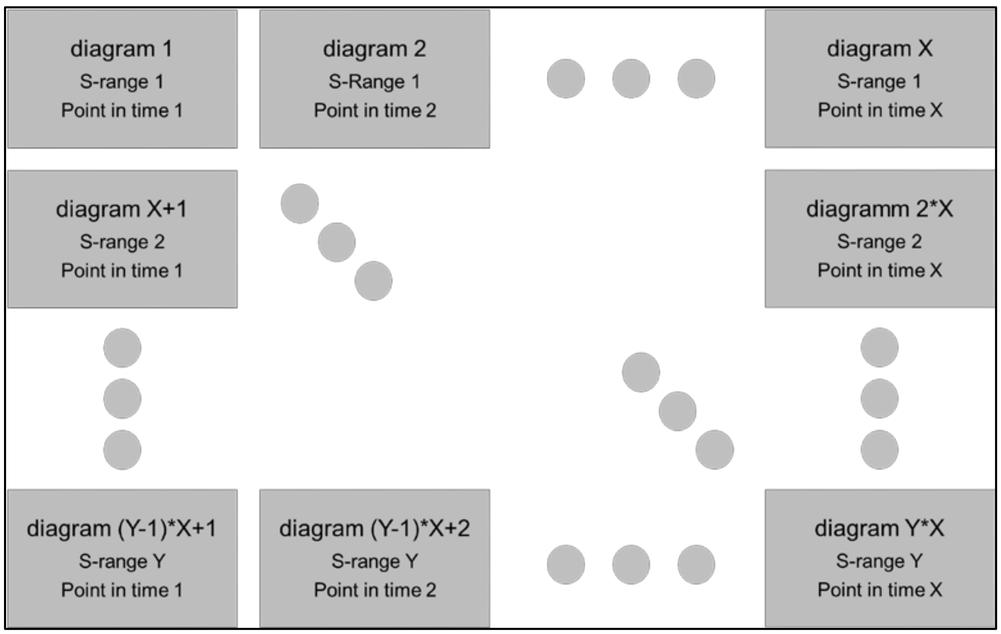

Figure 2. Possible layout of the chart matrix to represent the temporal course (in horizontal direction) and all risk factors (the respective chart contains an OxD matrix for a defined range of S): One row represents one S-range in its temporal course.

Despite the known requirements, for a compact overview the number of diagrams have to be reduced. As mentioned above, one diagram cannot represent the different points in time of the risk assessment. As an alternative, however, it is possible to depict the different S-areas in an OxD matrix at one point in time in one diagram. In order to be able to distinguish the areas from each other, a label with the number of combinations at defined positions must be applied in addition to the different color-coding, which is difficult to coordinate[2]. A legend is very helpful here. Figure 3 includes all mentioned points and shows the complete integration of the three S-ranges in one diagram. As seen, you can integrate this well arranged.

[2] Due to the limited size of the paper, there is no further explanation.

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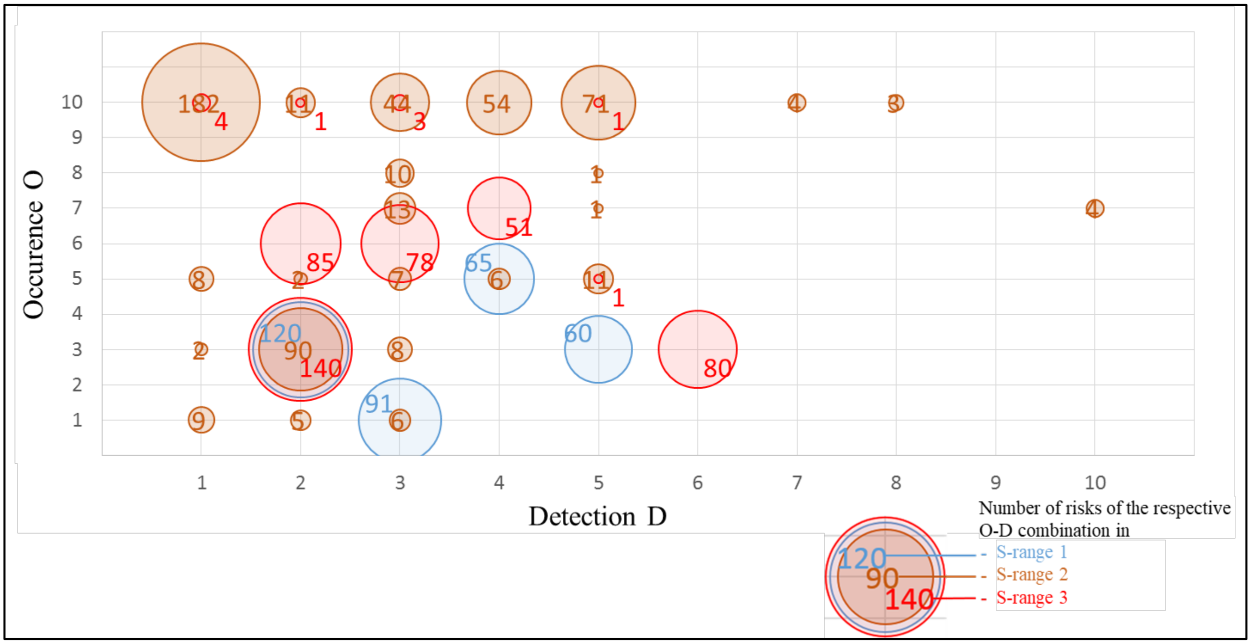

Figure 3. Integration of three different S-ranges in one diagram

4.3 Fusion of the individual representations

For a complete representation of the risk, the results from sections 4.1 and 4.2 must now be combined: Analogous to Figure 2, it is possible to show the chronological course of the risks by arranging the diagrams for different points in time. By integrating the third evaluation factor into one diagram, no further diagrams are necessary and all risk factors are still shown. In order to maintain clarity, however, there is no recommendation for a horizontal arrangement while using the DIN A4 or US letter format[3]. One OxD matrix is readable if it occupies the entire page width in vertical format. When using a maximum of four different points in time, this layout has the additional advantage that all charts fit on one page. Therefore, there is no spreading over several pages of the representation and you can easily survey the result of the risk assessment as Figure 4 shows.

[3] These are the most common German and American paper formats, which differ only slightly in their dimensions.

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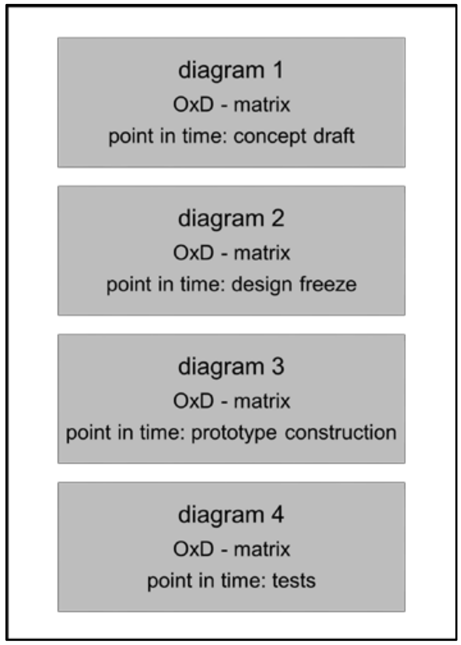

Figure 4. Schematic representation of the result of the risk assessment in DIN A4 / US Letter format

5. Conclusion

With the presented approach it is now possible to represent the risks of an FMEA over the course of time. Both the risk level and the risk relevance are represented, which was also a requirement for the approach to be developed. By using four points in time of the risk assessment, the representation could be limited to one DIN A4 / US letter page. This also meets the requirement for a compact overview. This was confirmed in a use case with 427 considered risks, which could also be represented clearly. Further investigations on the basis of further reference projects must now confirm that with the usual number of examined risks and their evaluations a meaningful and purposeful representation of the risk is also possible.

6. Acknowledgement

The presented approach is based on work supported by the State Ministry for Finance and Economy Baden-Württemberg (Ministerium für Finanzen und Wirtschaft Baden-Württemberg).

The support was granted within the project „FastStorageBW II - Erforschung neuartiger Hochleistungs- und Hochenergiespeicherzellen und deren Fertigungsmethodik für Ihre Herstellung. Vorindustrielle Erprobung und Skalierbarkeit der Technologie für eine spätere Großserienfertigung in Baden-Württemberg."

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