FlowSort-GDSS – A novel group multi-criteria decision support system for sorting problems with application to FMEA

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Article info
Article history:
Available online 23 April 2015

Keywords:
FMEA
Criticality assessment
Flow-Sort-GDSS
MCDM
PROMETHEE

ABSTRACT
Failure mode and effects analysis (FMEA) is a well-known approach for correlating the failure modes of a system to their effects, with the objective of assessing their criticality. The criticality of a failure mode is traditionally established by its risk priority number (RPN), which is the product of the scores assigned to the three risk factors, which are likeness of occurrence, the chance of being undetected and the severity of the effects. Taking a simple “unweighted” product has major shortcomings. One of them is to provide just a number, which does not sort failures modes into priority classes. Moreover, to make the decision more robust, the FMEA is better tackled by multiple decision-makers. Unfortunately, the literature lacks group decision support systems (GDSS) for sorting failures in the field of the FMEA.

In this paper, a novel multi-criteria decision making (MCDM) method named FlowSort-GDSS is proposed to sort the failure modes into priority classes by involving multiple decision-makers. The essence of this method lies in the pair-wise comparison between the failure modes and the reference profiles established by the decision-makers on the risk factors. Finally a case study is presented to illustrate the advantages of this new robust method in sorting failures.

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1. Introduction
The reduction of the non-quality costs is a main concern in all production and service systems because it increases the customer fidelity and reduces the after-sales costs. The FMEA is a long established quality improvement technique that dates back to 1940s. The first step in FMEA is to identify potential or known failure modes of a given system. These modes are then evaluated for their causes and effects, and the final purpose of FMEA is to correct the most critical failure modes. Traditionally, the criticality assessment of the failure modes in FMEA is carried out by calculating their risk priority numbers (or RPNs), which are given by the product of the likeness of occurrence (O), the severity of the effects (S), and the chance of being undetected (D), each one measured on a 1–10 scale, as follows:

\[ RPN = O \times S \times D \] (1)

Based on their RPN ranking, it is decided whether an improvement action needs to be implemented in order to reduce the RPN. The issue is to find the threshold that triggers this improvement action. This problem is therefore better solved with a sorting technique, where failures are sorted into predefined priority classes.

To the best of our knowledge, the most recent review on FMEA has been conducted by Liu, Liu, and Liu (2013) who have summarised a number of major shortcomings in the traditional FMEA approach. They have reviewed a number of academic journal articles published between 1992 and 2012 that aimed at overcoming these shortcomings. It is worth to remark that more than a half of the reviewed paper aim to overcome the following shortcomings:

(a) The relative importance of O, S and D is not taken into account.
(b) Different sets of the three risk factors can give the same RPN without considering their very different implications.
(c) The three risk factors are difficult to be precisely evaluated.

These shortcomings have been solved with multi-criteria decision making methods (see Section 2). However, these methods provide only a rank for the failure but do not sort them into priority classes. Having an ordered class of importance of failures allows the managers to focus in priority on all the elements of this class and then to tackle the elements of the next class. This gives a clear indication on which failures to correct first.
Moreover, several experts are generally involved in the FMEA. For example, engineers, process managers, product managers, quality inspectors and inline operators are called to design and monitor the quality of products and processes. As a consequence, the sorting method introduces ad hoc approach for the FMEA and accommodates multiple decision-makers.

This paper proposes a group decision support system, named FlowSort-GDSS, for sorting the failure modes into priority classes. This method belongs to the PROMETHEE family methods and therefore inherits their properties. Particularly to this method is that the decision-makers are asked to provide the reference profiles on the risk factors to define the priority classes according to their experiences and skills. The essence of this method lies in the pair-wise comparison between the failure modes and the reference profiles, either limiting or central profiles, which provides their global net flow, so named according with the PROMETHEE notation. The structure of this paper is as follows: Section 2 reviews the developments of the FMEA. Section 3 proposes the new method termed FlowSort-GDSS. Section 4 describes the application of FlowSort-GDSS for the FMEA in a large company operating in the blow moulding field. Finally, Section 5 concludes the paper with some future research suggestions.

2. Literature review

The FMEA approaches introduced in the last decades can be divided into three categories according to their failure mode prioritization methods: MCDM, mathematical programming, and integrated approaches.

With regard to MCDM methods, Braglia (2000) introduced the multi attribute failure mode analysis (MAFMA), which uses the analytic hierarchy process (AHP) to calculate weights for the risk factors. The same technique was also used later in Carmignani (2009), Zammor and Gabbirelli (2012) further decomposed the occurrence, severity and detectability into subcriteria and used analytic network process (ANP) to evaluate their weights. In addition to the multiplication reported in Eq. (1), other aggregation techniques have also been proposed, e.g. decision making trial and evaluation laboratory – DEMATEL (Seyed-Hosseini, Safaei, & Asgharpour, 2006), grey theory (Chang, Liu, & Wei, 2001) and evidence theory (Chin, Wang, Poon, & Yang, 2009a, 2009b). Liu et al. (2013) reported a trend to incorporate MCDM methods with fuzzy logic in order to overcome the shortcoming (c) mentioned in Section 1. For a recent review on fuzzy MCDM techniques, reader may refer to Mardani, Jusoh, and Zavadskas (2015). Some researchers have in fact merged multi-criteria techniques and fuzzy logic to accommodate the imprecision of the evaluations: fuzzy technique for order preference by similarity to ideal solution (TOPSIS) (Braglia, Frosolini, & Montanari, 2003; Hadi-Vencheh & Aghjani, 2013; Liu et al., 2011; Liu, Liu, Liu, & Mao, 2012; Vahdani, Salimi, & Charkhchian, 2015); VIKOR (Vizekriterjumska optimizacija i Kompromisno Resenje) with fuzzy logic (Liu et al., 2012); fuzzy AHP (Hu, Hsu, Kuo, & Wu, 2009; Kultu & Ekmeçioğlu, 2012); fuzzy logic with grey theory (Chang, Wei, & Lee, 1999); or simply applied fuzzy logic on the risk factors (Petrić et al., 2014). Mandal and Maiti (2014) adopted the similarity measure of fuzzy numbers in order to overcome the drawback of standard de-fuzzification approaches. However, these approaches neither support a group decision nor solve a sorting problem. A group-decision FMEA approach was proposed by Liu, You, Fan, and Lin (2014) where grey relational projection and D numbers representing the uncertain approach was proposed by Liu, You, Fan, and Lin (2014) where grey relational projection and D numbers representing the uncertain

3. FlowSort-GDSS

3.1. Introduction

FlowSort-GDSS is an extension of the FlowSort method, when several decision-makers are involved in the sorting decision
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