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Fuzzy FMEA application to improve purchasing process in a public hospital

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ABSTRACT

Failure mode and effects analysis (FMEA) is one of the well-known techniques of quality management that is used for continuous improvements in product or process designs. While applying this technique, determining the risk priority numbers, which indicate the levels of risks associated with potential problems, is of prime importance for the success of application. These numbers are generally attained from past experience and engineering judgments, and this way of risk assessment sometimes leads to inaccuracies and inconsistencies during priority numbering. Fuzzy logic approach is preferable in order to remove these deficiencies in assigning the risk priority numbers. In this study, a fuzzy-based FMEA is to be applied first time to improve the purchasing process of a public hospital. Results indicate that the application of fuzzy FMEA method can solve the problems that have arisen from conventional FMEA, and can efficiently discover the potential failure modes and effects. It can also provide the stability of process assurance.

1. Introduction

Today's hard economical conditions, in which health companies operate, force the managers of these companies to use various scientific methods and new technological equipments on the way to attain more productive usage of their resources. Particularly the situations such as increasing costs, limited budget, and severe competition require development of planning and supervisory activities. Among health companies the public hospitals are the foundations which are directly affected from these circumstances.

Public hospitals are also the organizations who work with limited resources. The allocative inefficiency is a fundamental flaw in the public hospitals and these inefficiencies drain the limited public resources allotted for health care [1]. The more rationally they manage their supplies, the less negative outcomes of deficiencies or corruptions exist. Extensive usage of medical technologies requires considerable amounts of resources to be consumed at temperate levels and where they are needed. It is clear that if equipment/material purchases are realized without making an evaluation of requirements and getting cooperation of the hospital management, then the capacities and the qualities of these purchased items could be so far away from meeting the hospitals real needs [2]. That is why the purchasing process is very important in hospitals and should be improved continuously.

Process improvement plays a key role in business process management for every organization as well as for health organizations. It is a series of actions taken to identify, analyze and improve existing processes within an organization to meet new goals and objectives. These actions often follow a specific methodology or strategy to create successful results.

Understanding processes so that they can be improved by means of a systematic approach requires the knowledge of a simple kit of tools or techniques. The effective use of these tools and techniques requires their application by the people who actually work on the processes, and their commitment to this will only be possible if they are assured that management cares about improving quality. Managers must show they are committed by providing the training and implementation support necessary.

The tools and techniques most commonly used in process improvement are: DRIVE (define, review, identity, verify, execute), process mapping, process flowcharting, force field analysis, cause and effect diagrams, pareto analysis, brainstorming charting, matrix analysis, spc, etc. Failure mode and effect analysis (FMEA) is one of these techniques. In the following sections, the FMEA based on fuzzy approach is to be applied first in a public hospital to improve its purchasing process. The paper is organized in such a way that FMEA and fuzzy FMEA is introduced in Sections 2 and 3, literature review is given in Section 4, purchasing process in hospitals is discussed in Section 5, and the fuzzy FMEA application is given thoroughly in Section 6. The paper ends with concluding remarks.

2. Failure mode and effect analysis (FMEA)

FMEA is an analytical technique that combines the technology and experience of people in identifying foreseeable failure modes

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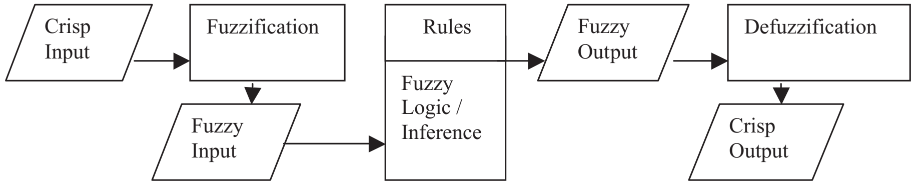

Fig. 1. Fuzzy logic process.

of a product or process and planning for its elimination [3]. It is widely used in manufacturing industries in various phases of the product life cycle and is now increasingly finding use in the service industry.

Traditional FMEA uses a risk priority number (RPN) to evaluate the risk level of a component or process. The RPN is obtained by finding the multiplication of three factors, which are the probability/occurrence of the failure (O), the severity of the failure (S) and the probability of not detecting the failure (D). Representing this mathematically will give:

$$\mathrm{RPN} = O \times S \times D$$

Traditional FMEA uses five scales and scores of 1–10, to measure the probability of occurrence, severity and the probability of not detection.

In traditional FMEA, the RPN ranking system is used to evaluate the risk level of failures, to rank failures, and to prioritize actions. This approach is simple but it suffers from several weaknesses. The traditional FMEA has been criticized to have a number of drawbacks such as follows:

(1) The assumption that the RPN elements are equally weighted leads to over simplification [4]. It neglects the relative importance among O, S and D. The three factors are assumed to have the same importance. This may not be the case when considering a practical application of the FMEA process [5].
(2) The RPN elements have many duplicate numbers [4]. The method that the traditional FMEA employs to achieve a risk ranking is critically debated. The purpose of ranking risk in order of importance is to assign the limited resources to the most serious risk items. Various sets of O, S and D may produce an identical value of RPN; however, the risk implication may be totally different. For example, consider two different events having values of 3, 5, 2 and 2, 3, 5 for O, S and D, respectively. Both these events will have a total RPN of 12 ($\mathrm{RPN}_1 = 3 \times 5 \times 2 = 30$ and $\mathrm{RPN}_2 = 2 \times 3 \times 5 = 30$), however, the risk implications of these two events may not necessarily be the same. This could entail a waste of resources and time or in some cases a high-risk event going unnoticed [5].
(3) The RPN scale itself has some non-intuitive statistical properties. It is derived from only three factors mainly in terms of safety; and the conventional RPN method has not considered indirect relations between components [4].

When conducting an FMEA for safety assessment purposes, precision should not be forced where data is unreliable and scarce [5]. Hence, to ask an analyst or an expert to assign scores ranging from 1 to 10 (as done in the RPN method) for the different factors considered would produce a false and unrealistic impression. Though this simplifies the computation, converting the probability into another scoring system, and then finding the multiplication of factor scores are believed to cause problems. The relations between the probabilities and the factors are different (linear or nonlinear).

In an attempt to overcome the aforementioned weaknesses associated with the traditional RPN ranking system, we use fuzzy approach in this paper for RPN determination as was given in the following section.

3. Fuzzy approach to FMEA

Fuzzy logic is a form of multi-valued logic derived from fuzzy set theory to deal with reasoning that is approximate rather than precise. The fuzzy logic variables may have a membership value of not only 0 or 1, but a value inclusively between 0 and 1. In fuzzy logic the degree of truth of a statement can range between 0 and 1 and is not constrained to the two truth values {true (1), false (0)} as in classic propositional logic [6]. Thus, the fuzzy logic provides a basis for approximate reasoning, that is, a mode of reasoning which is not exact or very inexact. It offers a more realistic framework for human reasoning than the traditional two-valued logic.

The term “fuzzy logic” emerged as a consequence of the development of the theory of fuzzy sets by Lotfi Zadeh. In 1965, Zadeh proposed fuzzy set theory [7], and later established fuzzy logic based on fuzzy sets. The process of fuzzy logic is given in Fig. 1.

Fuzzy logic has an algorithm that is described in the following steps [8]:

1. Define the linguistic variables and terms (initialization).
2. Construct the membership functions (initialization).
3. Construct the rule base (initialization).
4. Convert crisp input data to fuzzy values using the membership functions (fuzzification).
5. Evaluate the rules in the rule base (inference).
6. Combine the results of each rule (inference).
7. Convert the output data to non-fuzzy values (defuzzification).

Linguistic variables are the input or output variables of the system whose values are words or sentences from a natural language, instead of numerical values. A linguistic variable is generally decomposed into a set of linguistic terms.

Membership functions are used in the fuzzification and defuzzification steps of a fuzzy logic system (FLS), to map the non-fuzzy input values to fuzzy linguistic terms and vice versa. A membership function is used to quantify a linguistic term. There are different forms of membership functions such as triangular, trapezoidal, piecewise linear, Gaussian, or singleton.

Fuzzy logic concept can be expressed mathematically as follows. Let X be a nonempty set. A fuzzy set A in X is characterized by its membership function $\mu_A: X \to [0, 1]$ and $\mu_A(x)$ is interpreted as the degree of membership of element x in fuzzy set A for each $x \in X$. It is clear that A is completely determined by the set of tuples $A = ((u, \mu_A(u))/u \in X)$. Frequently $A(x)$ is used instead of $\mu_A(x)$. The family of all fuzzy sets in X is denoted by $\mathcal{F}(X)$.

If $X = (x_1, \ldots\ldots, x_n)$ is a finite set and A is a fuzzy set in X then the following notation is often used.

$$A = \frac{\mu_1}{x_1} + \ldots\ldots + \frac{\mu_n}{x_n}. \tag{1}$$

where the term μ_i/x_i, $i = 1, \ldots, n$ signifies that μ_i is the grade of membership of x_i in A and the plus sign represents the union.