Universidade do Minho
Escola de Engenharia

Semana da Escola de Engenharia
October 24 - 27, 2011

FUZZY DECISION MAKING IN MAINTENANCE PLANNING

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KEYWORDS
Maintenance planning, maintenance decision making, fuzzy set theory, uncertainty.

ABSTRACT

In maintenance management, decision making assumes a very important dimension. Maintenance systems are commonly feeded with large amounts of data that are quickly processed and almost exists total dependence of historical references and of the quality and experience of experts and maintenance engineers. However, such great availability of data makes the maintenance planning a very difficult process. Sometimes, irrealistic decisions come out from the process. In order to overcome theise difficulties, this study purposes a set of methodological guidelines based on fuzzy theory to be applied in the planning process of maintenance systems, getting optimized and more realistic results.

INTRODUCTION

During the last decade, several models in maintenance planning have been incorporating uncertainty of their parameters by using fuzzy numbers. Al-Najjar and Alsyouf (2003) and Lu and Sy (2009) developed models that support decision making in choosing the most efficient maintenance technique. Nevertheless, most of the current literature on maintenance modeling simply omits the uncertainty that is inherent to real data and maintenance parameters, paying little attention at the time of decision making. This work purposes some guidelines to take account in the maintenance planning process, from the data treatment phase to the instant of chosing of the best maintenance policy.

FUZZY NUMBERS IN MAINTENANCE PLANNING

Classical studies on reliability model the eventual occurrence of a specific event by means of the probability theory and treat failure rates, repair mean times or maintenance costs as crisp numbers. The mean value seems to be the most profitable information about an observed feature. It considers that there is a perfect knowledge about the interdependent relationships in the system and all parameters are constant values. However, such considerations are not reasonable to assume in real (complex) engineering systems. In fact, as the result of the variability inherent to many parameters the results of the models based on crisp values (e.g. mean value or expected average) cannot be taken as representative of the entire spectrum of results. To overcome these limitations, the application of the fuzzy set theory proves to be an interesting approach to be applied in most cases where it is conceptually adequate. Fuzzy numbers are adequate, for instance, to estimate the lifetime of a given equipment. Such information is, in many cases, provided by the manufacturer. In fact, in most cases, statements in plain language constitute the best mode to express the knowledge of a system. However, this information is naturally very inaccurate. Therefore, a realistic estimate is always an approximation. To overcome this shortcoming, Carvalho *et al.* (2010), for example, developed a maintenance policy, where the uncertainty of some costs, probabilities and reliability parameters is not omitted by the model, being represented through fuzzy numbers.

FUZZY DECISION MAKING

Making decisions is undoubtedly one of the most fundamental activities of human beings. Applications of fuzzy sets within the field of decision making have, for the most part, consisted of fuzzifications of the classical theories of decision making. While decision making under conditions of risk have been modelled by probabilistic decision theories and game theories, fuzzy decision theories attempt to deal with vagueness and nonspecificity inherent in human formulation of preferences, constraints and goals. That is, when probabilities of the outcomes in a maintenance model are not known, or may not even be relevant, and outcomes for each action are characterized only approximately, the decisions are made under *uncertainty*. This is the prime domain for fuzzy decision making and decision making under uncertainty is perhaps the most important category of decision making problems. In the first paper on fuzzy decision making (Bellman and Zadeh 1970) it is proposed a fuzzy model for decision making in which relevant goals and constraints are expressed in terms of fuzzy sets and a decision is determined by an appropriate aggregation of these fuzzy sets. A decision situation in this model is characterized by the following components:

- a set A of possible actions;
- a set of goals G_i ($i \in \mathrm{N}_n$), each of which is expressed in terms of a fuzzy set defined on A;
- a set of constrains C_j ($j \in \mathrm{N}_m$), each of which is expressed in terms of a fuzzy set defined on A.

In maintenance planning, an example of possible action can be the instant to carry out the preventive maintenance, of a goal can be the cost minimization and of a constraint the availability being above of certain value. Given a decision situation characterized by fuzzy sets A, G_i ($i \in \mathrm{N}_n$) and C_j ($j \in \mathrm{N}_m$), a *fuzzy decision*, D, is conceived as a fuzzy set on A that simultaneously satisfies the given goals G_i and constraints C_j. That is, for all $a \in A$,

$$D(a) = \min\left[\inf_{i \in N_n} G_i(a), \inf_{j \in N_m} C_j(a)\right] \quad (1)$$

Once a fuzzy decision has been reached, it is commonly necessary to translate such decision in terms of the "best" single crisp alternative, in order to allow its implementation. This may be accomplished in a straightforward manner by choosing an alternative $a^* \in A$ that attaints the maximum membership grade in D (Figure 1). Sometimes, it is preferable to determine a^* by an appropriate defuzzification method. A detailed application of those methods can be found in Klir and Yuan (1995).

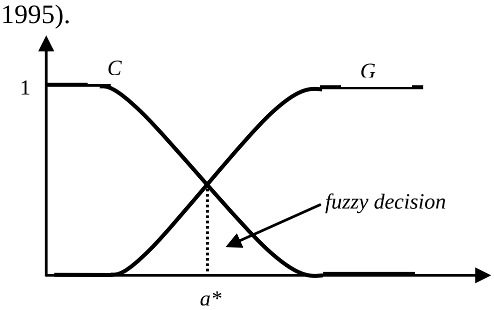

Figure 1 Illustration of a fuzzy decision

The fuzzy decision expressed by (1) can be extended to accommodate the relative importance of the various goals and constraints by the use of weighting coefficients. In this case, the fuzzy decision D can be determined by a convex combination of the n weighted goals and m constraints of the form

$$D(a) = \sum_{i=1}^{n} u_i G_i(a) + \sum_{j=1}^{m} v_j C_j(a) \quad (2)$$

for all $a \in A$, where u_i and v_j are non-negative weights attached to each fuzzy goal G_i ($i \in \mathrm{N}_n$) and each fuzzy constraint C_j ($j \in \mathrm{N}_m$), respectively, such that

$$\sum_{i=1}^{n} u_i + \sum_{j=1}^{m} v_j = 1 \quad (3)$$

Suppose, for instance, that for the maintenance manager is more convenient the cost minimization than the guarantee of availability above of a certain value. Then, u_i and v_j in the Equation (2) can be, for example, 0.6 and 0.4, respectively.

A direct extension of formula (1) may be used as well:

$$D(a) = \min\left[\inf_{i \in N_n} G_i^{u_i}(a), \inf_{j \in N_m} C_j^{v_j}(a)\right] \quad (4)$$

where the weights u_i and v_j possess the property specified in (3).

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