Maintenance Strategy Evaluation Using ANP and Goal Programming

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ABSTRACT

An optimal maintenance strategy mix is necessary for increasing availability and reliability levels of production facilities without significantly increasing operational costs. The selection of maintenance strategies is a typical Multiple Criteria Decision-Making (MCDM) problem with conflicting goals. Consideration of interdependence among the criteria and alternative policies for maintenance strategy provides valuable cost savings and greater benefits for any hybrid flow systems. For any decision maker, it is convenient to prioritize the criteria of MCDM problems and goals of goal programming problems in fuzzy terms. This paper presents an integrated approach for maintenance policy selection, using fuzzy Analytic Network Process (ANP) within a Goal Programming, based on fuzzy preemptive priority where goal hierarchies are specified in different levels of fuzzy importance. To overcome the criticism of inconsistency, unbalanced scale of judgments and uncertainty in the pair-wise comparison process, criteria weights are determined using modified fuzzy LLSM method.

Keywords: Analytical Network Process (ANP), Fuzzy Goal Programming (GP), Fuzzy Sets, Logarithmic Least Squares Method (LLSM), Maintenance Strategies

INTRODUCTION

Many companies think of maintenance as an inevitable source of cost. For these companies maintenance operations have a corrective function and are only executed in emergency conditions. Today, this form of intervention is no longer acceptable because of certain critical elements such as product quality, plant safety, and the increase in maintenance department costs which can represent from 15 to 70% of total production costs. Maintenance costs constitute an important part of the operating budget of manufacturing firms. Meckone and Wiess (1998) reported that the amount of money Du Pont spent, in 1991, company-wide on maintenance was roughly equal to its net income. Al-Najjar (1997) showed that maintenance expenses vary depending on the type of industry; typically, figures such as 15–40% of production costs may be encountered.
The consequences of an inefficient maintenance strategy go far beyond the direct costs of maintenance. Maintenance strategy evaluation means identifying best alternative maintenance policies for equipment in order to maximize the net benefit to the organization and allocating resources only among those alternatives, within the given constraints on resources. To select the optimum maintenance policy for equipment in an organization is difficult because there are lots of multiple tangible and intangible factors such as maintenance cost and time, serviceability, maintainability, skill required and risk involved in maintenance, inventories required, production loss etc., within the limited availability of firm’s resources. Hence, maintenance strategy evaluation problems are Multiple Criteria Decision Making (MCDM) problems. A group opinion has to be collected to evaluate various maintenance strategies, so as to know the interdependence relationship among criteria in equipment maintenance strategy selection problem is very important. Expert interview is conducted to collect group opinions for interdependent equipment maintenance problems.

Mathematical programming is basically a static optimization problem, consisting of different models such as linear programming, goal programming, dynamic programming, and game theory (Reza, Hossein, & Yvon, 1988). Goal Programming (Lee, 1972) is designed to deal with problems involving multiple conflicting objectives. However, to overcome the drawback of GP, decision makers must specify the goals and their priorities beforehand. The result of problem formulation shows a great difference as the decision maker’s judgments. Therefore, a systematic procedure is needed to determine the following factors in constructing the GP model through a group discussion: (1) objectives, (2) desired level of attainment for each objective, (3) a degree of interdependence relationship, and (4) penalty weights for overachievement or underachievement of each goal.

Another shortcoming of GP is the lack of a systematic approach for setting priorities and trade-offs between the objectives and criteria (Reza et al., 1988). This drawback is even more evident when both tangible and intangible factors need to be considered, when interdependent factors are involved, and when a number of people need to participate in the judgment. To overcome this problem, an Analytic Network Process (ANP), developed by Saaty (1996), was applied to set priorities for objectives and determine trade-offs between them.

The traditional ANP requires crisp judgments. However due to the complexity and uncertainty involved in real world decision problems, a decision maker(DM) may sometimes feel more confident to provide fuzzy judgments than crisp comparisons. This makes fuzzy logic a more natural approach to this kind of problems.


Among the above approaches, the extent analysis method has been employed in quite a number of applications due to its computational simplicity. Shin-ichi Ohnishi (2009) proposed fuzzy representation of criteria weights in order to reduce inconsistency in pairwise comparison matrix. Wang et al. (2008) showed by examples that the priority vectors determined by the extent analysis method do not represent the relative importance of decision criteria or alternatives and that the misapplication of the extent analysis method to fuzzy AHP problems may lead to a wrong decision to be made and some useful
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