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Fuzzy strategic replacement analysis

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Abstract

This paper presents a fuzzy methodology for replacement of equipment. Issues such as fuzzy modeling of degradation parameters and determining fuzzy strategic replacement and economic lives are extensively discussed. For the strategic purpose, addible market and cost effects from the replacements against the counterpart, i.e., the existing equipment cost and market obsolescence, are modeled fuzzily and interactively, in addition to the equipment deterioration. Both the standard fuzzy arithmetic and here re-termed requisite-constraint vertex fuzzy arithmetic (or the vertex method) are applied and investigated. Two numerical examples and the results are provided.

Keywords: Fuzzy sets; Equipment replacement; Fuzzy cash flow; Fuzzy regression; Fuzzy arithmetic

1. Introduction

In the modern competitive industrial and commercial climate, strategic and economic replacement of a plant, equipment, machinery, or process technology can be essential. When the existing equipment should be replaced can determine a firm's cost, profit, or even market share and competitive abilities.

Conventionally, however, equipment replacement analyses have been mostly done in a deterministic and crisp manner. The question of vagueness was usually ignored. Yet, there were forecast elements/parameters. Those elements could usually be complex and cannot be fixed. An equipment life thus determined should more suitably be a tolerable range of years instead of a crisp number. The concept of fuzzy set theory may provide a suitable tool for tackling this problem.

In spite of the amount of works on replacement models that have been reported in the literature (e.g., see [9,21,28,38,42,45,53] to name a few), investigation of the fuzzy set theory and its applications to this area is still limited. Only developments on fuzzy discounted cash flow analysis or capital budgeting (investment choice) methods and their applications were provided (e.g., see [2,8,13,23–25,31,32,41] and references therein). Regarding fuzzy replacement analysis, only a few works have been reported. These works may be classified into applying directly linguistic descriptions on the conditions of equipment [1,55], using fuzzy

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cost-components models [1,13], and combinations of the two approaches with either a fuzzy [7] or a crisp cost model [52]. General cost models have been used in these works. In terms of developing a fuzzy replacement analysis in strategic and elaborative means, no method is reported. This research is intended to fill this vacuum by introducing the concept of fuzzy sets into replacement of equipment based on equipment degradation characteristics.

Moreover, from strategic and financial viewpoints, a firm's ability to analyze the elements of equipment degradation as well as addible market- and cost effects of replacements is crucial to competitive and continual technological advance markets. These elements may be classified as equipment deterioration, cost obsolescence, and market obsolescence [37,44,50,51]. Among them, deterioration refers to the elements that are related to the characteristics of the equipment itself and the aging processes. Obsolescence, on the other hand, is a characteristic of the relative capabilities of new equipment to those of the present equipment. Meyer [37] provided a summary of the elements. Here a more thorough list of these elements and their parameters is given in Fig. 1. Indicated in Fig. 1, a pure replacement concerns only the equipment deterioration and cost obsolescence. Yet, for a strategic replacement it is necessary to concern all the three categories of elements and parameters.

Also in market competitions, changes in technology can usually be expected. Addible cost effects (either decrease or increase) may be brought about by replacement equipment. These effects can create newer equipment a phenomenon opposite to the cost obsolescence of the present equipment or reverse. In addition, changes in market effects (demand, market share, price, etc.) may also result and can create a phenomenon for the newer equipment opposite to the present equipment market obsolescence. Although some of the existing models have considered the addible market and cost effects of replacement [33,34,37,49–51], the modeling is not yet complete and needs advancement. In particular, a thorough modeling of the effects is needed. Depicted in Fig. 2, a framework with interactive relationships is proposed and used here to modeling the parameters. That is, addible market and cost effects of the replacements

<table>
<tr><td colspan="5">Elements of equipment degradation</td></tr>
<tr><td colspan="3">Actual (intrinsic)</td><td colspan="2">Opportunity (extrinsic, strategic)</td></tr>
<tr><td colspan="3">Deterioration</td><td>Cost obsolescence</td><td>Market obsolescence</td></tr>
<tr><td>Increasing use costs</td><td>Decreasing capacity & quality</td><td>Decreasing resale value</td><td>Increasing operating costs (compared to newer equipment)</td><td>Decreasing revenue potential (compared to newer equipment)</td></tr>
<tr><td>Energy, down time, repair, overhaul, preventive maintenance, floor space cost, insurance</td><td>Output, over time, scrap, rework, labor cost, subcontracting</td><td>Salvage value</td><td>Output, energy, down time, repair, preventive maintenance, floor space cost, insurance, cycle time, inventory, labor cost, scrap, rework, scheduling, design/ manufacture interface</td><td>Quality, product variety, flexibility, productivity, delivery, demand, technical importance, market share, price</td></tr>
<tr><td colspan="3">Function of age and cumulative use</td><td colspan="2">Function of technological change</td></tr>
<tr><td colspan="4">Pure replacement (PR):
Condition: fixed level of market obsolescence & partial cost obsolescence (such as output, price, market share, etc.)
Goal: minimization of producing costs</td><td></td></tr>
<tr><td colspan="5">Strategic replacement (SR):
Conditions: demand, market share, price, operating costs, etc.
functions of technological change
Goal: maximization of profits</td></tr>
</table>

Fig. 1. Elements and parameters of equipment degradation.