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FUZZY LOGIC APPLICATION FOR EXTRUDERS REPLACEMENT PROBLEM

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ABSTRACT

In a scenario of uncertainty and imprecision, before taking the replacement analysis, a manager needs to consider the uncertain reality of a problem. In this scenario, the fuzzy logic makes an excellent option. Therefore, it is necessary to make a decision based on the fuzzy model. This study is based on the comparison of two methodologies used in the problem of asset replacement. The study, thus, was based on a comparison between two extruders for polypropylene yarn bibliopegy, comparing mainly the costs involved in maintaining the equipment.

Keywords: Fuzzy set, Fuzzy Number, Fuzzy Replacement Problem, Fuzzy ranking, Membership Function.

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1. INTRODUCTION

The replacement decision is of critical importance to the company, as it is usually irreversible, *i.e.* not having liquidity and undertaking a significant amount of resources. Hence, a hasty decision to replace it could cause serious problems for the working capital in the company.

Nowadays, the importance of this question is increasing because obsolescence happens incredibly fast as the technology increases becoming a “new” and old “useful” equipment, because the market always occurs new possibilities more advantages and productivity even less maintenance and diminishing the total cost of operation. So the well-known financial deterministic ways to determine the economic lives of equipment’s will fail in this context of plenty of uncertainty and “*vagueness*”.

To solve the “*vagueness*”, which is embedded in this cost variable problem, you have to consider maintenance cost (Y), interest rate (i), *i.e.* Minimal Attractiveness Rate of Interest – MARR, initial Investment (C), capital recovery cost, among others. Before describing this method, a common deterministic method review will be done.

2. FUZZY LOGIC IN REPLACEMENT ANALYSIS

The theory of fuzzy was designed by L.A. Zadeh in 1975, in order to provide a mathematical tool for the treatment of “uncertain” or “vagueness” background information. The fuzzy logic based on this theory was initially constructed from the concepts already established in classical logic; operators are defined similarly to the traditionally ones, and others have been introduced over time, often eminently practical character needs.

The fuzzy logic allowed us to deal with the “vagueness” problem in different areas. In 1975, Zadeh created the fuzzy logic that can treat complex models with set fuzzy logic. The fuzzy logic can be used to solve different kinds of problems. However, even fuzzy systems, as they are posed now, can be described as shallow models in the sense that they are primarily used in deductive reasoning.

In this article use logic structures, fuzzy numbers ( ) and membership function will be specified (μ). Then, it will be used the fuzzy logic and arithmetics

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fuzzy will be used to calculate the Equivalent Uniform Annual Worth Fuzzy Value (EUAW) and compare with classical replacement analysis, the Equivalent Uniform Annual Cost (EUAC).

BISWAS et al., in 2011, studied replacement analysis. He proposed a methodology for the Equivalent Uniform Annual Worth Fuzzy Value (EUAW). It employed the Yager's ranking index for maintenance cost, where Y( ) presents the representative value of the fuzzy number A. Here, we consider for Equivalent Uniform in general:

EUA (x) = , equation 2.1

Now, when we calculate the Equivalent Uniform Annual Worth Fuzzy Value (EUAW) then the capital cost ( ), the scrap value ( ), the maintenance cost ( ) are fuzzy numbers and rate period n-years (a) is a discrete variable.

3. DETERMINISTIC REPLACEMENT METHOD

As stated by Thuessen & Fabrick, the equipment in operation is a denoted defensor (d) and the alternative or alternatives are called challengers (D). Some remarkable notes are the following: for “D” and “d” differing so much in operational working characteristics for “D” requires an high Initial investment value. Notwithstanding the maintenance cost is very low compared to the defensor’s one; the challenger’s cash flow is very different from the cash flow of the old asset; the recovery cost of capital of d is decreasing while its operational cost is high and always increasing; the salvage value of d, in most cases, is negligible or has a low amount.

In deterministic analysis (EUAC), besides obsolescence, tear and wear (physical degradation) is the other main reason for replacement. This is a very conflicting question, mainly when the firm is dealing with insurers/reinsurers prationioneers in order to set up the depreciation with an absolute accuracy of the life of certain equipment or infrastructure building.

Although engineering specific methods with higher complicated mathematical development for some specific areas help accountants and financial professionals to

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determine the depreciation of some equipment, there is no universally accepted depreciation methods.

Coming back to the economic aspects, in an eventual replacement, it should be taken into account in the Initial Investment the following costs denoted as first costs needed for the equipment to become operational: freight; package; insurance; foundations; special connections and pipelines; assembling (if this cost is not included in the original budget); other unexpected costs that are not object of insurance cover.

In regard to the defensor, the unit to be replaced, the remotion cost should include the disassembling cost, foundations remotion costs, closing electric connections costs and other similar costs. These costs must be deduced from the salvage value of the equipment, generating the Net Salvage Value (NSV). Even if the former amount was negative, it should be respected in depreciation calculations.

3.1. Deterministic replacement method considering sunk cost and equal lives for equipments

According to Sharpe and Chan Park, one of the main mistakes in financial engineering is to disregard that cost occurred in the past with the defensor, at the time of replacement, a decision couldn't have been. They are sunk costs. At a first glance, this concept is not easy to understand for non-financial professionals. To justify this statement, the Outsider View Point (OVP) consideration is introduced. From an outsider viewpoint, at the moment of replacement decision, all costs already incurred with defensor equipment including the acquiring cost of the same, do not need to be taken into account. All these costs incurred are sunk costs. The only cost, at the moment of replacement decision, if there is any, is its net salvage value (NSV) or even an offering proposal (OP) that the seller of the new equipment makes for the old asset.

Another remarkable point is to establish the Time Study Period (TSP) which means the time that the cash flows of the alternatives are being compared. In order to clarify all these concepts, an example that deals with an extruder's replacement is proposed below, whole data are the following:

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Table 1: Data for the replacement in Defensor (d).

Defensor (d)	
Data of Acquisition	01/01/2008
Initial Investment	US$ 400,000.00
Estimated life	10 years
Total Operational cost	US$ 1,500.00
NSV at the end of Life	US$ 40,000.00

Table 2: Data for the replacement in Challenger (D).

Challenger (D):	
Data of Acquisition	01/01/2013
Initial Investment	US$ 500,000.00
Estimated life	10 years
Total Operational cost	US$ 1,000.00
NSV at the end of Life	US$ 50,000.00

Note: consider MARR = 10% per year.

According to the data, the TSP = 10 years. It will be used to solve the Equivalent Uniform Annual Cost (EUAC) method in BISWAS et al., 2011. So EUAC value for the defender U$ 195 M and a EUAC for challenger equal to U$ 179 M.

4. FUZZY REPLACEMENT METHOD

The method of analysis of fuzzy equipment replacement is one of the most important and most common types of alternative comparisons found in practice. In a replacement analysis of fuzzy, one of the feasible alternatives involves the option for continued equipment operation.

There are different reasons which can contribute to an equipment replacement choice. Initially, the current asset (defender) may have a number of deficiencies including high set-up cost, excessive maintenance, declining production efficiency, heavy energy consumption, and physical impairment. And finally, potential replacement assets (challengers) may take advantage of new technology and be easily set up, maintained at low cost, high in output, energy efficient, and possess increased capabilities, perhaps at a vastly reduced cost (CENGIS; MURAT, 1998).

As it has been said, a great contribution of fuzzy set theory was its capability of representing “vagueness”. The theory also allowed mathematical operators and a programming to apply to the fuzzy domain. A fuzzy set is a class of objects with a continuum of grades of membership. Such a set is characterized by a membership function, which assigns to each object a grade of membership ranging between zero and one. Picture 1 demonstrates a triangular fuzzy number (TFN) $\tilde{P}$: Fuzzy set theory has also been applied to many engineering economic areas. Buckley (1987) developed fuzzy mathematics for compound interest problems. The theory can

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determine the fuzzy present value and fuzzy future value of fuzzy cash amounts, using fuzzy interest rates. Chiu and Park (1994) developed comprehensive left and right side representation of fuzzy finance (THOGA, MURAT, CENGIZ, 2005).

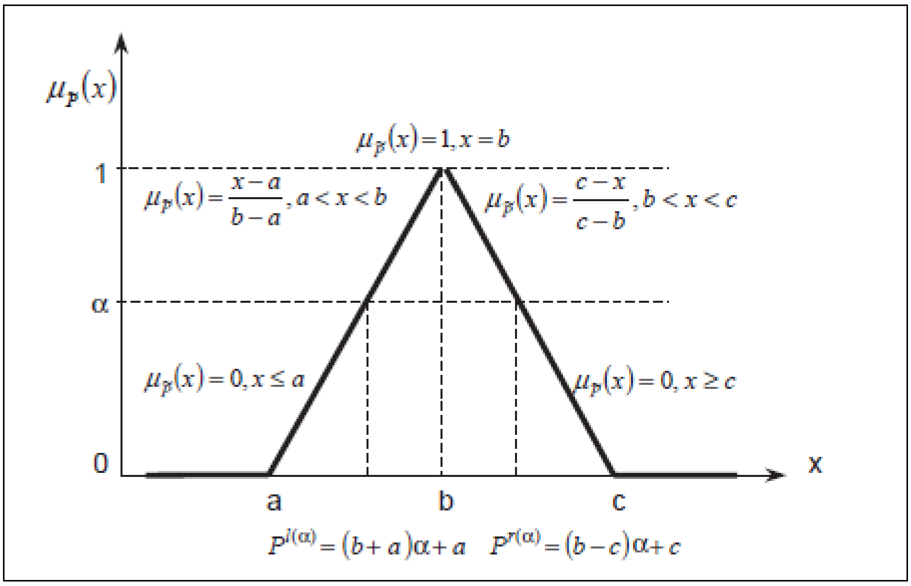

Figure 1: Left and Right representation of a TFN, $\tilde{P}$

The equivalent uniform annual worth (EUAW) understands that all income and expenses (irregular and uniform) must be converted into an equivalent uniform annual value, which is the same in each period.

The methodology proposed by BISWAS et al., in 2011, uses the concepts seen before. However, the fuzzy replacement method will be calculated with fuzzy theory sets. For this, the Equivalent Uniform Annual Worth Fuzzy Value (EUAW) is obtained from the result of the fuzzy operations in equation 2.1.

Besides that, it is important to point out that all costs incurred between 01/01/2006 to 31/12/2016 are sunk cost and do not matter in a replacement decision. As stated by Yager the calculus can be performed by the formula below:

$$Y(\quad) = \int_0^1 (0{,}5\, x\; (\; C_\alpha^L + C_\alpha^U)\,)\; d\alpha \quad \text{, equation 3.1}$$

In this case, it must be considered TSP, optic which constrains the method when the lives of two equipment (or project) are different and one (life) is shorter than the other. The replacement problem will be one time in the future where cash flows are equivalent dates.

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Regarding the time horizon, the decision maker can consider all the future or an interval time where the cash flows are equivalents. As it is almost impossible to predict all the facts that will affect the variables that constitute the cash flow in the future, the Net Present Value can be considered the result of the selection between within the time frame.

In order to make it clear, an example of two extruders according will be show, according table 1:

Table 3: Data for the replacement example with different lives.

Extruder	Defensor (d)	Challenger (D)
NPV (US$)	NA	NA
Initial Investment	US$ 400,000.00	US$ 500,000.00
Annual Cost of Operational	US$1,500,000	US$1,000,000
Useful Life (years)	10	10
NSV at the end of Life	US$ 40,000.00	US$ 50,000.00

Notes:

1. NA – not appliacable;
2. Considering MARR = 10% per year

Choosing a TSP = 10 years, it is possible to calculate NPV (equipament) by two ways, which will be shown below.

Before introducing the calculus, picture 2 embracing the two replacement possibilities will be presented:

(a) Recognizing the reminiscent value "d" (i.e the time unused between years 08 to 18)

In this way of calculus, the EUAW of "d" will be distributed for its 10 years of useful life. Next, the Yager's ranking index for maintenance cost, Y( ) for defensor (d):

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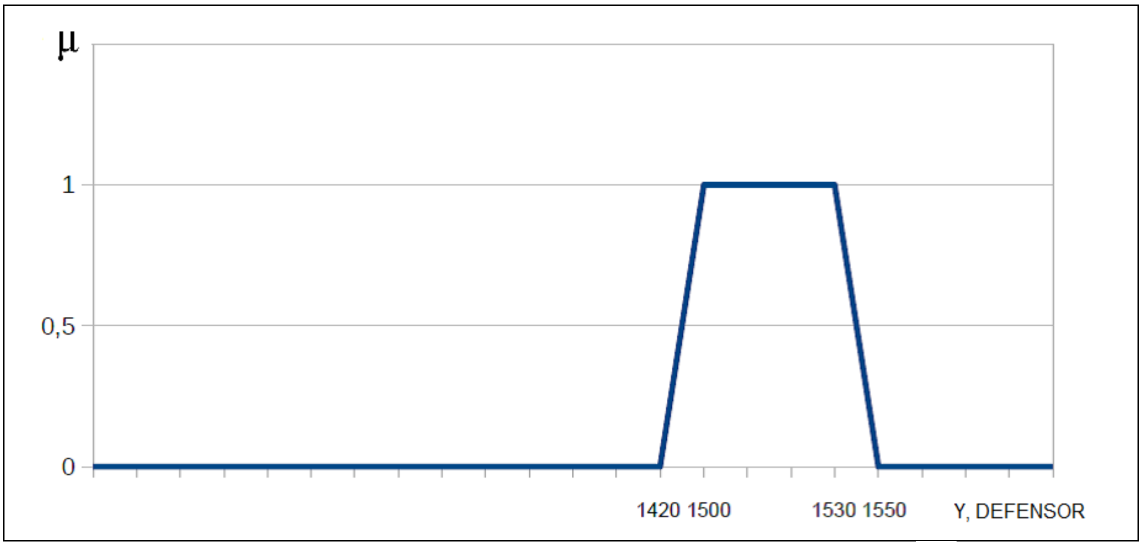

Figure 2: the maintenance cost value of “d” for its 10 years and Y( ) = 0,4 (“low”).

Therefore, the Equivalent Uniform Annual Worth Fuzzy Value (EUAW) for defensor (d):

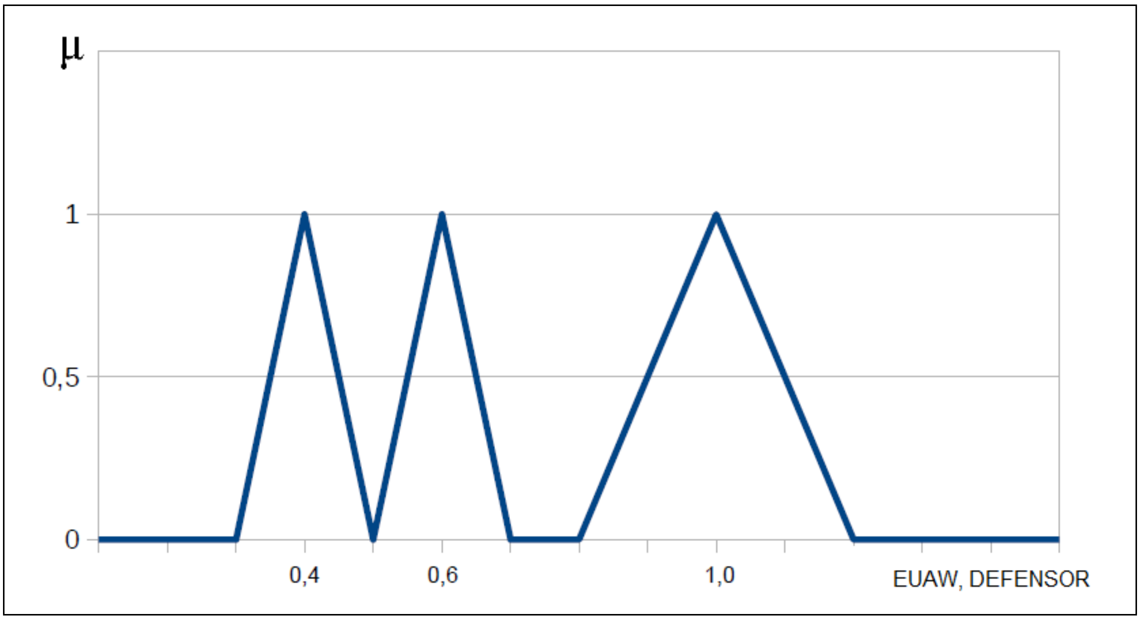

Figure 3: the cost value (EUAW) of “d” for its 10 years equal to 1,0.

In this way of calculus, it will be distributed the EUAW of “D” for its 10 years of useful life. Next, the Yager's ranking index for maintenance cost, Y( ) for challenger (D):

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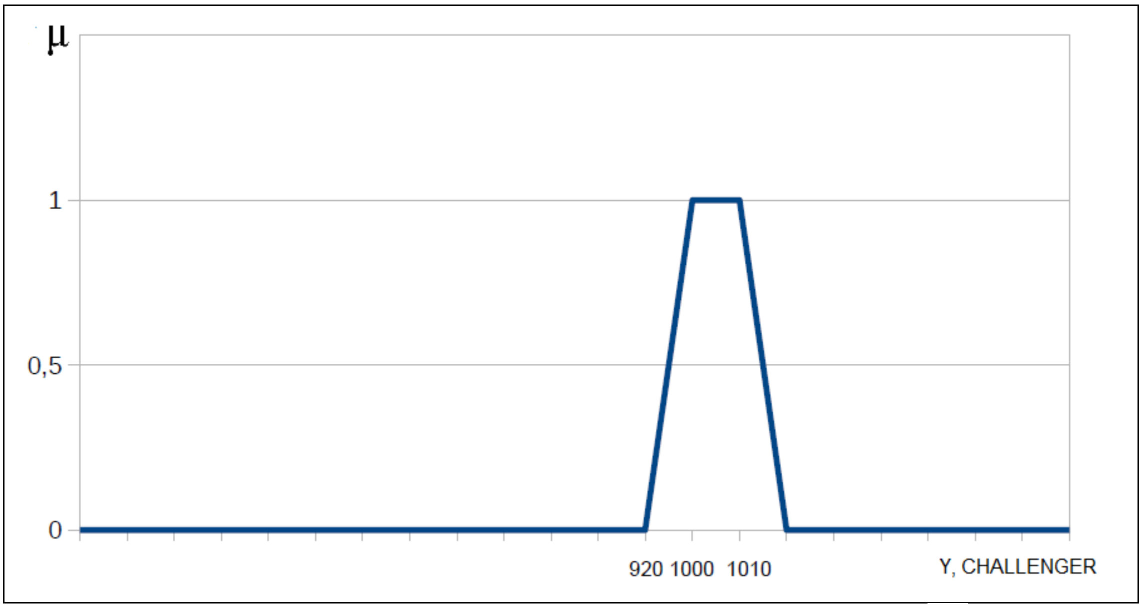

Figure 4: the maintenance cost value of "D" for its 10 years and Y( ) = 0,2 ("very low").

Therefore, the Equivalent Uniform Annual Worth Fuzzy Value (EUAW) for challenger (D):

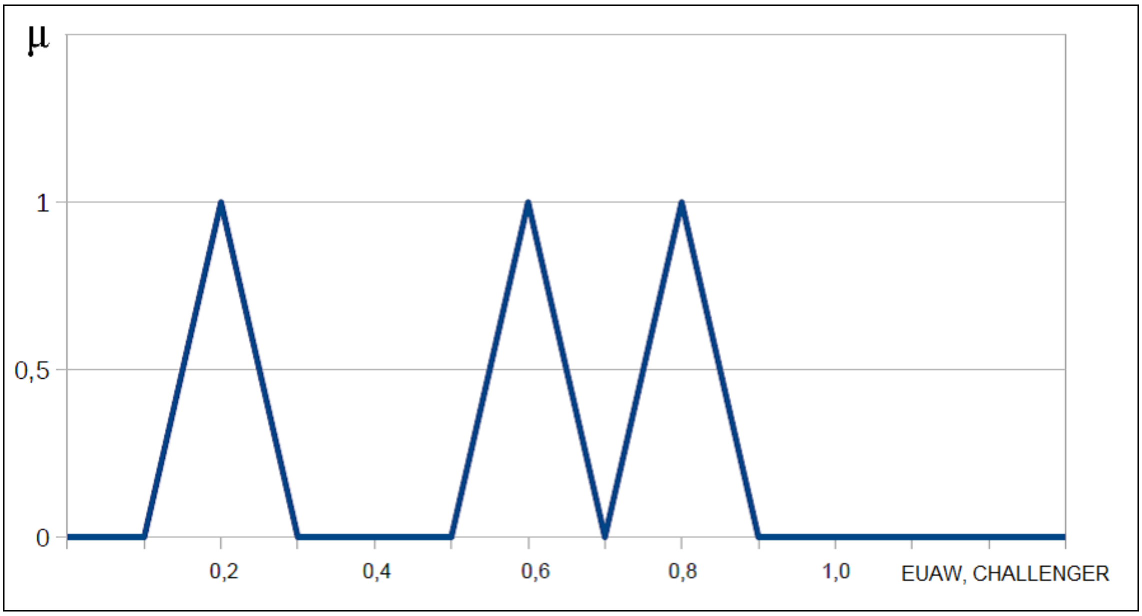

Figure 5: the cost value (EUAW) of "D" for its 10 years equal to 0,8.

(a) Recognizing the reminiscent value "d" (i.e. the time unused between years 13 to 23).

With this, it can be seen that the value of the Equivalent Uniform Annual Worth Fuzzy Value (EUAW) for challenger (D) is equal to 0,8 ("high"), less than the

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value EUAW for defensor (d), which is "very high", equal to 1,0; suggesting replacement of the extruder.

5. CONCLUSIONS

In this work, two methodologies were considered to deal with the problem of asset replacement. The first did not consider the vagueness of the capital costs, residual value, maintenance or running costs. In the second method we consider the imprecise nature of this information, so we started using and enjoying the fuzzy logic.

It is more realistic and closer to our daily life situation. Here, we use the Yager ranking method to handle this type of EUAW. This method moves the EUAC for Crisp Replacement Problem with its corresponding classification rates. This method is simple and easy to apply for the practical resolution Fuzzy Replacement Problem.

A numerical example was used to show the simplicity and effectiveness of the proposed method. It also shows that the appropriate decision for replacement of Fuzzy Replacement Problem can be made easily. We hope that the proposed method can be used for future studies in the Fuzzy Replacement Problem when the value of money depends on time.

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