**[Note: The length of the paper should not be exceeded more than 6 pages]**

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[**Investigation of various performance concerns for an industrial machinery**](https://www.sciencedirect.com/science/article/pii/S0950423015300991)

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**Abstract**-The current research work seeks to propose an integrated framework based on fuzzy AHP and fuzzy TOPSIS approaches for selecting the optimal maintenance strategy for a real industrial system of a process industry. Under fuzzy AHP, a hierarchical structure for making decision on maintenance strategy has been generated and the weights for different criteria and sub-criteria were computed by using Geometric Mean (GM) method. These weights were further included in fuzzy TOPSIS approach to obtain final ranking of the five considered maintenance strategies.

**Keywords- Fuzzy AHP, fuzzy TOPSIS, maintenance strategy, Geometric Mean, sensitivity test**

1. **INTRODUCTION**

From the last few years’ ammonia emissions in urea fertilizer industries, and the reduction of these emissions, have become an increasingly challenging issue. The continuous ammonia emissions cause burning of skin, eyes, mouth, and lungs of human beings and therefore, accidental emissions resulting from sudden failure of plant operation comes into spotlight. The sudden failure of a plant operation due to inefficient maintenance policy not only affects the profitability of the considered industry but also has significant impact on human health.

1. **RESEARCH BACKGROUND**

In this section, the authors have provided a brief review of available literature related to maintenance decision making for various real operating systems or subsystems of different process industries. To name a few, Bevilacqua and Braglia (2000) applied AHP tool to select the best maintenance strategy for gasification and combined cycle plant in an Italian oil refinery. Sachdeva and Kumar (2008) expounded the application of AHP approach for deciding upon the criticality of best maintenance strategy in a paper industry. The maintenance strategy selection done by various others under different criteria in different industries has been presented in Table 1.

Table 1. List of Main Criteria and Sub Criteria for Maintenance Policy Selection

|  |  |  |  |
| --- | --- | --- | --- |
| Code | Criteria | Sub criteria | References |
| CT | Cost | Hardware cost; Software cost | Panchal and Kumar (2017) |
| VA | Value added | Training; Spare part inventory  | Panchal et al. (2017) |
| SA | Safety | Environmental safety; Human safety | Panchal and Singh (2017) |

1. **RESEARCH METHODS**

**3.1 Fuzzy set theory**

In MCDM problems there is high degree of uncertainty and imprecision within the collected data/information. To handle such uncertainties and vagueness of the collected data fuzzy set theory proposed by L.A Zadeh in 1965 has been used effectively (Kokso, 1999; Ross et al., 2003; Tanaka, 2001; Zadeh, 1996; Zimmermann, 1996). The basic definitions of fuzzy set theory are as follows:

**Definition 1:** In a crisp set or classical set, the membership of an object is precisely defined whereas a fuzzy set contains the object that satisfies the imprecise property of membership. In crisp set there exist only two probabilities: either an element is a member of a set or it is not. Mathematically, a crisp set is represented by the indicator function as shown below:

$ M\_{A}\left(x\right)=\{ 1, if x ϵ A 0, ifx\notin A $ (1)

Unlike the crisp set, a fuzzy set can accommodate various degrees of membership on the real-continuous interval$ \left[0,1\right]$, where the endpoints of 0 and 1 conform to no membership and full membership respectively.

**A2**

**A1**

**z**

**0**

**1**

**a2**

**a1**

**b2**

**c2**

**b1**

**c1**

**d**

$$v\left(A\_{2}\geq A\_{1}\right)$$

Fig 2: The intersection between A1 and A2

**3.2 Fuzzy AHP**

AHP is a type of additive weighting method developed primarily by Saaty (1980). Being a MCDM approach, it has the ability to integrate qualitative and quantitative information in the decision making process (Bevilacqua and Braglia, 2000). However, it has been criticized on account of various limitations associated with pure AHP: $\left(i\right)$ It utilizes discrete scale 1-9 and is unable to account for the uncertainty in decision making.$ \left(ii\right)$ AHP method is unable to deal with an unbalanced scale of judgment.$ \left(iii\right)$ It can be used only for crisp information. Steps of fuzzy AHP approach are discussed as follows:

1. **Case study**

To exemplify the application of proposed framework, ASU system of a urea fertilizer industry has been considered in the present study. ASU, one of the critical functional unit of the considered industry consists of various subsystems/equipment namely compressor, hot and cold heat exchanger, reactors, ammonia converter, pump, pipes, safety valve, pressure gauge etc. Currently, due to high inimitability in the market and ease in implementation, Corrective Maintenance (CM) strategy is in use for the considered system.

**4.1 Application of research methods**

Under fuzzy AHP approach, on the basis of intensive discussions with maintenance experts’ team (comprising one maintenance manager and three senior maintenance personnel) and exploring available literature related to maintenance decision making (Wang et al., 2007; Bevilacqua and Braglia, 2000)

**Table 2**: The Fuzzy Comparison Matrix for Criteria w. r. t. Goal

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Goal | **G1** | **G2** | **G3** | **G4** | **G5** | **G6** |
| **G1** | (1,1,1) | (1/2,1,2) | (1,2,3) | (2,3,4) | (4,5,6) | (3,7/2,4) |
| **G2** | (1/2,1,2) | (1,1,1) | (4,9/2,5) | (1,2,3) | (1/4,1/3,1/2) | (1/3,1/2,1) |
| **G3** | (1/3,1/2,1) | (1/5,2/9,1/4) | (1,1,1) | (1/2,1,2) | (1/3,2/5,1/2) | (1/5,1/4,1/3) |

1. **Results and discussion**

From result table, it is noted that for PM the closeness coefficient $\left(D\_{i}\right)$ value is ….. which is higher than other maintenance strategies. Therefore, it is regarded as the best maintenance strategy for the considered system.

1. **Conclusion**

With an increase in the complexities of real industrial systems, maintenance decision making has become a challenge for maintenance managers. In the present study, the authors have used an integrated MCDM framework for the selection of an optimal maintenance strategy for ASU of a urea fertilizer industry.

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