

EVALUATION OF CRITERIA FOR THE SELECTION OF MAINTENANCE MODELS USING TOPSIS

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Abstract: Efficient industrial maintenance management is a key pillar in ensuring the effective operation of machinery and equipment in production environments. In this context, the strategic selection of the maintenance model to be used becomes a critical challenge, directly affecting the reliability, availability, and overall performance of industrial assets. The main objective is to develop a tool that simplifies and refines the process of selecting the appropriate maintenance model for the processes and machines involved in the selection. The tool will be developed by considering key variables such as equipment costs, recurrence of failures, comparison of expenses related to failures, preventive or predictive interventions, and more. In addition, the models will be validated by analyzing correlations between the model and these factors for different types of machines and equipment in various processes, to strengthen the data accuracy. Using the developed tool, the expected outcomes include a significant reduction in expenses, labor, and materials, as well as a significant increase in maintenance availability and effectiveness (Autonomous, Preventive, Predictive, and Failure-based maintenance). This will demonstrate the substantial impact of proper model selection. Effective management of maintenance model selection through interaction with various factors ensures successful implementation and enables benefits in multiple categories, improving key performance indicators and the reliability of equipment within company operations.

Keywords: Asset management, Decision making, Productivity, Industrial maintenance, TOPSIS.

Abstract: Efficient industrial maintenance management is a fundamental pillar for ensuring the effective operation of machinery and equipment in production environments. In this context, the strategic selection of the maintenance model to be used becomes a fundamental challenge, as it directly affects the reliability, availability, and overall performance of industrial assets. The main objective is to develop a tool that simplifies and refines the process of selecting the appropriate maintenance model for the processes and machines involved in the selection. The tool will be developed taking into account key variables such as equipment costs, failure recurrence, comparison of failure-related expenses, preventive or predictive interventions, etc. In addition, the models will be validated by analyzing the correlations between the model and these factors for different types of machines and equipment in various processes, in order to reinforce the accuracy of the data. With the tool developed, it is expected to achieve a significant reduction in expenses, labor, and materials, as well as a

considerable increase in maintenance availability and effectiveness (autonomous, preventive, predictive, and failure-based maintenance). This will demonstrate the substantial impact of proper model selection. Effective management of maintenance model selection through interaction with various factors ensures successful implementation and delivers benefits across multiple categories, improving key performance indicators and equipment reliability within company operations.

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INTRODUCTION

The rapid growth of companies demands more reliable infrastructure and equipment to stay competitive and meet client demands within established timelines. This is achieved through regular maintenance and inspections, which prevents the deterioration of infrastructure and equipment, reducing the risk of malfunctioning processes (Cai and Choi, 2020).

In a maintenance management system, a measure of planned work versus unplanned work is known as the maintenance mix or maintenance index. According to various scholars, the index for best maintenance practices suggests that 15% of work should be unplanned, and 85% should be planned (Planned Maintenance Percentage, 2022). Maintenance is beginning to play a more significant role in many production-related industries, and its correct management has had a major impact on productivity and profitability (Lado and Singh, 2019).

Decision-making is crucial when choosing the appropriate methodology for maintaining a company's infrastructure and equipment. Although information about maintenance methods is vast and new technologies are constantly evolving, there may be a lack of knowledge regarding the efficiency of maintenance methods for different operational contexts in companies.

BACKGROUND

Liang and Parlikad (2020) propose using predictive data to decide whether preventive maintenance should be performed well before the next shutdown for corrective maintenance (CM). Therefore, within this method, a decision is made about "what" preventive maintenance (PM) to perform. However, the "what," "how," and "when" are already defined for CM.

For this, the support of intelligent sensors is needed. These are specific devices that generate data on physical parameters (e.g., humidity, temperature, vibration speed, etc.) and provide additional functionalities for autonomous control and configuration to manage complex processes more efficiently (Zhang et al., 2019). While this method moves toward planned maintenance selection, it only presents one model as a solution: preventive maintenance.

Within the existing literature, no method has been found for selecting the appropriate maintenance model for different organizational contexts, representing an opportunity to perform data analysis on different models in various contexts for more robust and objective decision-making.

THEORETICAL FRAMEWORK

Limitations / Implications of the Research

Since data must be gathered from different types of machines and infrastructure in various contexts, data collection will be extensive to achieve the goal of obtaining a reliable method for selecting the maintenance model. Managing a database can become problematic if not adequately handled, so proper follow-up is necessary as new data is acquired.

Practical Implications

Understanding how to use the tool and its factors will help organizations make more accurate decisions regarding investment in the right maintenance models. By visualizing all the options weighted in monetary value, we can make more objective decisions. For engineers, supervisors, and maintenance managers, this tool will streamline their work by enhancing maintenance effectiveness.

Originality/Value

This study creates a new approach for how industries select the type of maintenance, facilitating and increasing the value of maintenance for their equipment and infrastructure. The selection of positive and negative values will help determine how close or far the maintenance programs are from optimal according to the study's results.

Data

The vast amount of data an organization generates daily can be a great opportunity to make the right decisions and improve maintenance processes. While preventive maintenance and condition-based maintenance use measurement equipment such as thermography, ultrasound, vibration, etc., this only

applies to evaluating the condition of equipment included in these programs. The data evaluated in this study will be primarily based on work orders, whether proactive or reactive.

OBJECTIVES

General Objective

To develop a decision-making tool focused on the strategic selection of different maintenance models, ranging from Maintenance 1.0 to 4.0, in order to improve asset reliability, extend the life of industrial assets, and optimize resource use, considering equipment costs, failure recurrence, and a comparison of failure versus repair costs.

Specific Objectives

- A) Identify the factors that positively or negatively impact maintenance models.
- B) Evaluate significant factors for selecting the appropriate model.
- C) Develop the maintenance selection model using TOPSIS.
- D) Validate the model implementation.

IMPACT OR BENEFIT IN SOLVING A PROBLEM RELATED TO THE PRODUCTIVE SECTOR OR GENERATING SCIENTIFIC KNOWLEDGE

Thanks to the competitiveness of organizations at the global level, equipment reliability is one of the factors that will increase competitive levels. Implementing an appropriate model will positively impact operations.

This study aims to achieve the following impacts and benefits:

- Obtain relevant and accurate data on maintenance methods implemented in different contexts (Ciudad Juárez).
- Propose an optimal maintenance method selection model guided by the factors identified in the study.
- Identify possible improvements to maintenance systems within organizations.

METHODOLOGY

Information analysis in a research process requires understanding the characteristics of the various approaches that can be used. Without a doubt, the quantitative approach is a suitable option that facilitates data analysis, enabling the retrieval of key insights contributing to the acquisition and understanding of hidden knowledge from information sources (Muñoz et al., 2024).

To identify complex projects, it is necessary to first identify the factors responsible for such complexity. These factors are known as drivers and can be identified through a review of existing literature and expert opinions from organizations (Piya et al., 2019).

As a decision analysis tool, TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) seeks to choose an alternative that has the closest distance to the positive ideal solution (PIS) and the farthest distance from the negative ideal solution (NIS) (T. Kuo, 2017).

Determining the weight of factors responsible for project complexity is often challenging and generates uncertainty in decision-making. This uncertainty regarding factor weights influences the quality of project selection. In such uncertain decision-making situations, fuzzy set theory could be used as a useful tool (Liang et al., 2019; Yazdi et al., 2020; Ma et al., 2020).

AHP (Analytic Hierarchy Process) provides a nonlinear approach for implementing both deductive and inductive reasoning without relying on logical reasoning outside of context. This is achieved by simultaneously considering various factors, allowing interdependence and feedback, and making necessary numerical adjustments to reach a synthesis or conclusion (Saaty, T. L, 1980).

The TOPSIS method is based on the principle that the optimal solution is the one with the smallest distance to the positive ideal solution and the largest distance from the negative ideal solution. Chakraborty & Mandal (2018) state that alternatives are ranked using a global index, which is calculated based on distances to the ideal solutions obtained through the method.

Materials

Within the literature review, we have access to 30 databases from the Autonomous University of Ciudad Juarez. For data collection, we will use organizational databases, but electronic devices will be necessary for data management, as well as software licenses for data analysis, such as Minitab 20, depending on the progress of the research.

Proposed Method

AHP Method

The AHP model follows these steps:

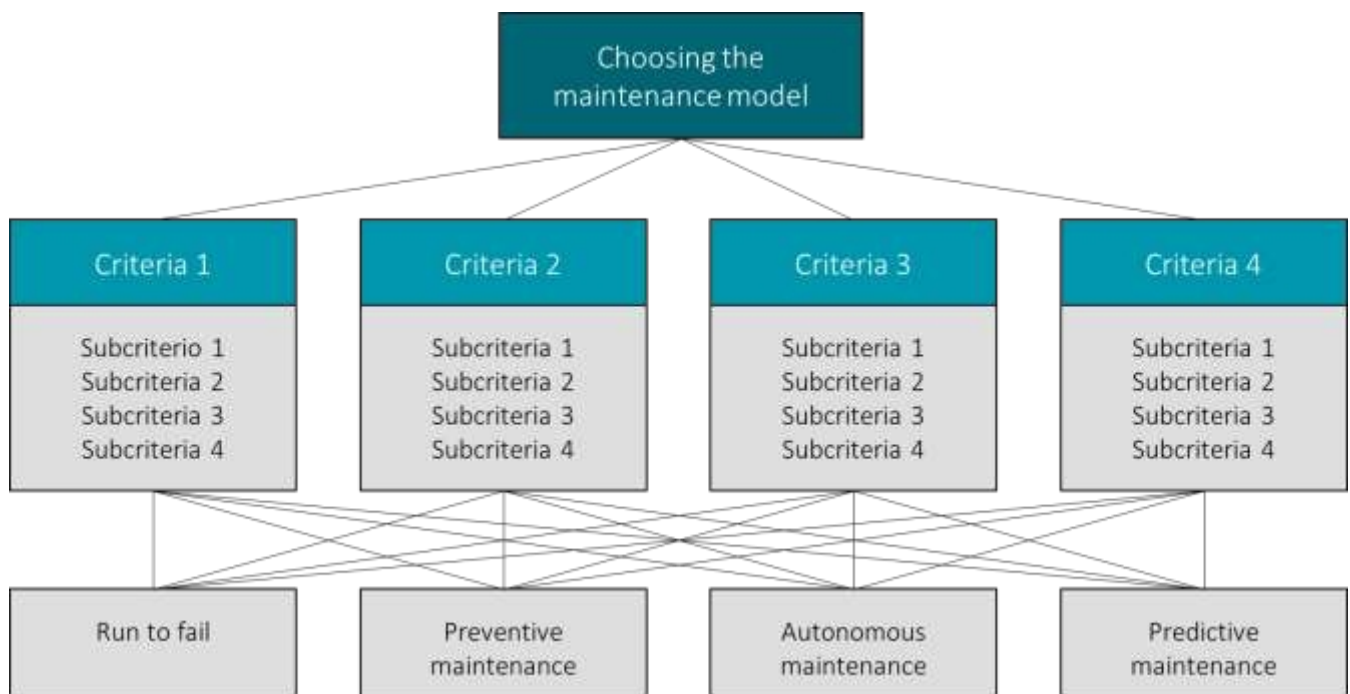
- Structuring the decision problem and selecting criteria.
- Prioritizing criteria through pairwise comparisons (weighting).
- Pairwise comparison of options for each criterion (scoring).

- Obtaining a relative general score for each option.

After evaluating the impact of all elements and calculating priorities for the hierarchy, lower-priority elements may be discarded due to their relatively minor impact on the overall objective. Priorities can be recalculated entirely, with or without changes in expert judgments (Saaty, 1990).

AHP constitutes a general measurement theory. Its application involves deriving ratio scales from discrete and continuous pairwise comparisons within multilevel hierarchical structures. This process allows systematic evaluation and prioritization of alternatives, facilitating decision-making in complex environments, as shown in Figure 1.

Figure 1. AHP: Choosing the maintenance model.



Note. Figure created by the author, 2025 TOPSIS

Model

Step 1: Construction of the Decision Matrix

| | | | | |
|-------|----------|----------|-------|----------|
| | W_1 | W_2 | | W_n |
| | C_1 | C_2 | | C_n |
| A_1 | X_{11} | X_{12} | | X_{1n} |
| A_2 | X_{21} | X_{22} | ... | X_{2n} |
| | | | | |
| A_m | X_{m1} | X_{m2} | | X_{mn} |

Step 2: Normalization of the Decision Matrix

$$n_{ij} = x_{ij} / \sqrt{\sum_{j=1}^m (X_{ij})^2}, j=1, \dots, m$$

Step 3: Construction of the Weighted Normalized Decision Matrix

$$v_{ij} = w_j \times n_{ij} \quad j = 1, \dots, n, i = 1, \dots, m$$

Step 4: Obtaining the Positive Ideal Solution (PIS) and Negative Ideal Solution (NIS)

$$A^+ = \{v_1^+, \dots, v_n^+\} = \{(max_{i \in j} v_{ij}) (min_{j \in j'} v_{ij})\}$$

$$A^- = \{v_1^-, \dots, v_n^-\} = \{(min_{i \in j} v_{ij}) (max_{j \in j'} v_{ij})\}$$

Step 5: Calculation of Euclidean Distance

$$d_i^+ = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^+)^2}, i = 1, \dots, m$$

$$d_i^- = \sqrt{\sum_{j=1}^n (v_{ij} - v_j^-)^2}, i = 1, \dots, m$$

Step 6: Calculation of Relative Closeness to the Ideal Solution

$$R_i = \frac{d_i^-}{(d_i^+ + d_i^-)}, i = 1, \dots, m$$

Step 7. The order of preferences will simply be arranged in descending order, starting with those that are closest to the ideal solution R_i (highest relative proximity).

LINK WITH THE PRODUCTIVE SECTOR

This study requires the participation of different types of manufacturing companies in the region to obtain accurate data. Therefore, the relationship with the productive sector will be direct, and in the end, these same companies will be where the models are validated, thus obtaining a positive impact. Students who

are completing their professional internships will also participate, gathering the necessary information for this study.

The intellectual property registration with INDAUTOR for the results obtained will be under the name of the Ciudad Juárez campus, and these results will later be disseminated across other campuses.

CONCLUSIONS

The study on the evaluation of criteria for the selection of maintenance models using the TOPSIS methodology proves to be an efficient and innovative approach, providing a structured framework for decision-making that significantly benefits the industrial sector by improving maintenance processes through the weighting of multiple criteria.

The implementation of a maintenance model selection tool, based on key factors such as costs, failure recurrence, and the comparison of expenses related to failures and repairs, will enable organizations to optimize resource utilization, enhance the reliability and availability of their assets, and consequently extend their useful life. This can be achieved without compromising the effectiveness of each maintenance model and without incurring excessive or insufficient expenditures, which constitutes a competitive advantage in today's environments characterized by intense competition and constant change.

Therefore, the validation of this model will deliver concrete results in terms of cost reduction and increased equipment availability, demonstrating the positive impact of an appropriate selection of maintenance models in the industrial sector. Moreover, it highlights the value of adopting an efficient decision-making methodology in contrast to the empirical approaches that still predominate in current industrial practices.

FUTURE RESEARCH DIRECTIONS

There are several opportunities to continue and expand this line of research. First, it would be valuable to investigate the integration of advanced data analysis techniques, such as machine learning, to optimize the selection of maintenance models and minimize the impact of unforeseen factors or operational changes.

Additionally, the applicability of the tool could be explored in different industrial sectors, considering the variability of processes and equipment used, to further refine the accuracy of decisions. It would also be important to study the impact of implementing the tool on operational efficiency and the reduction of real-time failures, providing continuous evaluation that allows for proactive adjustments to maintenance strategies.

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A special thanks to the National Council of Humanities, Sciences, and Technologies (CONAHCYT) for the support provided through the National Scholarships Program for Graduate Studies 2023-2, for the publication of this article.

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