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Hydraulic projects prioritization in the steel industry: An analytic hierarchy process approach

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Abstract. The increased use of high-precision operational functions in the steel industry makes hydraulic systems one of the items that require more attention. The prioritization in the modernization of hydraulic projects is one of the critical issues in maintenance management, which involves multiple criteria that should be considered. To solve such problems, multi-criteria decision methods are considered an advantage. To define the model's multi-criteria structure, the Benefits, Opportunities, Costs, and Risks, based on Analytic Hierarchy Process, were applied, considering the possibility of group decision-making. The aim of this research is to propose an evaluation framework for the prioritization of hydraulic projects in the steel industry. With this study, managers and executives can define adequate policies and methods that allow them to guide their decisions in a clear way. Three alternatives were associated with criteria and sub-criteria, available in a hierarchical decision tree, based on the literature and feedback received from

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the industry experts. The proposed model was applied in a steel plant located in the Brazilian State of Rio de Janeiro. As a general result, this research contributes to the development of a useful decision support tool, enabling a clear view of the most significant factor disposed on a hierarchical tree, and the priority classification of hydraulic system projects in the context of the steel industry.

Keywords: AHP; BOCR; Hydraulic systems; MCDM; Project selection; Steel industry.

1. Introduction

In industrial plants, hydraulic systems play a crucial role in the operational processes, where some breakdowns of specific equipment may lead to severe consequences, like environmental disasters and personal accidents. Such problems can result in a production downtime leading to a heavy loss of profits [1]. Continuous improvement within an organization requires specific strategies to achieve its main goals. The project's implementation focuses on a strong improvement of the operational performance, which directly influences the result of the company. The most common project selection errors are related to an inadequate choice of resources. Therefore, project prioritization is a process that aims to create a ranking of pre-established relevant criteria to allocate resources effectively [2].

The hydraulic equipment in an organization or linked processes to them may result in costs associated with lost production as penalties, lower availability, or increased operational risks. In this context, the prioritization of projects for hydraulic systems needs proper treatment, where multi-criteria decision-making (MCDM) techniques can help with fundamental decisions according to the desired level of service, with the lowest possible risk.

The Analytic Hierarchy Process (AHP) is one of the most popular and widely applied MCDM methods, it is easy to understand and apply [3]. The AHP connected with a Benefits, Opportunities, Costs, and Risks (BOCR) analysis allows the decision-maker to consider the positive and negative aspects of the problem separately, which will promote an improvement in the procedure's effectiveness [4].

For these reasons, our main goal is to propose an evaluation framework for hydraulic projects prioritization in the steel industry. This research seeks to develop strategies to assist managers in decision-making by identifying the criteria and sub-criteria, that satisfy the appropriate requirements for a critical assessment of projects prioritization, which can be solved through MCDM. The AHP was developed by Prof. Thomas Saaty [5, 6] is an MCDM method of great value due to its efficiency and flexibility in assisting decision-making, which has been applied to several problems due to its applicability and simplicity [7].

Considering this context, our research question is: How to apply the AHP-BOCR approach to develop an evaluation framework for hydraulic project prioritization in the steel industry? This manuscript has four more sections: Section 2 describes the literature review giving the theoretical background, Section 3 displays the research methodology, Section 4 presents the results where the proposed framework is applied to a real case, and Section 5 presents conclusions, highlighting the findings and contributions of this paper.

2. Literature review

The prioritization of projects has been widely studied in recent years, where through the Scopus database, with the combination of the words: "projects prioritizations" or "projects selection", and "MCDM" or "MCDA" or "Decision-Making" or" Multicriteria" or "AHP" or "Analytic Hierarchy Process", from 2013 to 2023 (first month), were totalizing 504 scientific articles. A selection of fifty articles relevant to the theme of this research focused on decision-making approaches like AHP, AHP-BOCR, applied to maintenance, steelmaking, and hydraulic systems. The selected papers are related to open access, articles/reviews, conference papers, and the English language.

2.1. Multi-criteria decision-making methods (MCDM)

MCDM is applied to various management decision problems such as technical, economic, and social, among others. These problems sometimes need to be thoroughly evaluated since organizations need to produce more, with higher quality and in less time, with a reduced cost [8]. MCDM is separated into two different sections: Multi-Attribute Decision Making (MADM) and Multi-Objective Decision Making (MODM). MADM consists of a limited finite number of alternatives, the MODM is a mathematical method that deals with infinite alternatives [9, 10].

2.2. AHP BOCR

The AHP [5, 6, 11] is one of the most applied MCDM methods for decision-making problems in several areas such as industry, engineering, logistics, computer science, health, education, and mathematics [9]. Regarding the MCDM for solving problems with uncertainty, the AHP - BOCR method was preferred due to its ease of applicability.

A clear understanding of sustainability evaluation associated with BOCR analysis can provide a clear understanding of the interdependencies of projects' benefits (B), opportunities (O), costs (C), and risks (R) in terms of exploiting the B and O and avoiding the C and R [12]. The BOCR analysis is applied to build a criteria system, which provides a clear understanding of the benefits, opportunities, costs, and risk issues that may influence the sustainability evaluation [13].

2.3. Classification Criteria

The study was conducted qualitatively through the criteria identified in the bibliographic research and by experts' judgments, and quantitative based on quantifiable data from the three sub-criteria of costs. Table 1 summarizes the sub-criteria identified in the literature.

Table 1. Criteria and sub-criteria

Criterion	Sub-criterion	Reference
	Cleaner production (B1)	[13]
Benefits	Sustainable industrial income (B2)	[13]
	Occupant's satisfaction (B3)	[14]
	Compliance with regulations (O1)	[14]
Opportunities	Product differentiation (O2)	[15]
	Sharing technology and knowledge (O3)	[15]
	Operation and maintenance (C1)	[16]
Costs	Investment (C2)	[16]
	Training (C3)	[14]
	Dependency of foreign technology (R1)	[16]
Risks	Inadequate supervision and management (R2)	[13]
	Dependency on few suppliers (R3)	[15]

3. Materials and Methods

This study was led in a steel industry located in south-eastern Brazil with more than 10,000 workers who operate large equipment such as blast furnaces, hot and cold strip mills, casting lines, among others. In this type of plant, sometimes it's a challenge to determine the prioritization of the needs of hydraulic systems projects modernization since some of these projects hold a different criticality level relating to the production and maintenance priorities. Along the same line, the arrangement of the project's prioritization in a hierarchical tree with weights based on quantitative and qualitative criteria helps to formulate the research problem.

The quantitative analyses were based on the existing data and information from the costs associated to the hydraulic project, and the qualitative analysis was carried out through judgments that have been made by experts through their individual experience and knowledge, aiming to achieve an assertive conclusion of the most relevant project to prioritize.

The decision problem deals with the prioritization of three alternatives:

- Project 1: Modernization of the hydraulic system in the entry section. Complements the power unit, filtration and cooling unit, accumulator unit, and four hydraulic benches.
- Project 2: Modernization of the hydraulic system in the central section. Complements the power unit, filtration and cooling unit, accumulator unit, and three hydraulic benches.
- Project 3: Modernization of the hydraulic system of coil turner. Complements the power unit, filtration and cooling unit, accumulator unit, and one hydraulic bench.

The expert interviews were made as follows: Two engineers from the maintenance engineering department and one engineer from the production area. Their opinions were equally taken since all the experts are engaged with project management.

3.1. Method

For the AHP BOCR method application, the developed hierarchy is shown in Figure 1.

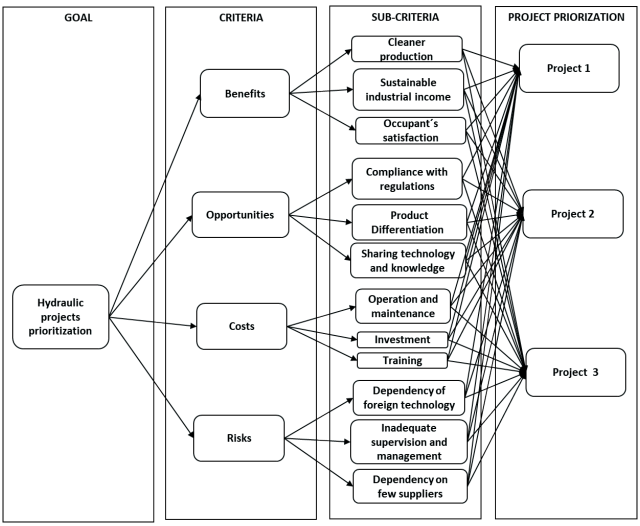

Figure 1. Hierarchy for AHP application

Experts from the plant compare criteria and sub-criteria items according to their relative importance, referred to as priority in the AHP BOCR. The basis for comparison is the Fundamental Scale, also known as the Saaty Scale [6] presented in Table 2.

Table 2. Saaty Scale

Value	Definition
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong Importance
9	Extreme Importance
2, 4, 6, and 8	Intermediate Importance

In the AHP, each expert uses Table 2 and sets up a comparison matrix ***A***. The aggregate comparison matrix ***A*** is obtained through the aggregate comparison of matrices ***A*** with their geometrical mean. The aggregation of individual judgments (AIJ) is indicated when the experts work in the same company [17]. Priorities are obtained with the right eigenvector ***w*** of ***A***, as presented in Eq. (1), where λ_{max} is the maximum eigenvalue of ***A*** [18].

$$\boldsymbol{A}\,\boldsymbol{w} = \lambda_{\max}\,\boldsymbol{w} \quad (1)$$

The Consistency Index *CI* is a measure of the consistency of ***A***. *CR* compares λ_{max} with the matrix order *n*, the number of comparing elements (alternatives or criteria). *CI* can be calculated according to Eq. (2).

$$CI = \frac{(\lambda_{\max} - n)}{(n-1)} \quad (2)$$

The Random Index *RI* can be obtained in Table 3 as a function of *n* [6].

Table 3. Random Index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The Consistency Ratio *CR* is a better measure of the consistency of ***A***. *CR* compares *CI* with *RI*, according to Eq. (3).

$$CR = \frac{CI}{RI} \quad (3)$$

Consistent matrices have $l_{max} = n$, then $CI = 0$ and $CR = 0$. Inconsistent matrices have at least one comparison, resulting in $l_{\max} > n$. It is pertinent that CR should not be greater than 0.1. If it happens, a review of the judgments will be required.

4. Results

Three experts have been interviewed and gave values for each variable regarding the application of the AHP BOCR method. The aggregated comparisons have been easily computed using Excel, where in Table 4 are presented the values in which the sub-criteria B3, O1, C1, and R2 demonstrated the highest priority. The obtained results are in accordance with the demands of operational reliability for hydraulic projects in the steel industry. The comparison obtained a consistent judgment index, since the CR are within the acceptable value (≤ 0.1), thus validating the experts' judgments.

Table 4 - Aggregated priority of sub-criteria

B	Cleaner production (B1)	Sustainable industrial income (B2)	Occupant's satisfaction (B3)
19.228%	6.528%	4.425%	8.276%
O	Compliance with regulations (O1)	Product differentiation (O2)	Sharing technology and knowledge (O3)
38.982%	27.886%	2.661%	8.435%
C	Operation and maintenance (C1)	Investment (C2)	Training (C3)
30.714%	13.626%	4.061%	13.027%
R	Dependency of foreign technology (R1)	Inadequate supervision and management (R2)	Dependency on few suppliers (R3)
11.076%	4.246%	4.439%	2.392%

Secondly, priorities for the selected projects according to the proposed Table 5 must be assigned.

Table 5 – Alternating weights

Level	Description	Priority
1	Poor	40%
2	Fair	50%
3	Good	70%
4	Very Good	85%
5	Excellent	100%

Table 6 presents the priorities of Projects 1, 2, and 3 according to sub-criteria.

Table 6 – Project Priority

		Priority	Project 1	Project 2	Project 3
B	B1	6.528%	85%	50%	70%
	B2	4.425%	85%	50%	70%
	B3	8.276%	100%	85%	100%
O	O1	27.886%	100%	100%	100%
	O2	2.661%	100%	70%	40%
	O3	8.435%	100%	100%	100%
C	C1	13.626%	100%	100%	100%
	C2	4.061%	40.%	70.%	70%
	C3	13.027%	100%	100%	100%
R	R1	4.246%	85%	85%	85%
	R2	4.439%	40%	40%	40%
	R3	2.392%	70%	70%	70%
		Overall	91.5%	87.3%	90.0%

Project 3 has the highest priority. The final overall priority order is Project 1 > Project 3 > Project 2.

5. Conclusions

This study presented an approach to develop an evaluation framework for hydraulic project prioritization in the steel industry, using the AHP BOCR method with weights, where the proposed objective of this study was reached through an assertive conclusion of the most relevant project to prioritize. To pursue the objectives of this research, the AHP-BOCR method has been combined with a literature review, which has become fundamental in establishing the sub-criteria. The elaborated decision hierarchy allows the segmentation of priorities where the sub-criteria that demonstrated the highest relevance were: B - occupant´s satisfaction, O - compliance with regulations, C - operation and maintenance, and R - inadequate supervision and management. The ranking order of prioritization of the projects was Project 1, Project 3, and Project 2. A preference matrix that holds the pairwise comparisons provide a perspective with valuable guidelines that can influence the weights for the final decision. Through the criteria and sub-criteria results overviewing, the users can have a greater assertiveness in decision-making. The proposed framework for hydraulic project prioritization in the steel industry with the application of the AHP- BOCR methodology matches the research question once makes it easier to identify the most relevant sub-criteria, which proves to be a useful tool for helping managers with decision-making problems. For future studies, the same methodology can be applied to other classification arrangements, such as logistics, financial area, and so on.

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References

1. Alenany, A., Helmi, A. M., & Nasef, B. M. (2021). Comprehensive analysis for sensor-based hydraulic system condition monitoring. International Journal of Advanced Computer Science and Applications, 12(6), 133-140. http://doi:10.14569/IJACSA.2021.0120615
2. Rudnik, K., Bocewicz, G., Kucińska-Landwójtowicz, A., & Czabak-Górska, I. D. (2021). Ordered fuzzy WASPAS method for selection of improvement projects. Expert Systems with Applications, 169 doi:10.1016/j.eswa.2020.114471
3. Canco, I., Kruja, D., & Iancu, T. (2021). AHP, a reliable method for quality decision making: A case study in business. Sustainability, 13(24). http://doi.org/10.3390/su132413932
4. Cafasso, D., Calabrese, C., Casella, G., Bottani, E., & Murino, T. (2020). Framework for selecting manufacturing simulation software in industry 4.0 environment. Sustainability (Switzerland), 12(15) doi:10.3390/SU12155909
5. Saaty, T. L. (1974). Measuring the fuzziness of sets. Journal of Cybernetics, 4(4), 53-61. http://doi:10.1080/01969727408546075
6. Saaty, T. L. (1980). The analytic hierarchy process. New York: McGraw-Hill.
7. Saaty, T. L., & Vargas, L. G. (2001). Models, Methods, Concepts & Applications of the Analytic Hierarchy Process. Boston, MA: Springer US. http://doi:10.1007/978-1-4615-1665-1
8. Ohta, R., Salomon, V. A. P., & Silva, M. B. (2018). Selection of industrial maintenance strategy: Classical AHP and fuzzy AHP applications. International Jour-

nal of the Analytic Hierarchy Process, 10(2), 254-265. http://doi:10.13033/ijahp.v10i2.551

9. Martino Neto, J., Salomon, V. A. P., Ortiz-Barrios, M. A., & Petrillo, A. (2022). Compatibility and correlation of multi-attribute decision making: A case of industrial relocation. Annals of Operations Research, http://doi:10.1007/s10479-022-04603-9

10. Rahman, H. U., Raza, M., Afsar, P., Alharbi, A., Ahmad, S., & Alyami, H. (2021). Multi-criteria decision making model for application maintenance offshoring using analytic hierarchy process. Applied Sciences (Switzerland), 11(18). http://doi:10.3390/app11188550

11. Saaty, T. L. (2013). Principia mathematica decernendi. Pittsburgh, PA: RWS Publications

12. Tabatabaee, S., Mahdiyar, A., Durdyev, S., Mohandes, S. R., & Ismail, S. (2019). An assessment model of benefits, opportunities, costs, and risks of green roof installation: A multi criteria decision making approach. Journal of Cleaner Production, 238 doi:10.1016/j.jclepro.2019.117956

13. Wei, Q. (2021). Sustainability evaluation of photovoltaic poverty alleviation projects using an integrated MCDM method: A case study in guangxi, china. Journal of Cleaner Production, 302 doi:10.1016/j.jclepro.2021.127040

14. Neves-Silva, R., & Camarinha-Matos, L. M. (2022). Simulation-based decision support system for energy efficiency in buildings retrofitting. Sustainability (Switzerland), 14(19) doi:10.3390/su141912216

15. Kumar, D. (2019). Buyer-supplier relationship selection for a sustainable supply chain: A case of the indian automobile industry. International Journal of the Analytic Hierarchy Process, 11(2), 215-227. doi:10.13033/ijahp.v11i2.605

16. Alizadeh, R., Soltanisehat, L., Lund, P. D., & Zamanisabzi, H. (2020). Improving renewable energy policy planning and decision-making through a hybrid MCDM method. Energy Policy, 137 doi:10.1016/j.enpol.2019.111174

17. Saaty T.L., & Peniwati, K. (2013). Group decision making. Pittsburgh, PA: RWS Publications

18. Saaty, T. L. (1977). A scaling method for priorities in hierarchical structures. Journal of Mathematical Psychology, 15(3), 234–281. https://doi.org/10.1016/0022-2496(77)90033-5