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A MULTI-CRITERIA DECISION MODEL FOR CLASSIFYING BEST PRACTICES TO REDUCE MAKING-DO WASTE

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ABSTRACT

This paper proposes a multi-criteria decision-making model, combining the Fuzzy-Delphi and TOPSIS techniques, to support managers in making decisions to determine management practices with the best impact to improve efficiency and reduce waste while guaranteeing the prerequisites of planned activities. The approach combined the opinions of decision-makers interviewed and later integrated into a decision matrix involving multiple criteria, the subjectivity of the views in classifying alternatives, and the weights assigned. The proposed model showed the diversity of the model's application and the importance of the results guaranteeing a complete kit for reducing making-do waste. It is concluded that the three best management solutions that most influence the guarantee of the prerequisite activities are process standardization, event simulation, and Lean practices.

KEYWORDS

Improvisation, categories, impacts, making-do waste, civil construction.

INTRODUCTION

According to the Brazilian Chamber of the Construction Industry (CBIC) (2024), civil construction was responsible for 16% of the total number of new formal jobs generated in 2023, reinforcing the sector's ability to promote the economy. Despite its representativeness, the construction sector faces significant challenges in growing demand for quality, generating pressure on production factors, especially skilled labor, creating shortages and raising costs.

Indeed, higher production costs associated with waste in construction processes are attributed to inefficiencies in project management and the use of equipment, materials, labor, and capital (Formoso et al., 2017). Several authors over the years, such as Ohno (1988) have developed studies that highlight and reinforce the importance of planning, managing, and

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controlling works as a way of mitigating wastes in the construction industry. In order to improve the problems highlighted, the focus is on concepts aimed at improving the production system, and among the various solutions, the Lean Philosophy stands out as relevant to the need to increase the quality of the construction process, standardization, high variability, reduction of production costs associated with wastes during construction processes by providing principles and tools capable of improving planning and control (Koskela, 2004).

Many companies in the construction sector face limitations related to the absence of the complete kit (prerequisites to perform a specific task), resulting in unpredictable works, problems that are linked to variability in production processes and informalization of the work package (Koskela, 2004; Ronen, 1992). This lack of ideal start-up conditions can lead to making-do waste. Koskela, Bølviken, and Rooke (2013) point to making-do as central construction waste and the leading cause of other wastes. The terms unfinished work, work in progress, buffer, rework, work completion, and work stoppage have been reconceptualized over lean history to be associated with making-do.

However, it should be noted that these terms already had the theoretical basis of making-do (Ronen, 1992). Since then, studies have been developed in various stages of life to apply the concept of making-do waste for minimization or the elimination of activities that do not add value to the process. Examples vary such as project preparation (Neve & Wandahl, 2018), construction site logistics (Ghanem, Hamzeh, Seppänen & Zankoul, 2018), the supply chain (Taggart, Koskela & Rooke, 2014), and production slack (Fireman, Saurin & Formoso, 2018). Other studies related to making do are applied for developing or augmenting methods or tools to facilitate the identification of these wastes (Leão; Formoso et al., 2016) or by identifying other wastes in a cause-and-consequence discussion concerning making-do waste (Koskela et al., 2019). Amaral et al. (2023) deepened the studies related to making-do waste by presenting possible correlations between prerequisites, categories, and impacts. They evaluated 6,339 compliance and non-compliance data items in a comparative analysis between two different cities, making it possible to understand the scenario of multi-family residential developments under different contexts. Moreover, they also identified the causes and recurrence of waste generated by each missing prerequisite while understanding the existence of activities that can benefit the production system.

Good practices in the construction area can be understood as solutions used to suppress interruptions in some activity on the construction site (Valente & Aires, 2017). According to the authors, adopting good practices and structured management methods makes the results more transparent, impacting costs, deadlines, and quality. According to Amaral et al. (2024a), many of these good practices are implicit in the knowledge of construction managers and are applied informally in practice. The authors proposed a methodology to identify suitable management practices according to their application in the life cycle of a construction project. The good practices identified were those that can reduce the occurrence of making-do waste by ensuring compliance with the requirements of the complete kit.

The analysis of which strategy to follow, based on the problem identified, requires expert judgment. To do so, managers must consider the context, considering the variables involved and the resources available. To assist in this process, a multi-criteria analysis can be carried out, in which, among the various efficient solutions, the most effective one must be chosen, considering several simultaneous criteria. Clemen & Reilly (2001) describe that decision-making is generally a complex task, as it involves multiple conflicting objectives. Achieving one objective may require renouncing another due to the absence of a course of action that manages to meet all of them simultaneously. Decision methods considering more than one criterion are defined as multi-criteria decision methods (MCDM). In these methods, some alternatives are evaluated according to several defined criteria, with each criterion leading to a particular ordering of the alternatives, which makes it necessary to adopt some mechanism capable of constructing a general ordering of preferences, called ranking (Kahraman, 2008).

The Fuzzy-Delphi method (FDM) was proposed by Murray, Pipino & Gatch (1985) and later presented by Kaufmann & Gupta (1988) and Ishikawa et al. (1993). FDM represents a formal communication technique or strategy, initially conceived as a methodical, interactive, and predictive procedure based on a panel of experts. Applying the Fuzzy-Delphi method to group decision-making can resolve the imprecision of the common understanding of expert opinions. The experts' prediction (or interval value) was then used to derive the fuzzy numbers, resulting in the Fuzzy-Delphi method (FDM).

FDM was selected because it combines fuzzy set theory with a Delphi approach (Ishikawa et al., 1993) to include the uncertainty of the decision-making process and expert analysis. FDM is an expert opinion survey technique that includes three main aspects: anonymous response, interaction with controlled feedback, and statistical response from the group.

Meanwhile, the TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method was proposed by Tzeng & Huang (2011) and has been widely used to rank alternatives in order of preference. The basic principle of TOPSIS is to choose an alternative as close as possible to the positive ideal solution and as far away as possible from the negative ideal solution. The positive ideal solution is formed by taking the best values the alternatives achieve while evaluating each decision criterion. In contrast, the negative ideal solution by taking the worst values (Kahraman, 2008).

Based on the context presented, this article aims to propose a multi-criteria decision-making model, combining FDM and TOPSIS methods, to help managers make decisions when determining a good management practice that has the best impact on guaranteeing the prerequisites of planned activities.

METHODOLOGICAL APPROACH

This study used the methodological approach of the decision-support process proposed by Morais & Almeida (2006). The Fuzzy-Delphi method was selected to collect and evaluate the opinions of several decision-makers. It provides a more accurate result than using the arithmetic average. In the case of TOPSIS, it is a simple, widely used, and recognized method. Thus, the Fuzzy-Delphi method was used, using the consistency aggregation method to form a consensus among the experts and determine a single decision matrix, which was then submitted to the TOPSIS method, which proposes ordering alternatives.

DESCRIPTION OF THE PROBLEM

Defining the problem is the first step in the decision-making process for applying a multi-criteria method. The problem, in the context of the construction industry, is the need to improve the management and efficiency of the sector, addressing studies on actions that can be considered beneficial to the process. The solution would be actions to guarantee the prerequisites for the start of activities and avoid making-do wastes.

To assign weights, 10 (ten) experts were selected as decision-makers in their fields. These professionals were selected based on their professional experience and decision-making power within the work environment in which they operate, ensuring that each decision-maker had the necessary expertise to assess the established criteria. The decision-makers ranked the importance of alternatives concerning the criteria according to the linguistic variables: information, materials and components, labor, equipment/tools, temporary facilities, interdependent tasks, external conditions, and space.

Table 1 details the characterization of the decision-makers. The weight for each criterion was classified according to the scenario in which the method was applied, according to the linguistic variables: very low, low, medium, high, and very high. Based on this evaluation, those items "low" in one of the criteria were disregarded. The evaluations were aggregated using the average of the linguistic terms used for each evaluation criterion. Table 2 details the linguistic variables used as evaluation terms by the decision-makers

Table 1: Characterization of decision-makers

Graduation	Number	Professional experience	Number	Decision degree	Number
Student	Up to 5	N.A (Not Applicable)	0	N.A (Not Applicable)	0
Completed higher education	1	Between 5 and 10 years	6	Operational	1
Postgraduate	6	Between 10 and 15 years	3	Tactical	7
Master's degree or above	3	Over 15 years	1	Strategic	2

Table 2: Characterization of decision-makers' importance degree

Level Education	Professional experience (years)	Decision degree	Linguistic variable	l	m	u	Fuzzy triangular number
Student	Up to 5	N.A (Not Applicable)	Low	0	0.2	0.4	0; 0.2; 0.4
Completed higher education	Between 5 and 10	Operational	Average	0.2	0.4	0.6	0.2; 0.4; 0.6
Postgraduate	Between 10 and 15	Tactical	High	0.4	0.6	0.8	0.4; 0.6; 0.8
Master's degree or above	Over 15	Strategic	Very high	0.6	0.8	1	0.6; 0.8; 1

A triangular fuzzy number can be written in the form (l, m, u), where l and u represent the bases, and m is the middle of a triangular fuzzy number. A fuzzy set is interpreted as the bridge that connects the imprecise concept to its numerical modelling, giving everyone in the universe a value between 0 and 1, representing the degree of this individual's pertinence to the fuzzy set. Fuzzy logic can deal with highly variable, linguistic, undefined, or uncertain data or knowledge and can provide logical, reliable, and transparent information.

Amaral et al. (2024a) identified good management practices that can act as facilitators in meeting the minimum requirements of the complete kit. The authors proposed a classification according to their application in the construction life cycle: feasibility, construction, or design. The results made it possible to evaluate the options for implementing actions for each phase to avoid making-do waste. Specifically, in this work, management solutions applied during the execution and design stages were selected from Amaral et al. (2024a) as evaluation alternatives for model testing and determination. Some similar concepts were grouped to determine the alternatives to be evaluated and have been conceptualized according to their practical applications on construction sites, as shown in Table 3.

Table 3: Conceptualization and application of alternatives

Management Solutions	Concept	Application	References
BIM	Methodology that integrates all the data necessary to build a facility	Parametric modeling, improved representation of the project; Team coordination, quantities, budgets, and schedules; Information and time management	Menezes (2011)
Lean	Philosophy whose objective is to eliminate waste, reduce costs, minimize internal supplier variability, and meet customer requirements	Physical production processes Management processes Project process Production planning and control process	Shah and Ward (2007)
Supply chain management	Management of all activities involved in supply chain logistics	Managing the process of purchasing and receiving materials; Supplier qualification and evaluation; Inventory control	Goldsby & Martichenko (2005)
Project management	Set of processes used in a project to produce a product or service	Management of deadlines, costs, and quality; Strategic and performance planning; Knowledge and skills management; Benchmarking	Ika (2009) Alberico (2018)
Big Data	Advanced analytical techniques operating on large data sets	Big data management; Data analysis through mathematical and computational techniques	Munaro (2020)
Disruptive digital technologies	Technologies whose insertion into the market can alter or break an established paradigm	Workplace Automation, Internet of Things, Cloud Technology; Advanced Robotics; Autonomous Vehicles; Energy Storage; 3D Printing; Artificial Intelligence	Schuelke-Leech (2018)
Event simulation	Multiplication of human ability through the contribution of knowledge and the ability to interact and perform an increasing number of functions within the production process	Computer simulation (software); Simulation of planning; programming, and coordination of activities to control time and cost	Banks (1998)
Versatility of the workforce	Multiplication of human capacity through the ability to interact and perform an increasing number of functions in the production process	Increased productivity; Reduced hiring costs; Lower turnover; Process flexibility	Cardoso et al. (2019)
Process standardization	Process standardization is establishing consistent, uniform business procedures and process documentation for performing specific tasks	Process performance indicators; Standard operating procedures	Corcarelli (2010)

The alternatives were structured, and the criteria used to evaluate them in a multi-criteria decision-making model. The evaluators assessed the degree of influence of management solutions on guaranteeing the prerequisites of planned activities.

DECISION-MAKING MODEL

The adopted multi-criteria decision-making model integrates the FDM method with the TOPSIS method. This integration aggregates experts' opinions and ranks the alternatives to identify the best possible alternative when comparing multiple criteria.

METHOD FUZZY-DELPHI

The first step was to assess the importance of each criterion for the decision-makers using fuzzy numbers. Semi-structured interviews were conducted with the experts to assess the importance of the criteria with the question: "What is the degree of influence of good practices in guaranteeing the prerequisite in the complete kit concept?". The decision-makers started with a linguistic classification, as shown in Table 4.

Table 4: Importance of criteria

Linguistic variables for decision-maker assessment	Fuzzy triangular number		
	l	m	u
Very Low	0	0.1	0.2
Low	0	0.2	0.4
Average	0.2	0.4	0.6
High	0.4	0.6	0.8
Very high	0.6	0.8	1

The next step was to create a weighted matrix that considered the weight of the decision-makers. The weighted aggregation of the decision-makers' evaluations was carried out according to the weight of each decision-maker, by multiplying the decision-makers' weight matrix with the evaluation matrix. We then calculated each criterion's degree of performance value (Gi) (Equation 1).

$$G_i = \left(\frac{(U_i - L_i) + (M_i - L_i}{3}\right) + L_i \quad (1)$$

Where: U_i: maximum value of m in the evaluation matrix. L_i: minimum value of l in the evaluation matrix. M_i: geometric average of m in the evaluation matrix. Finally, the decision matrix D is drawn up.

METHOD TOPSIS

The resulting decision matrix ($\widetilde{D}$) from the FDM application was used with the weight vector W to apply the TOPSIS method.

$$\widetilde{D} = \begin{array}{c c} & \begin{array}{ccc} C_1 & C_2 & C_j \end{array} \\ A_1 \dots A_n & [d_{11}\ d_{12} \dots d_{nm}] \end{array} \quad (2) \qquad \widetilde{W} = [\widetilde{w}_1 + \widetilde{w}_2 + \cdots + \widetilde{w}_m] \quad (3)$$

Where A is the alternatives to be evaluated; C is the evaluation criteria, d is the result of the evaluation of alternative (A) in relation to criterion (C); and W is the weight of the criteria. The matrix was normalized according to Equation: $x' = (x - min(x)) / (max\ (x) - (min\ (x)\big)$. Where x' is the normalized value; x is the non-normalized value; $min\ (x)$ is the minimum value of x; and $max\ (x)$ is the maximum value of x. The normalized matrix with the respective weights was then calculated by multiplying the normalized matrix by the respective weights of the criteria. The weights for each criterion were calculated according to the criteria of each decision-maker. In this work, the criteria were defined based on the work of Amaral et al. (2023), in which the causes and recurrence of the missing prerequisites that generated the making-do wastes were explored. It was determined that the weight of the missing prerequisites that showed more significant recurrence in the classification would have greater weight. Using the classified data from Goiânia and Fortaleza, the missing prerequisites with the highest recurrence were information, materials and components, labor, and interdependent tasks, which were classified with a very high weight. The prerequisites with the least recurrence were equipment and tools, temporary facilities, external conditions, and space, which were classified as medium weight.

The evaluation of the method began with the alternatives proposed to guarantee the planning criteria for the activities. Good practices were defined as alternatives for the decision-making matrix, while the prerequisites were defined as criteria. The evaluation matrix proposed to assess the degree of influence of good practices in guaranteeing the complete kit of planned activities is composed of the alternatives A={A1-BIM, A2-LEAN, A3-Supply chain management, A4-Project management, A5-Big Data, A6- Disruptive (digital) technologies, A7-BIM, A8-Versatility of the workforce, A9-Standardization of services} and criteria C={C1-Information, C2-Materials and components, C3-Workforce, C4-Equipament or tools, C5-Temporary facilities, C6-Interdependent tasks, C7-External condition, C8-Space}. The method combines the weights assigned and the choices made by the experts to classify the ideal solution. These data are important criteria as they contribute effectively to decision-making.

To analyze the behavior of the alternatives in different scenarios, simulations were carried out in which different weights were considered for the criteria. Table 5 shows the weights considered for each criterion and the scale of the criteria weights. The weights were normalized to ensure that the total sum of the weights was equal to 1.

Table 5: Weight criterion relationship

Prerequisites	Weight	Numerical scale
Information	Very high	5
Materials and components	Very high	5
Workforce	Very high	5
Equipment and tools	Average	3
Space	Average	3
Interconnected services	Very high	5
External conditions	Average	3
Installations	Average	3

The positive ideal solution (PIS) and the negative ideal solution (NIS) were then calculated using equations 5 and 6.

$$S+ = \{(vij \mid j \in J), (minvij \mid j \in J')\} \quad (5) \qquad S- = \{(vij \mid j \in J), (minvij \mid j \in J')\} \quad (6)$$

Where: j and J' represent the set of criteria. For each alternative, the Euclidean distance of each evaluation is calculated for the vector of solutions S+ and S-. Equations 7 and 8 are used for this.

$$Di+ = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_+)^2} \quad (7) \qquad Di- = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_-)^2} \quad (8)$$

Where $Di+$ and $Di-$ is the positive and negative ideal distance, respectively; vij represents the maximum evaluation of each criterion, and vj represents the evaluation of the alternative in each criterion. Finally, the relative proximity to the positive ideal position is determined using the approximation coefficient CC_i according to Equation 9, which corresponds to the overall performance (or final score) of alternative i.

$$CC_i = \frac{D_i^-}{D_i^+ + D_i^-}, i = 1,2, \ldots, m. \quad (9)$$

The alternatives were ranked in descending order according to the results of the CC_i coefficient. The alternative with a relative proximity closest to 1 was considered ideal, while the one with a result closest to 0 was considered anti-ideal.

RESULTS AND DISCUSSIONS

The result of applying the method is the alternative considered ideal within the scenario of the decision-maker's classification and the criteria weights. The weights assigned by the decision-makers were Very High 20.0%, Medium 26.7% and High 53.3%. The decision-makers selected to have high (53.3%) and very high (20.0%) weights concerning the pre-defined classification criteria. The Fuzzy-Delphi method allowing for better uncertainty management and subjectivity in the experts' opinions. It was possible to represent the uncertainty and imprecision of the answers by relating the linguistic variables of the importance of the decision-makers evaluation criteria to fuzzy numbers. The method improved the validity of the decisions based on feedback during the interviews, which ensured that the decision-makers final decision matrix was well-founded and accepted. The decision-making matrix shown in Table 6 reflects the collective opinions after the direct influence of the experts' weights.

Table 6: Resulting decision matrix

Alternatives	Criteria							
	Information	Materials and components	Workforce	Equipment Tools	Temporary facilities	Interdependent tasks	External conditions	Space
BIM	0.47714	0.43055	0.32809	0.29743	0.26277	0.43055	0.30307	0.39934
LEAN	0.43753	0.43080	0.42278	0.39308	0.29230	0.41302	0.30531	0.40056
Supply chain management	0.43753	0.51896	0.38224	0.38224	0.25946	0.32341	0.40827	0.36002
Project management	0.45162	0.37210	0.34794	0.30604	0.26087	0.38005	0.31966	0.33948
Big Data	0.42404	0.41230	0.42404	0.30604	0.23571	0.32346	0.28460	0.28874
Disruptive (digital) technologies	0.44370	0.41460	0.42669	0.41137	0.33191	0.36710	0.27248	0.34794
Event simulation	0.40701	0.39857	0.42669	0.41797	0.38852	0.42044	0.39013	0.39672
Versatility of the workforce	0.33780	0.42669	0.52759	0.38894	0.27248	0.47869	0.25816	0.31238
Standardization of services	0.48020	0.50692	0.50563	0.49749	0.32476	0.45705	0.24704	0.36113

The decision method used the TOPSIS matrix to calculate the distance of each alternative from the ideal solution, allowing an objective ranking of the alternatives. Each alternative was given a score, which makes it possible to understand how good or bad each alternative is concerning the others.

With the TOPSIS method, it was possible to use weights for the evaluation criteria. These weights were fundamental in reflecting the relative importance of each criterion in evaluating the alternatives. The relative importance of the criteria was defined based on the experts' assessment. Table 7 illustrates the decision matrix resulting from aggregating the weights of each criterion and the maximum positive and negative solutions.

Table 7: Calculation of maximum solutions

Criteria		Information	Materials and components	Workforce	Equipment/ tools	Temporary facilities	Interdependen t tasks	External conditions	Space
Maximum solution+	S+	0.156	0.156	0.156	0.094	0.094	0.156	0.094	0.094
Maximum solution -	S-	0	0	0	0	0	0	0	0

This step resulted in the calculation of the maximum solutions. The ideal positive solution is the best possible for each criterion, representing the most desirable performance an alternative can achieve, while the ideal negative solution is the worst possible for each criterion, i.e., the least desirable performance. If the maximum negative solution is zero, the alternative has no disadvantage for the criteria, i.e., as all the good management practices have shown positive results about the prerequisites, they do not negatively influence the guarantee of the prerequisites. These two references are used in TOPSIS to rank the alternatives. The method continues with calculating Euclidean distances, which calculates the shortest straight line between two points. In the context of TOPSIS, this calculates how close each alternative is to the ideal solutions. The interpretation of the results of the calculations of the ideal solutions and Euclidean distances can be interpreted as positive ideal solution is the best possible performance; negative ideal solution is the worst possible performance. Positive Euclidean distance: the lower the result, the better. Negative Euclidean distance: the higher the result, the better.

Thus, in the final TOPSIS ranking, alternatives with smaller positive Euclidean distances and more considerable negative Euclidean distances tend to be ranked higher, as they are closer to the ideal solution. In the application, alternative 9 (process standardization) tends to be ranked higher, as it had a lower Euclidean distance value about the positive ideal solution. Alternative 5, on the other hand, had a higher Euclidean distance value, indicating lower performance and, consequently, a less favorable ranking. Euclidean distance and relative proximity are closely related in the TOPSIS method. Relative proximity indicates how close an alternative is to the positive ideal solution compared to the negative ideal solution. A relative closeness value close to 1 indicates that the alternative is very close to the positive ideal solution, i.e., it outperforms the others. A value close to 0 indicates a lower performance since the alternative is closer to the negative ideal solution. Table 8 illustrates the result of calculating the relative proximity of each alternative.

At the end of the TOPSIS application, the alternatives are ranked based on their relative proximity to the positive ideal solution. Thus, the three best management solutions that influence the guarantee of the prerequisite are: process standardization, event simulation, and Lean.

The ranking of the solutions is directly linked to the opinions of the selected decision-makers and the weights assigned to each of them. These opinions were aggregated using the Fuzzy-Delphi application method and then ranked using the TOPSIS method.

During the application of TOPSIS, another factor influencing the result was the definition of the criteria weights, which were based on an analysis of the results in the work by Amaral et al. (2023). Other scenarios for defining weights can be defined to simulate the behavior of ranking alternatives in relation to the criteria weights, thus improving the information for the manager's decision-making. A scenario was defined in which all the weights have the same "high" importance, another in which the labor and materials and components criterion is valued according to the analysis of the results in the work by Amaral et al. (2024b), and even a scenario in which the most relevant prerequisite is external conditions, highlighting the solutions we can employ in the face of situations we cannot control, such as the weather, pandemics or strikes.

Table 8: Calculation of relative proximities

ALTERNATIVE	RELATIVE PROXIMITY	
BIM	CC_1	0.49
Lean	CC_2	**0.54**
Supply chain management	CC_3	**0.51**
Project management	CC_4	0.36
Big Data	CC_5	0.32
Disruptive (digital) technologies	CC_6	0.46
Event simulation	CC_7	**0.55**
Versatility of the workforce	CC_8	0.50
Standardization of services	CC_9	0.74

Scenarios 1 and 2 returned to the same ranking of alternatives. Scenario 3, in which the labor, materials, and components criteria had greater weight, returned alternatives related to supply chain management, standardization of processes, and multi-skilling of the workforce. In scenario 4, the external condition criterion was considered to have the greatest weight, and the alternatives with the best performance were event simulation, supply chain management, and Lean. Applying the method to different scenarios makes it possible to identify strengths and weaknesses and understand which criteria contributed to the performance of each alternative, making data analysis more transparent and rational for decision-making.

CONCLUSIONS

The analysis considered different scenarios for defining the weights of the criteria, allowing for a comprehensive and flexible evaluation of the alternatives and demonstrating the possible applications of the model. Process standardization, event simulation, and Lean were the best management solutions identified. These solutions were considered the most effective in guaranteeing prerequisites for the main scenario, considering the data survey proposed by Amaral et al. (2023).

Using the multi-criteria model helps to determine good practices by relating them in different scenarios and multiple criteria to the prerequisites of activities, contributing to managers' decision-making. In this way, managers have tools that enable them to make assertive management decisions to reduce the occurrence of making-do wastes, guaranteeing the necessary conditions for an activity to be available at the right time.

The method can be applied to any set of decisions that requires an aggregation of opinions, which are taken together, and requires a ranking of the alternatives. A practical situation at the production stage would be: Which activity should my team prioritize? The criteria could be: What would impact my schedule or the cost of delaying these activities on my budget?

Suggestions for future work include improving the model by integrating and comparing the ranking using other multi-criteria decision-making techniques and adding new solutions for analysis, which were not evaluated in this study, for example, the concept of industry 4.0 and industry 5.0, linear regression techniques, or even the concept of the internet of things and the use of machine learning algorithms to predict and mitigate wastes.

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