

A multicriteria model for ranking best practices to mitigate making-do waste

Modelo multicritério de ranqueamento de boas práticas na contenção das perdas por making-do

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Abstract

This article proposes a multicriteria model for ranking best practices to mitigate making-do waste, combining Fuzzy-Delphi and TOPSIS. The study aims to present a model that supports construction managers in ranking practices and assessing their impacts on efficiency and waste reduction, ensuring planned activities, confirming complete work packages, and mitigating waste. The approach incorporated decision-makers' opinions, who evaluated which solutions have the greatest influence on securing activity prerequisites. These evaluations were integrated into a decision matrix involving multiple criteria, including subjective perspectives in classifying alternatives and the weights assigned. Results confirmed the occurrence of complete work packages capable of reducing making-do waste. The study concludes that the three solutions with the greatest influence are process standardization, event simulation, and lean practices. Future research includes enhancing the model by integrating and comparing rankings with other multicriteria techniques and incorporating additional solutions not assessed here.

Keywords: Improvisation. Prerequisites. Work packages.

Resumo

Este artigo propõe modelo multicritério de ranqueamento de boas práticas na contenção das perdas por making-do, combinando as técnicas Fuzzy-Delphi e TOPSIS. O objetivo do artigo é propor um modelo que auxilie o gestor de obras a ranquear as boas práticas de gestão e seus impactos na eficiência e redução do desperdício, garantindo os pré-requisitos das atividades planejadas, promovendo a confirmação do kit completo e a mitigação dos desperdícios. A abordagem combinou as opiniões dos tomadores de decisão que avaliaram qual a solução de gestão mais influência na garantia dos pré-requisitos das atividades planejadas. Essas foram integradas em uma matriz de decisão que envolveu múltiplos critérios, como a subjetividade das visões na classificação das alternativas e os pesos atribuídos. Os resultados garantiram a ocorrência do kit completo capaz de reduzir a ocorrência das perdas por making-do. Conclui-se que as três melhores soluções de gestão que mais influenciam na garantia das atividades pré-requisitos são a padronização de processos, a simulação de eventos e as práticas Lean. Pesquisas futuras incluem o aprimoramento do modelo por meio da integração e comparação de classificações com outras técnicas multicritério e da incorporação de soluções adicionais não avaliadas aqui.

Palavras-chave: Improvisação. Pré-requisitos. Pacotes de trabalho.

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Introduction

In Brazil, the construction industry plays a crucial role in economic and social development, contributing significantly to the Gross Domestic Product (GDP) and serving as a key driver of formal employment. In 2023, the sector accounted for 16% of all new formal jobs (CBIC, 2024). Despite its relevance, the industry faces critical challenges, particularly making-do waste, which arises when activities begin without the required prerequisites, compromising process efficiency and generating waste (Koskela, 2004). This issue is further exacerbated by rising demand, which places pressure on production factors, especially skilled labor, leading to scarcity and increased costs (FIRJAN, 2020).

Mattos (2019) emphasizes that the Brazilian construction industry faces limitations in productivity, planning, and project management. Consequently, the sector's main challenge in the coming years will be to achieve productivity gains by analyzing labor-related factors in depth.

Furthermore, inefficiencies in management, involving equipment, materials, labor, and capital increase production costs and waste (Formoso *et al.*, 2017). Authors such as Ohno (1988), Koskela (1992), Sommer (2010), and Amaral *et al.* (2023) have highlighted the importance of planning, management, and control as key strategies for waste mitigation. Notably, actions aimed at improving the production system, such as addressing making-do waste, are directly linked to sectoral inefficiencies. As defined by Koskela (2004), making-do refers to a type of waste that occurs when an activity is initiated or continued without all necessary resources being available. Making-do waste can be briefly related to the concept of improvisation. However, improvisation is not necessarily negative, as Sommer (2010) points out that the decision to improvise is often based on the experience of leaders coordinating activities or following common industry practices. This underscores the need for structured methods that balance flexibility and efficiency in construction management.

Based on the identified problem, the analysis of which strategy to follow requires specialized judgment and an understanding of the available variables and resources. Multicriteria analysis supports this process, enabling the selection of the most effective solution from among various efficient alternatives by considering multiple criteria simultaneously. Given the complexity of decision-making and the need for expert judgment in choosing the best management solutions, multicriteria methods play a key role by allowing managers to identify and prioritize practices that reduce making-do waste.

The existing knowledge gap concerns the need for identifying and ranking management practices that are appropriate in the context of making-do waste, which requires a systematic approach based on clear criteria. This gap highlights the need to develop a model capable of ranking best management practices in construction, focusing on those with the greatest impact on ensuring the prerequisites of planned activities.

Based on the context presented, this article aims to propose a multicriteria decision-making model to assist construction managers in ranking best management practices for decision-making. To validate the model, it was applied to assess management practices and their impact on efficiency and waste reduction, ensuring activity prerequisites, confirming complete work packages, and mitigating waste.

Theoretical framework

Making-do waste in construction

Lean philosophy is important as it provides principles and tools that can improve planning and control (Koskela, 2004). Companies in the construction sector face limitations related to Production Planning and Control (PPC), as well as the absence of complete work packages when beginning activities, resulting in unpredictability regarding costs and schedules, issues associated with variability in production processes, and the informalization of work packages (Koskela, 2004; Ronen, 1992).

One of the main causes of waste in the construction industry is making-do waste, characterized by the waste incurred carrying out activities without all necessary resources in their optimal form (Koskela, 2004). Koskela, Bolviken and Rooke (2013) identified making-do as the primary type of waste in the sector and highlighted that its occurrence can exacerbate other forms of production waste.

The terms unfinished work, work in progress, buffer, rework, work completion, and work stoppage have been reconceptualized over the history of Lean to be associated with making-do. It is important to note that these terms had already been coined before developing the Lean construction theory. Ronen (1992) and Koskela (2000) laid the theoretical foundation for making-do in their work, highlighting that the latter built upon the former to establish the concept of the complete work package (prerequisites for performing a specific task).

Since then, studies have been conducted aiming to apply the concept of making-do to minimize waste or eliminate activities that do not add value to the process. Examples include project preparation (Neve; Wandahl, 2018), construction site logistics (Ghanem *et al.*, 2018), supply chain management (Taggart; Koskela; Rooke, 2014), and production slack (Fireman; Saurin; Formoso, 2018). Other studies related to making-do focus on developing or enhancing methods and tools to facilitate the identification of these wastes (Leão; Isatto; Formoso, 2016) or on identifying additional wastes through a cause-and-effect discussion of making-do waste (Koskela; Bolviken; Rooke, 2013).

Amaral *et al.* (2023) advanced the research by correlating prerequisites, categories, and impacts, analyzing 6,339 instances of compliance and non-compliance in a study that provided insights into comparative scenarios across projects in different contexts. They identified the causes and recurrence of waste generated by each missing prerequisite while also recognizing activities that could benefit the production system. In another case study, Marinho and Barros Neto (2021) reached conclusions similar to those of Amaral *et al.* (2023), finding that interdependent activities were the most frequent causes of waste.

Understanding the concept of making-do waste and the need to reduce it to enhance productivity highlights the importance of defining corrective actions and best practices. According to Santos *et al.* (2012), best practices are embedded in construction managers' knowledge and are often applied informally. In the construction sector, best practices can be understood as solutions used to prevent interruptions in construction site activities (Valente; Aires, 2017). The authors note that adopting best practices and structured management methods increases transparency in outcomes, impacting costs, schedules, and quality.

Amaral *et al.* (2024b) highlighted the importance of best practices and structured management methods in process outcomes. The authors proposed a methodology for identifying and classifying best practices according to their application within the lifecycle of a construction project. The identified best practices were those capable of reducing the occurrence of making-do waste by ensuring compliance with the minimum requirements of the complete work package.

Regarding making-do waste, various methods have been applied to predict and mitigate these losses. Karaz and Teixeira (2023) proposed a methodology to mitigate construction waste, focusing on making-do, by integrating line-of-balance techniques, BIM, and the Last Planner System. In a subsequent study, Karaz, Teixeira and Amaral *et al.* (2024a) simulated the dynamic effects of making-do waste using system dynamics to identify effective strategies to reduce it.

Despite these advances in the literature, a significant gap remains in the development of structured methodologies that support managers in selecting the best management practices to mitigate this waste. Therefore, adopting multicriteria decision-making methods is essential, allowing management practices to be ranked and prioritized according to objective criteria.

Multicriteria decision-making methods

Methods such as Fuzzy-Delphi (FDM) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) are widely used to address complex decision-making problems, providing greater reliability in selecting the best alternatives (Clemen; Reilly, 2001; Kahraman, 2008).

Clemen and Reilly (2001) describe decision-making as a generally complex task, as it involves multiple conflicting objectives. Achieving one objective may require compromising another due to not having a course of action that can meet all objectives simultaneously. Decision-making methods that consider more than one criterion are defined as multicriteria decision-making (MCDM) methods. In these methods, alternatives are evaluated according to multiple defined criteria, whereby each criterion produces a particular ranking of the alternatives. This requires using a mechanism capable of creating an overall preference ranking, also known as classification (Kahraman, 2008).

FDM represents a formal communication technique or strategy, conceived as a methodical, interactive, and predictive procedure based on a panel of experts. Applying FDM to group decision-making can address the imprecision inherent in shared understanding of opinions. Expert forecasts (or interval values) are then used to derive fuzzy numbers, resulting in FDM.

FDM was selected because it combines fuzzy set theory with a Delphi approach (Ishikawa *et al.*, 1993) to account for the uncertainty of subjective information arising from the decision-making and expert analysis process. FDM is an expert-opinion research technique that incorporates three main aspects: anonymous responses, controlled feedback interaction, and statistical aggregation of group responses. According to Bellman and Zadeh (1970), fuzzy set theory addresses the uncertainty of human thought and behavior in

decision-making. Fuzzy set theory was first proposed by Zadeh (1965). In a fuzzy environment, decision-making involves objectives and classes of alternatives whose boundaries cannot be clearly defined by numerical scales (Bellman; Zadeh, 1970). This occurs because the perception of these concepts is qualitative rather than numerical. Therefore, fuzzy set theory can develop decision-making models in which evaluations can be expressed in natural and subjective language.

The TOPSIS method has been widely used to rank alternatives in order of preference. Its principle is to select an alternative that is as close as possible to the positive ideal solution and as far as possible from the negative ideal solution (Kahraman, 2008).

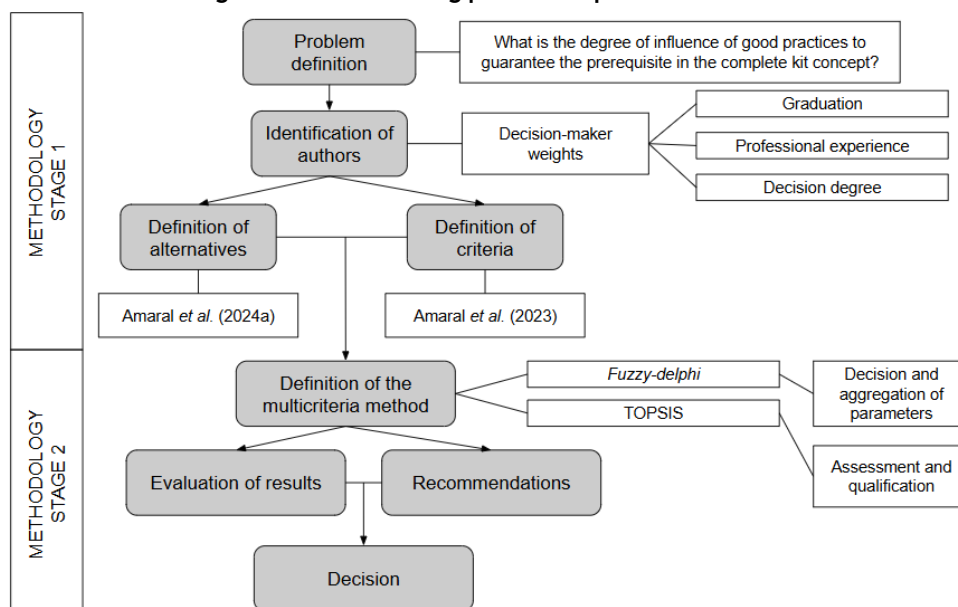
FDM was chosen to collect and evaluate the opinions of multiple decision-makers, providing more accurate results than the arithmetic mean. In contrast, TOPSIS is a widely used and well-recognized method in the literature. In this study, FDM was applied as a consistency aggregation method to achieve consensus among experts and generate a single decision matrix, which was then submitted to the TOPSIS method to produce a ranking of alternatives. The combination of these methods enables more structured decision-making, ensuring objective criteria when selecting best management practices.

Considering this gap in the literature, this study proposes a multicriteria decision-making model that combines the Fuzzy-Delphi and TOPSIS methods, aiming to provide a structured approach to assist managers in selecting practices that minimize making-do waste. This model directly contributes to addressing the existing gap by offering an approach based on objective criteria rather than relying solely on subjective judgment.

Methodology

From the perspective of research technical procedures, this article uses quantitative modeling, as defined by Bertrand and Fransoo (2002). This type of modeling can further be distinguished by empirical versus axiomatic classification and, additionally, by descriptive versus normative research. Accordingly, based on the concepts proposed by Bertrand and Fransoo (2002), this study can be classified as normative axiomatic quantitative modeling. It is axiomatic because it attempts to generate solutions within a defined model and to ensure that these solutions provide insights into the structure of the problem. Regarding normative modeling, it focuses on developing strategies and actions to improve outcomes documented in the existing literature or to compare multiple strategies for addressing a specific problem, as done in this research by creating a decision-making model. Figure 1 illustrates the methodological approach of the decision-support process in the proposed model.

Figure 1 - Flowchart showing the decision-making process steps



Problem description

Defining the problem is the first step in the decision-making process when applying a multicriteria method. In the context of the construction industry, the problem lies in the need to improve management and efficiency by addressing actions that may be beneficial to the process. The solution involves implementing measures to ensure the prerequisites for initiating activities and to prevent making-do waste. This study proposes evaluating the influence of best practices in ensuring the complete work package of activities through a multicriteria decision-making method. In this approach, the prerequisites required to start an activity serve as decision objectives, occupying the role of decision criteria. Conversely, the evaluated alternatives are the management practices. This framework allows for the assessment of each management practice's performance according to its impact on each prerequisite.

For the assignment of weights, ten experts were selected as decision-makers in their respective fields (Table 1). These experts were chosen based on their professional experience and decision-making authority within their work environments. In this evaluation, no expert with characteristics that would classify them as having a "low" level of importance was considered, ensuring that each decision-maker had the required expertise to assess the established criteria.

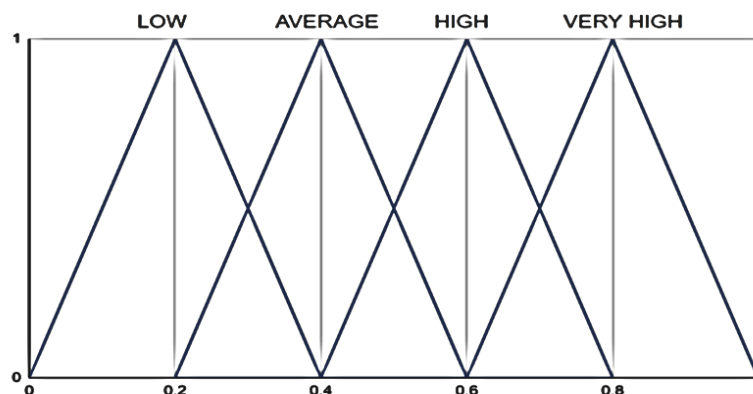
The evaluations were aggregated using the average of the linguistic terms for each assessment criterion. Decision-makers rated the importance of alternatives concerning the criteria according to the following linguistic variables: Information, Materials and Components, Labor, Tools and Equipment, Temporary Facilities, Interdependent Tasks, External Conditions, and Space.

The weight for each criterion was classified according to the scenario in which the method was applied. The linguistic variables used for classification were: very low, low, average, high, and very high. Based on this assessment, items rated as "low" on any criterion were disregarded. Evaluations were aggregated using the average of the linguistic terms applied to each assessment criterion. Table 1 and Figure 2 provide details of the linguistic variables used as evaluation terms by the decision-makers.

Table 1 - Characterization of the Decision-Makers

Quantity	Education	Professional experience	Level of decision-making	Linguistic Variable for the Experts' Degree of Importance	L	m	u	Triangular Fuzzy Number
0	Student	Up to 5 years	N.A (Not applicable)	Low	0	0.2	0.4	0, 0.2, 0.4
1	Completed Higher education	From 5 to 10 years	Operational	Average	0.2	0.4	0.6	0.2, 0.4, 0.6
6	Post-graduate	From 10 to 15 years	Tactical	High	0.4	0.6	0.8	0.4, 0.6, 0.8
3	Master's or above	Over 15 years	Strategic	Very high	0.6	0.8	1	0.6, 0.8, 1

Figure 2 - Linguistic scale for the importance of criteria in characterizing decision-makers



A triangular fuzzy number can be expressed as (l, m, u), where l and u represent the lower and upper bounds, and m represents the midpoint of the triangular fuzzy number. A fuzzy set is interpreted as a bridge connecting an imprecise concept to its numerical modeling, assigning a value between 0 and 1 to each element in the universe, representing the degree of membership of that element in the fuzzy set. Fuzzy logic can handle highly variable, linguistic, undefined, or uncertain data and knowledge, providing logical, reliable, and transparent information.

Specifically, in this study, the alternatives selected for evaluation to test and determine the model were management solutions applied during the execution and design phases, as reported by Amaral *et al.* (2024b). These phases had the highest number of related tasks, highlighting their importance for achieving positive project outcomes. Similar concepts were grouped to define the alternatives to be assessed in the study.

The alternatives were conceptualized according to their practical applications on construction sites, as shown in Table 2. They were structured with the criteria used to evaluate them within a multicriteria decision-making model. Evaluators assessed the degree of influence of each management solution ensuring the prerequisites of planned activities.

Table 2 - Conceptualization of the alternatives

Management solution	Concept	Application	References
BIM	Methodology integrating all data required for facility construction	• Parametric modeling – enhanced project representation • Team coordination – quantities, budgets, and schedules • Information and time management	Menezes (2011)
Lean	A philosophy aimed at eliminating waste, reducing costs, minimizing internal supplier variability, and meeting customer needs.	• 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 material purchasing and receiving process • Supplier competence and evaluation • Inventory control	Goldsby and Martichenko (2005)
Project Management	Set of processes used in a project to produce a product or service	• Management of schedules, costs, and quality • Strategic and performance planning • Knowledge and skills management • Comparative assessment	Ika (2009); Alberico, Silva and Corrêa (2018) and Alencar and Santana (2010)
Big Data	Advanced analytical techniques operating on large datasets	• Big Data management • Data analysis using mathematical and computational techniques	Belluzo <i>et al.</i> (2016)
Digital disruptive technologies	Technologies whose market can disrupt or break an established paradigm	• Workplace automation, Internet of Things, Cloud technology, Advanced robotics, Autonomous vehicles, Energy storage, 3D printing, Artificial intelligence	Schuelke-Leech (2021) and Marcandali (2019)
Event simulation	Operational research tool that creates a virtual model to test and analyze the behavior of a system or process before implementing it in practice	• Computational simulation (software) • Simulation of planning, scheduling, and coordination of activities for time and cost control	Banks (1998) and Vergara <i>et al.</i> (2017)
Labor versatility	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	Bálsamo and Zoki (2001) and Cardoso, Abreu and Marchiori (2019)
Process standardization	Process standardization refers to the establishment of consistent and uniform business procedures, with process documentation, to carry out specific tasks.	• Process performance indicators • Standard operating procedures	Coscarelli (2010)

The criteria for evaluating each alternative are related to the impact of adopting them. The chosen criteria were the prerequisites needed to initiate and develop a task, where failure to identify or provide any of these prerequisites in advance results in making-do waste. The parameters for studying making-do waste, such as prerequisites, categories, and impacts of waste, were identified by Koskela (2000) and Sommer (2010) and are presented in Table 3.

The process then structures the alternatives and the criteria that will be used to evaluate them within a multicriteria decision-making model. Evaluators assessed the degree of influence of management solutions ensuring the prerequisites of planned activities. This assessment is adapted to the decision-making context, evaluating performance parameters and the method's effectiveness in supporting decisions. The results were derived from the applied methods and, along with the recommendations, presented to the decision-makers. Based on the applied methods, the results and accompanying recommendations were presented to the decision-makers.

Decision-making model

The multicriteria decision-making model developed in this study is illustrated in Figure 3. This model combines the FDM, which facilitates the aggregation of expert opinions. It also uses the TOPSIS method to rank alternatives and identify the optimal option by comparing multiple criteria.

Fuzzy-Delphi method

The FDM stage, which involves defining the decision-makers for the evaluated criteria and aggregating their weights, was detailed in the previous section. The subsequent stages of the method are described below.

The first step assessed the importance of each criterion for the decision-makers using fuzzy numbers. Semi-structured interviews were conducted with the experts to evaluate the criteria by asking: "What is the degree of influence of best practices ensuring the prerequisite within the complete work package?" The decision-makers used a linguistic scale, as presented in Table 4 and Figure 4, using the terms very low, low, average, high, and very high.

Next, the weighted matrix is constructed, taking into account the weights of the decision makers. A weighted aggregation of the evaluators' assessments is performed according to each decision-maker's weight, by multiplying the decision-makers' weight matrix with the evaluation matrix.

Table 3 - Prerequisites required to initiate an activity

Prerequisites	Descriptions	Authors
Information	Availability of adequate information regarding work plans	Sommer (2010) Koskela (2004)
Materials and components	Availability of materials and components in the required quality and quantity, according to project specifications and standards	Sommer (2010) Koskela (2004)
Labor	Availability of the necessary human resources, in terms of quantity and qualification	Sommer (2010) Koskela (2004)
Tools and equipment	Availability and functionality of equipment for activities	Sommer (2010) Koskela (2004)
Space	Availability of workspace, circulation areas, or material storage	Sommer (2010) Koskela (2004)
Interdependent tasks	Highly interdependent activities that affect subsequent tasks	Sommer (2010) Koskela (2004)
External conditions	Wind, rain, or extreme temperatures	Sommer (2010) Koskela (2004)
Temporary facilities	Temporary electrical and hydraulic installations, scaffolding and enclosures for site safety, and storage area isolation	Sommer (2010)

Source: Fontenele *et al.* (2020).

Figure 3 - Stages of the FDM combined with TOPSIS

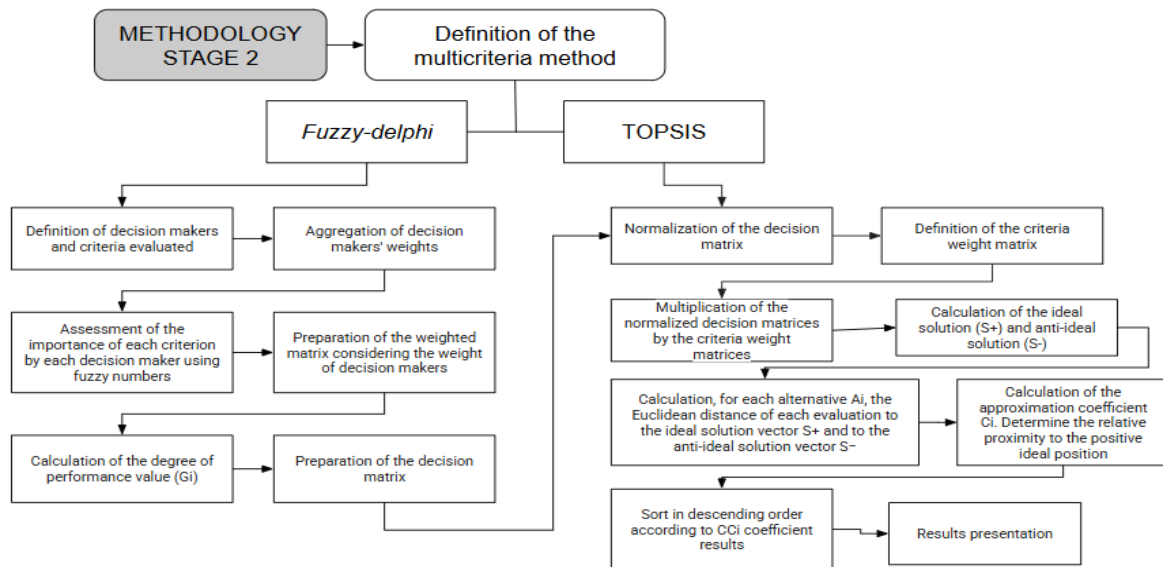
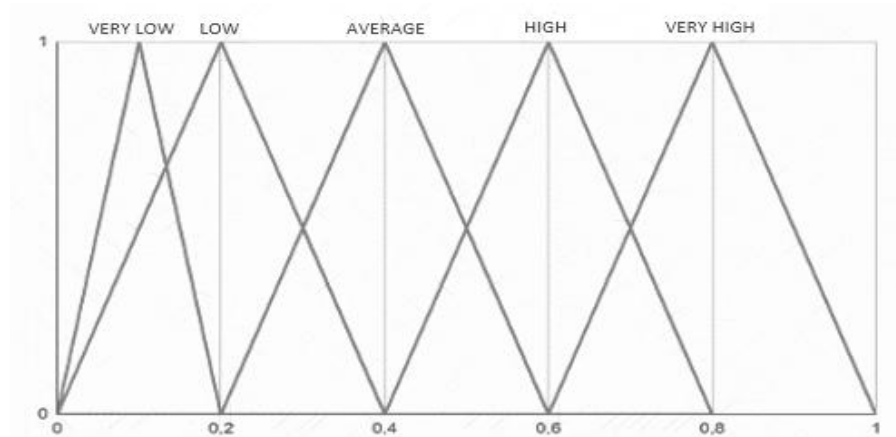


Table 4 - Importance of criteria

Linguistic Variables for Decision-Maker Evaluation	Triangular fuzzy 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

Figure 4 - Linguistic Scale for the Importance of Classification Criteria



Subsequently, the performance value degree (G_i) for each criterion is calculated, as shown in Equation 1.

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

Where:

U_i is the maximum value of m in the evaluation matrix;

L_i is the minimum value of l in the evaluation matrix; and

M_i is the geometric mean of m in the evaluation matrix.

Finally, decision matrix D is constructed.

TOPSIS method

In this study, the resulting decision matrix (D), presented in Equation 2, from the application of the Fuzzy-Delphi method, with the weight vector W (Equation 3), was used to implement the TOPSIS method.

$$Di = \begin{matrix} & C_1 & C_2 & \dots & C_n \\ \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} & \begin{pmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{pmatrix} \end{matrix} \quad \text{Eq. 2}$$

$$\tilde{W} = [\tilde{w}_1 + \tilde{w}_2 + \dots + \tilde{w}_m] \quad \text{Eq. 3}$$

Where:

A_i is the n alternatives to be evaluated ($i = 1, 2, \dots, n$);

C_j is the m evaluation criteria ($j = 1, 2, \dots, m$);

d_{ij} is the result of the evaluation of alternative n with respect to criterion m ; and

W_j is the weight of the criteria m .

The matrix was normalized according to Equation 4:

$$d' = (x - \min(x)) / (\max(x) - (\min(x))) \quad \text{Eq. 4}$$

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 weighted normalized matrix was then obtained by multiplying the normalized matrix by the respective weights of the criteria, such that $p_{ij} = w_j \cdot x_{ij}$.

The weights for each criterion were calculated according to the evaluators' judgments. In this study, the criteria were defined based on Amaral *et al.* (2023), who investigated the causes and recurrence of missing prerequisites that led to making-do waste. It was established that the weight assigned to missing prerequisites with higher recurrence in the classification would be greater. Using data from Goiânia and Fortaleza, the missing prerequisites with the highest recurrence, i.e., information, materials and components, labor, and interdependent tasks, were classified with a very high weight. Conversely, the prerequisites with lower recurrence, i.e., equipment and tools, temporary facilities, external conditions, and space, were classified with Average weight.

The evaluation of the method began with proposed alternatives to meet the activity planning criteria. Best practices were defined as the alternatives for the decision-making matrix, while the prerequisites were defined as the criteria. The proposed evaluation matrix, designed to assess the degree of influence of best practices in ensuring the complete set of planned activities, consists of the following alternatives: A = {A1 - BIM, A2 - LEAN, A3 - Supply Chain Management, A4 - Project management, A5 - Big Data, A6 - Digital Disruptive Technologies, A7 - Event simulation, A8 - Labor versatility, A9 - Process Standardization} and criteria C={C1 - Information, C2 - Materials and components, C3 - Labor, C4 -Tools and equipment, C5 - Temporary installations, C6 - Interdependent tasks, C7 - External conditions, C8 - Space}. The method combines the assigned weights and the choices made by the experts to rank the ideal solution. These data represent important criteria, as they effectively contribute to decision-making.

To analyze the behavior of the alternatives in different scenarios, simulations were conducted in which different weights were assigned to the criteria. Table 5 presents the weight assigned to each criterion, while Table 6 shows the weighting scale. The weights were normalized to ensure that their total sum equals 1.

Table 5 - Weight vs Criteria

Criteria	Weight
Information	Very high
Materials and components	Very high
Labor	Very high
Tools and equipment	Average
Temporary facilities	Average
Interdependent tasks	Very high
External conditions	Average
Space	Average

Table 6 - Criterion weighting scale

Linguistic variable	Numeric scale
Very low	1
Low	2
Average	3
High	4
Very high	5

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

$$S^+ = \{(v_j^+ | j \in J), (p_{ij} | j \in J')\} \quad \text{Eq. 5}$$

$$S^- = \{(v_j^- | j \in J), (p_{ij} | j \in J')\} \quad \text{Eq. 6}$$

Where j and J' denote elements of the criterion set.

Thus, the ideal solution is calculated as $S^+ = (p_1^+, p_2^+, \dots, p_n^+)$ and the anti-ideal solution as $S^- = (p_1^-, p_2^-, \dots, p_n^-)$, where p_n^+ represents the highest evaluation for each criterion n, while p_n^- represents the lowest evaluation. For each alternative, the Euclidean distance of each evaluation is calculated for the solution vectors S^+ and S^- using Equations 7 and 8.

$$d_i^+ = \sqrt{\sum_{j=1}^n (v_j^+ - p_{ij})^2} \quad \text{Eq. 7}$$

$$d_i^- = \sqrt{\sum_{j=1}^n (v_j^- - p_{ij})^2} \quad \text{Eq. 8}$$

Where:

d_i^+ is alternative distance (i) up to S^+ ;

d_i^- is alternative distance (i) up to S^- ;

p_{ij} is the weighted value of alternative (i) in criteria (j);

v_j^+ is value S^+ in criteria (j); and

v_j^- is value S^- in criteria (j).

Finally, the relative closeness to the positive ideal position is determined using the closeness coefficient CC_i according to Equation 9, which corresponds to the overall performance (or final score) of alternative i.

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-}, i = 1, 2, \dots, m. \quad \text{Eq. 9}$$

The alternatives were ranked in descending order according to the results of the CC_i coefficient. The alternative with a relative closeness closest to 1 was considered ideal, while the one with a result closest to 0 was not considered ideal.

Results and discussion

The first step in applying the method defined the evaluation alternatives and criteria. The alternatives represent management best practices that influence the mitigation of making-do waste, while the criteria reflect the prerequisites necessary for activity planning. The application of the method yields the alternative considered ideal within the scenario defined by the decision-makers' rankings and the criteria weights.

Selecting the ten decision-makers who participated in the study ensured that they had the required expertise to evaluate the criteria. Each one assessed the importance of the alternatives in relation to the criteria using the linguistic variables presented in Table 4.

The outcome of the method is directly influenced by the weights assigned by the experts, determining the relevance of each criterion in the final evaluation. Additionally, the choices made based on their experience and judgment play a crucial role in the final result. Therefore, the method combines the weights assigned by the experts with their individual choices to classify the ideal solution. Table 7 shows the characterization of the decision-makers, and Figure 5 presents the weights assigned.

The selected decision-makers were assigned high (53.3%) and very high (20.0%) weights in relation to the classification criteria. Most of these professionals have postgraduate education, over five years of professional experience, and occupy tactical or strategic positions in their workplaces.

The level of decision-making indicates that the results can be reliably assessed, as occupying tactical and strategic levels suggests that these decision-makers have a broad and strategic view of the organization, which is crucial for high-impact decisions.

In this context, the FDM supports the development of the model by enabling better management of uncertainty and subjectivity concerning opinions. By linking the linguistic variables of the decision-makers' evaluations of criterion importance to fuzzy numbers, the method allows for the representation of uncertainty and imprecision in their responses.

This method enabled the aggregation of opinions while improving the quality and validity of the resulting decision-making matrix. The decision-making matrix, shown in Table 8 for ranking the alternatives using the TOPSIS method, reflects the collective opinions after the direct influence of the experts' weights.

The decision-making method used the TOPSIS matrix to calculate the distance of each alternative from the ideal solution, enabling an objective ranking of the alternatives. Each alternative received a score, attempting to understand how good or poor it is relative to the others.

The TOPSIS method also incorporated weights for the evaluation criteria. These weights were essential to reflect the relative importance of each criterion in assessing the alternatives. The relative importance of the criteria was determined based on expert evaluations following the analysis of making-do waste conducted by Amaral *et al.* (2023). These weights were normalized to ensure proportionality in evaluating the alternatives, accurately representing the relative importance of each criterion.

Table 7 - Characterization of the decision makers

Education	Quantity	Professional experience	Quantity	Level of decision	Quantity
Student	0	Up to 5 years	0	NA (Not applicable)	0
Completed higher education	1	From 5 to 10 years	6	Operational	1
Post-graduate	6	From 10 to 15 years	3	Tactical	7
Master's or above	3	Over 15 years	1	Strategic	2

Figure 5 - Weights attributed to decision makers

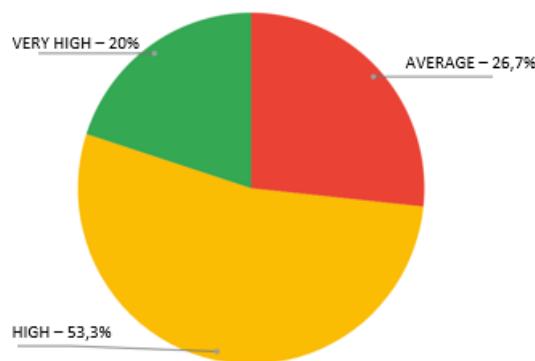


Table 8 - Resulting Decision-Making Matrix

Alternatives	Criteria							
	Informa-tion	Materials and compo-nents	Labor	Tools and equip-ment	Temporary facilities	Interde-pendent 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
Digital disruptive 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
Labor versatility	0,33780	0,42669	0,52759	0,38894	0,27248	0,47869	0,25816	0,31238
Process Standardization	0,48020	0,50692	0,50563	0,49749	0,32476	0,45705	0,24704	0,36113

Next, the resulting decision matrix, considering the aggregation of the weights for each criterion and the maximum positive and negative solutions, is presented in Table 9.

This step calculated the extreme solutions. The positive ideal solution represents the best possible outcome for each criterion, reflecting the most desirable performance, while the negative ideal solution represents the worst possible outcome for each criterion, reflecting the least desirable performance.

In this context, the fact that the negative ideal solution is zero indicates that the alternative in question presents no disadvantage for the criteria. In other words, as all management best practices yielded positive results concerning the prerequisites, they do not negatively affect the process. These two reference points are used in TOPSIS to rank the alternatives.

The method proceeds with the calculation of Euclidean distances, which represent the shortest straight-line distance between two points. In TOPSIS, these distances are used to determine how close each alternative is to the ideal solutions. A smaller positive Euclidean distance indicates better performance, while a larger negative Euclidean distance indicates better performance.

In the final TOPSIS ranking, alternatives with smaller positive Euclidean distances and larger negative Euclidean distances tend to rank higher, as they are closer to the ideal solution. Table 10 presents the results of this calculation.

In the applied case, Alternative 9 (process standardization) tends to rank higher because it showed a smaller Euclidean distance to the positive ideal solution. In contrast, Alternative 5 had a larger Euclidean distance, indicating poorer performance and, consequently, a less favorable ranking.

Table 9 - Calculation of the maximum solutions

Weights/ Alternatives		Criteria							
		Informa- tion	Materials and compo- nents	Labor	Tools and equip- ment	Tempo- rary facilities	Interde- pendent tasks	External conditi- ons	Space
Weights	Weights	Very high	Very high	Very high	Average	Average	Very high	Average	Average
	Numerical weights	5	5	5	3	3	5	3	3
	Normalized weights	0.2	0.2	0.2	0.1	0.1	0.2	0.1	0.1
Alternatives	BIM	0.153	0.062	0.000	0.000	0.017	0.108	0.033	0.093
	Lean	0.109	0.062	0.074	0.045	0.035	0.090	0.034	0.094
	Supply chain management	0.109	0.156	0.042	0.040	0.015	0.000	0.094	0.060
	Project management	0.125	0.000	0.016	0.004	0.015	0.057	0.042	0.043
	Big Data	0.095	0.043	0.075	0.004	0.000	0.000	0.022	0.000
	Digital disruptive technologies	0.116	0.045	0.077	0.053	0.059	0.044	0.015	0.050
	Event simulation	0.076	0.028	0.077	0.056	0.094	0.098	0.083	0.091
	Labor versatility	0.000	0.058	0.156	0.043	0.023	0.156	0.006	0.020
	Process standardiza- tion	0.156	0.143	0.139	0.094	0.055	0.134	0.000	0.061
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

Table 10 - Euclidean distance calculations

Alternative	Euclidean distance +		Euclidean distance -	
BIM	d1 +	0.23	d1-	0.22
Lean	d2 +	0.18	d2-	0.21
Supply chain management	d3 +	0.22	d3-	0.23
Project management	d4 +	0.27	d4-	0.15
Big Data	d5 +	0.28	d5-	0.13
Digital disruptive technologies	d6 +	0.21	d6-	0.18
Event simulation	d7 +	0.18	d7-	0.22
Labor versatility	d8 +	0.23	d8-	0.23
Process standardization	d9 +	0.11	d9-	0.31
BIM	d1 +	0.23	d1-	0.22

Euclidean distance and relative closeness are closely related in the TOPSIS method. Relative closeness indicates how near an alternative is to the positive ideal solution compared to the negative ideal solution. A relative closeness value close to 1 means the alternative is very close to the positive ideal solution,

demonstrating superior performance relative to the others. A value near 0 indicates poorer performance, meaning the alternative is closer to the negative ideal solution.

At the end of the TOPSIS method, the alternatives are ranked based on their relative closeness to the positive ideal solution (Table 11). The three best management solutions influencing the fulfillment of the prerequisites are process standardization, event simulation, and Lean.

The ranking of these solutions is directly linked to the opinions of the decision-makers, as well as the weights assigned to each of them. These opinions were aggregated through the FDM stage and subsequently ranked using the TOPSIS method. Another factor influencing the results during the TOPSIS application was the definition of the criteria weights, which were determined based on the results analysis reported in Amaral *et al.* (2023).

Other scenarios can be defined for assigning weights to simulate how the ranking of alternatives behaves in relation to the criterion weights, thereby enhancing decision-making information for managers. One scenario assumes all weights have the same “high” importance; another emphasizes the labor and materials and components criteria, based on the analysis of results in Amaral *et al.* (2023); and a third scenario considers the most relevant prerequisite to be external conditions, highlighting solutions that can be applied in situations beyond control, such as weather, pandemics, strikes, or stoppages. The results are presented in Table 12.

All alternatives that achieved the best results are highlighted in Table 12. Scenarios 1 and 2 returned the same ranking of alternatives, indicating stability in the weights assigned to the criteria. In Scenario 3, where the labor and materials and components criteria had higher weights, the top-ranked alternatives were Supply Chain Management, noted for its ability to optimize logistical flows and reduce waste; Process Standardization, which improves predictability and efficiency of activities; and Labor Versatility, which contributes to operational flexibility and better utilization of human resources.

In Scenario 4, where the criterion of external conditions was assigned the highest weight, the top alternatives were Event Simulation, which allows for anticipating external impacts and minimizing operational risks; Supply Chain Management, once again demonstrating its importance in adapting to unexpected changes; and Lean Construction, highlighting its effectiveness in lean management and reducing process variability.

Analyzing different scenarios demonstrates how prioritizing criteria can significantly influence the selection of the most effective solutions. This enables managers to adjust their decisions according to the specific context of the project, ensuring greater accuracy and efficiency in mitigating making-do waste.

Table 11 - Calculation of relative closeness

Alternative	Relative closeness	
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
Digital disruptive technologies	CC_6	0.46
Event simulation	CC_7	0.55
Labor versatility	CC_8	0.50
Process standardization	CC_9	0.74

Table 12 - Examples of the method application

SCENARIO 1: Criteria according to analyses by Amaral <i>et al.</i> (2023)				SCENARIO 2: Criteria with the same importance			
Criteria	Criteria weight	Relative proximity		Criteria	Criteria weight	Relative proximity	
Information	Very high	BIM	0,49	Information	Average	BIM	0,47
Materials and components	Very high	Lean	0,54	Materials and components	Average	Lean	0,54
Manpower	Very high	Supply chain management	0,51	Manpower	Average	Supply chain management	0,52
Equipment/tools	Average	Project management	0,36	Equipment/tools	Average	Project management	0,34
Temporary installations	Average	Big Data	0,32	Temporary installations	Average	Big Data	0,27
Interdependent tasks	Very high	Disruptive (digital) technologies	0,46	Interdependent tasks	Average	Disruptive (digital) technologies	0,47
External conditions	Average	Event simulation	0,55	External conditions	Average	Event simulation	0,62
Space	Average	Workforce versatility	0,50	Space	Average	Workforce versatility	0,45
----	----	Standardization of processes	0,74	----	----	Standardization of processes	0,66
SCENARIO 3: Criteria according to analyses by Amaral <i>et al.</i> (2022)				SCENARIO 4: Criterion of greatest importance: external conditions			
Criteria	Criteria weight	Relative proximity		Criteria	Criteria weight	Relative proximity	
Information	Low	BIM	0,37	Information	Low	BIM	0,43
Materials and components	Very high	Lean	0,49	Materials and components	Low	Lean	0,48
Manpower	Very high	Supply chain management	0,56	Manpower	Low	Supply Chain Management	0,63
Equipment/tools	Low	Project management	0,23	Equipment/tools	Low	Project management	0,38
Temporary installations	Low	Big Data	0,33	Temporary installations	Low	Big Data	0,26
Interdependent tasks	Low	Disruptive (digital) technologies	0,43	Interdependent tasks	Low	Disruptive (digital) technologies	0,37
External conditions	Low	Event simulation	0,48	External conditions	Very high	Event simulation	0,69
Space	Low	Workforce versatility	0,55	Space	Low	Workforce versatility	0,35
----	----	Standardization of processes	0,76	----	----	Standardization of processes	0,47

Conclusions

This study builds on previous research on making-do waste by proposing a method applicable to any collaborative decision-making process that requires aggregating opinions and ranking alternatives. Practical questions can thus be addressed, such as: Which activity should my team prioritize? What would be the impact on my schedule, or the cost of delaying these activities on my budget?

Using the multicriteria decision-making model identifies the best managerial practices by linking them to different scenarios and the prerequisites of activities, thereby facilitating decision-making for managers. Thus, it provides tools that enable managers to make informed decisions, reduce improvisation waste, and ensure the necessary conditions for the beginning of an activity.

The analysis considered different scenarios to define the weights of the criteria, allowing a comprehensive and flexible evaluation of the alternatives and demonstrating the model's potential applications. The calculation of relative closeness was directly related to the importance of the criteria weights, reflecting the relative significance of each criterion and enabling the analysis of different priorities. Alternative 9, Process Standardization, emerged as the best option in three scenarios, while in one scenario, the top choice was Alternative 8, Event Simulation. The correlation between these two alternatives can significantly reduce

making-do waste. Process Standardization establishes consistent procedures, while Event Simulation allows these procedures to be tested and adjusted in a virtual environment before implementation. Together, they enhance construction efficiency and quality, reduce costs, and minimize waste.

Process Standardization, Event Simulation, and Lean were identified as the top management solutions. These were considered the most effective in ensuring prerequisites for the main scenario, based on the data collected by Amaral *et al.* (2023).

Suggestions for future research include refining the model by integrating and comparing rankings using other multicriteria decision-making techniques and incorporating new solutions for analysis, such as those mentioned in Amaral *et al.* (2024b) that were not evaluated in this study, for example, the concepts of Industry 4.0 and Industry 5.0, linear regression techniques, the Internet of Things, and using machine learning algorithms to predict and mitigate waste.

References

- ALBERICO, A. X. A. R. X.; SILVA, M. A. O.; CORRÊA, L. R. **Gerenciamento de projetos na construção civil: tempo, custo e qualidade**. *Construindo*, v. 10, n. 2, p. 1–20, 2018.
- ALENCAR, L. H.; SANTANA, M. O. Análise do gerenciamento de múltiplos projetos na construção civil. *Revista de Gestão e Projetos*, v. 1, n. 1, p. 74–92, 2010.
- AMARAL, T. G. do *et al.* Perdas por making-do na etapa de vistoria e entrega de obra. In: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 19., Canela, 2022. **Anais [...]** Porto Alegre: ANTAC, 2022.
- AMARAL, T. G. *et al.* Results of the Causes and Impacts of *Making-do* Wastes in Production in Fortaleza, Ceará, Brazil. In: ANNUAL CONFERENCE OF THE INTERNATIONAL GROUP FOR LEAN CONSTRUCTION, 31., Fortaleza, 2023. **Proceedings [...]** Fortaleza, 2023.
- AMARAL, T. G. do *et al.* Modelo de classificação das perdas por making-do com uso de aprendizado de máquina. In: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 20., Maceió, 2024. **Anais [...]** Porto Alegre: ANTAC, 2024.
- AMARAL, T. G. *et al.* The relationship between making-do waste and good management practices in the construction industry: a systematic literature review. In: ANNUAL CONFERENCE OF THE INTERNATIONAL GROUP FOR LEAN CONSTRUCTION, 32., Auckland, 2024. **Proceedings [...]** Auckland: IGLC, 2024b.
- BÁLSAMO, L. A.; ZOQUI, E. J. **Estruturação de setor produtivo como base para a polivalência e o trabalho em grupo**. In: ENCONTRO NACIONAL DE ENGENHARIA DE PRODUÇÃO. **Anais [...]**. 2001.
- BANKS, J. Principles of simulation. **Handbook of Simulation**, v. 12, p. 3–30, 1998.
- BELLMAN, R. E.; ZADEH, L. A. Decision-making in a *fuzzy* environment. **Management Science**, v. 17, n. 4, p. B-141–B-164, 1970.
- BELLUZO, B. G. *et al.* Big Data e suas aplicações na engenharia civil. In: BRAZILIAN TECHNOLOGY SYMPOSIUM, São Carlos, 2016. **Proceedings [...]** São Carlos, 2016.
- BERTRAND, J. W. L. M.; FRANSOO, J. C. Operations management research methodologies using quantitative modeling. **International Journal of Operations & Production Management**, v. 22, n. 2, p. 241–264, 2002.
- CÂMARA BRASILEIRA DA INDÚSTRIA DA CONSTRUÇÃO. **O papel da construção civil no desenvolvimento econômico e social do Brasil**. Brasília, 2024. Available at: cbic.org.br/enic-o-papel-da-construcao-para-o-desenvolvimento-economico-e-social-do-brasil/. Access: 09 set. 2025.
- CARDOSO, G. C.; ABREU, J. P. M.; MARCHIORI, F. F. Resultados obtidos com a aplicação da polivalência da mão de obra na construção civil: revisão sistemática. In: SIMPÓSIO BRASILEIRO DE GESTÃO E ECONOMIA DA CONSTRUÇÃO, 11., Londrina, 2019. **Anais [...]** Porto Alegre: ANTAC, 2019.
- CLEMEN, R. T.; REILLY, T. **Making hard decisions with decision tools**. 2. ed. Pacific Grove: Duxbury/Thomson Learning, 2001.

- COSCARELLI, R. A. **Reestruturação e padronização de processos através de métodos e ferramentas de gestão empresarial na construção civil**. Belo Horizonte, 2010. Dissertação (Mestrado em Engenharia Civil) – Universidade Federal de Minas Gerais, Belo Horizonte, 2010.
- FEDERAÇÃO DAS INDÚSTRIAS DO ESTADO DO RIO DE JANEIRO. **O impacto da construção civil na economia**. Rio de Janeiro: FIRJAN, 2020.
- FIREMAN, M. C.; SAURIN, T. A.; FORMOSO, C. T. The role of slack in standardized work in construction: an exploratory study. In: ANNUAL CONFERENCE OF THE INTERNATIONAL GROUP FOR LEAN CONSTRUCTION, 26., Chennai, 2018. **Proceedings [...]** Chennai, 2018.
- FONTENELE, A. *et al.* Perdas por *making-do*: um estudo de caso em canteiros de obras de Fortaleza/CE. In: ENCONTRO NACIONAL DE TECNOLOGIA DO AMBIENTE CONSTRUÍDO, 18., Porto Alegre, 2020. **Anais [...]** Porto Alegre: ANTAC, 2020.
- FORMOSO, C. T. *et al.* The identification and analysis of *making-do* waste: insights from two Brazilian construction sites. **Ambiente Construído**, Porto Alegre, v. 17, n. 3, p. 183-197, 2017.
- GHANEM, M. *et al.* A New perspective of construction logistics and production control: an exploratory study. In: ANNUAL CONFERENCE OF THE INTERNATIONAL GROUP FOR LEAN CONSTRUCTION, 26., Chennai, 2018. **Proceedings [...]** Chennai, 2018.
- GOLDSBY, T. J.; MARTICHENKO, R. **Lean six sigma logistics**: strategic development to operational success. Boca Raton: J. Ross Publishing, 2005.
- IKA, L. A. Project success as a topic in project management journals. **Project Management Journal**, v. 40, n. 4, p. 6-19, 2009.
- ISHIKAWA, A. *et al.* The Max-min Delphi Method and *Fuzzy* Delphi Method via *Fuzzy* Integration. **Fuzzy Sets and Systems**, v. 55, p. 241-253, 1993.
- KAHRAMAN, C. Multi-criteria decision-making methods and fuzzy sets. In: KAHRAMAN, C. (ed.) **Fuzzy multi-criteria decision making**. Boston: Springer, 2008. (Springer Optimization and Its Applications, v. 16).
- KARAZ, M.; TEIXEIRA, J. M. C.; AMARAL, T. G. D. Mitigating *making-do* practices using the last planner system and BIM: a system dynamic analysis. **Buildings**, v. 14, n. 2314, 2024.
- KARAZ, M.; TEXIERA, J. C. A system dynamic modelling approach for integrated *Lean*-BIM planning and control methods. In: ANNUAL CONFERENCE OF THE INTERNATIONAL GROUP FOR LEAN CONSTRUCTION, 31., Lille, 2023. **Proceedings [...]** Lille, 2023.
- KOSKELA, L. **An exploration towards a production theory and its application to construction**. Thesis (Ph.D) - Technical Research Centre of Finland, Espoo, 2000.
- KOSKELA, L. **Application of the new production philosophy to construction**. Stanford: Stanford University, 1992.
- KOSKELA, L. *Making-do*: the eighth category of waste. In: ANNUAL CONFERENCE OF THE INTERNATIONAL GROUP FOR LEAN CONSTRUCTION, 12., Helsingør, 2004. **Proceedings [...]** Helsingør, 2004.
- KOSKELA, L.; BØLVIKEN, T.; ROOKE, J. Which are the wastes of construction? In: ANNUAL CONFERENCE OF THE INTERNATIONAL GROUP FOR LEAN CONSTRUCTION, 21., Fortaleza, 2013. **Proceedings [...]** Fortaleza, 2013.
- LEÃO, C. F.; ISATTO, E. L.; FORMOSO, C. T. Proposta de modelo para controle integrado da produção e da qualidade com apoio da computação móvel. **Ambiente Construído**, Porto Alegre, v. 16, n. 4, p. 109-124, out./dez. 2016.
- MARCANDALI, S. Tecnologias disruptivas no design: aplicações e métodos. **Movimento Maker e Fab Labs**, v. 17, p. 64, 2019.
- MARINHO, M. S.; BARROS NETO, J. P. Análise de causas, efeitos e ocorrências de perdas *making-do*, retrabalho e falta de terminalidade em uma obra civil. In: SIMPÓSIO BRASILEIRO DE GESTÃO E ECONOMIA DA CONSTRUÇÃO, 12., Porto Alegre, 2021. **Anais [...]** Porto Alegre: ANTAC, 2021.
- MATTOS, C. **Produtividade, planejamento e gerenciamento de projetos na construção civil**. São Paulo: Pini, 2019.

- MENEZES, G. L. B. B. Breve histórico de implantação da plataforma BIM. **Cadernos de Arquitetura e Urbanismo**, v. 18, n. 22, p. 152-152, 2011.
- NEVE, H.; WANDAHL, S. Towards identifying *Making-do* as lead waste in refurbishment projects. In: ANNUAL CONFERENCE OF THE INTERNATIONAL GROUP FOR LEAN CONSTRUCTION, 26., Chennai, 2018. **Proceedings [...]** Chennai, 2018.
- OHNO, T. Toyota Production System: Beyond Large Scale Production. **Productivity Press**, New York, 1988.
- RONEN, B. The complete kit concept. **International Journal of Production Research**, v. 30, n. 10, p. 2457-2466, 1992.
- SANTOS, R. G. *et al.* Boas práticas na gestão de obras: soluções para interrupções no canteiro de obras. In: ENCONTRO NACIONAL DE GESTÃO DE PROJETOS, Fortaleza, 2012. **Anais [...]** Fortaleza: ENGEPROJ, 2012.
- SCHUELKE-LEECH, B. A. Disruptive technologies for a green new deal. **Current Opinion in Environmental Science & Health**, v. 21, p. 100245, 2021.
- SHAH, R.; WARD, P. T. Defining and developing measures of *Lean* production. **Journal of Operations Management**, v. 25, n. 4, p. 785-805, 2007.
- SOMMER, L. **Contribuições para um método de identificação de perdas por improvisação em canteiros de obras**. Porto Alegre, 2010. Dissertação (Mestrado em Engenharia Civil) – Programa de Pós-Graduação em Engenharia Civil, Universidade Federal do Rio Grande do Sul, Porto Alegre, 2010.
- TAGGART, M.; KOSKELA, L.; ROOKE, J. The role of the supply chain in the elimination and reduction of construction rework and defects: an action research approach. **Construction Management and Economics**, v. 32, n. 7–8, p. 829–842, 2014.
- VALENTE, A. C. da C.; AIRES, V. M. **Gestão de projetos e Lean construction: uma abordagem prática e integrada**. Curitiba: Appris, 2017.
- VERGARA, W. R.; TEIXEIRA, R. T.; YAMANARI, J. S. Análise de risco em projetos de engenharia: uso do PERT/CPM com simulação. **Exacta**, v. 15, n. 1, p. 74–88, 2017.
- ZADEH, L. A. *Fuzzy sets*. **Information and Control**, v. 8, n. 3, p. 338–353, 1965.

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Os dados de pesquisa só estão disponíveis mediante solicitação.

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