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ARTICLES

A COMBINATION OF FITRADEOFF AND COGNITIVE MAPS FOR OBJECT DEFINITION IN PUBLIC PROCUREMENT

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ABSTRACT. Public bidding is a Brazilian subject of great importance, being subject to control by the federal audit court, to prevent deviations and corruption. Even national legislation has undergone recent changes to make the use of this instrument more effective. In the public aspect, the bidding process goes through the determination of the need, the publication process, the choice, the contracting, and the post-contract period. Since some of the bidding modalities are exclusively based in "lowest price" and prevent the direct use of MCDA selecting the alternatives, this paper proposes using a combined approach, using MCDA and cognitive maps, to help in the determination of the bidding object. This approach is applied to a hypothetical situation, and the case study shows the convenience of its practical use in a real situation. The specific case is related to structural covering, using NBR15575 as a criteria definition subsidy. The study shows a contribution of cognitive maps to express the rationale according to legal principles and providing elements of the MCDA model. While FITradeoff supports the definition of the object, which is fundamental to avoid failures in the contracting process. The recent FITradeoff web version is used and the advantage of using the method is the reduction of decision-maker biases, increasing the transparency of the process.

Keywords: multicriteria, decision, operations research, public administration, Multicriteria Decision Analysis, FITradeoff.

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1 INTRODUCTION

Public Administration requires instruments to make it possible to contract services, make purchases, perform services, promote the sale or purchase of immovable or movable property, grant concessions and lease or permit property to third parties.

Transactions are used to hire private individuals and legal entities to fulfill these needs. The legislation creates the conditions and mechanisms that allow contracting to be done in accordance with the principles of public administration.

Procurement is the process of contracting goods and services in the Public Administration, that can be referred along this text as bidding once normally occurs through a competitive process. Procurement refers to a series of formal acts that are recorded in a process that follows the Federal Constitution's principles. It is regulated in specific legislation (Brasil, 1993), which establishes the formal rules and procedures public agencies must use to acquire/contract.

With the advent of the New Procurement Law (Brasil, 2021), the principles applicable to the general rules of purchasing and contracting were significantly expanded. In addition to the principles established in Brasil (1993) (legality, impersonality, morality, equality, publicity, administrative probity, binding to the call for bid and objective judgment), the following principles were added:

- efficiency – to obtain the best result with the minimum of resources;
- public interest – concerns the supremacy of public interest over private interest;
- planning – consists of replacing the public agent's individual criteria, improvisation and empiricism with planned and tested methods;
- transparency – the government must be transparent in its actions;
- effectiveness – concerns the one who fulfills his tasks or functions perfectly, reaching the proposed objective;
- segregation of duties – concerns the internal control mechanisms of the public administration, materialized through the separation of attributions and functions of authorization, approval, execution, control and accounting;
- motivation – the government must always provide a reason for its acts and, if they are provided for by law, it must justify them;
- legal security – to prevent the unjustified deconstitution of legal acts or situations, even if there has been some non-compliance with the legal text during its constitution;
- reasonableness – it is based on the concept of reasonableness, that is, common sense, justice, what is rational, legitimate, sensible and fair;
- competitiveness – it serves so that the public administration can reach the best contract through the promotion and expansion of access to the bidding process;

- proportionality – it is a principle that basically prohibits the public administration from acting in excess or using useless, disadvantageous, unreasonable and disproportionate acts;
- celerity – it is a principle that seeks a quick, accelerated process;
- economy – it is a principle that seeks to maintain quality, but with cost reduction;
- sustainable national development – it is a principle that seeks to be careful with the environment combined with the preservation and generation of employment and income, the search for sustainable development.

Those principles may be understood as conflicting criteria, and the use of a Multicriteria Decision Making tool should be considered as viable to perform the choice for such bidding, and several works presented similar problems to help choosing a winner proposal. However, the most common modalities of public purchasing will prevent the use of such instrument, since they are referenced as "minimum price". The study was devoted to a different use of operations research methodologies to assist in public bidding: the object definition.

From the planning principle, one can infer that the Government must plan entire bidding and all public contracting. Although the planning and performance of the contract are independent phases, it is of utmost importance to properly plan the bid proceeding to accurately contemplate the need to be satisfied with the performance of the contract, the correct definition of the subject matter or technical solution, and the accurate estimate of the reference price, as well as all other definitions that are essential to effectively and efficiently configure the bid and the contract.

According to Brasil (1993) the subject matter of the bid invitation must be elaborated in a succinct and clear manner, and great attention must be paid to all its clauses, to avoid that its defects and poor detail may jeopardize the progress of the bid process, resulting in annulled bids due to confusing and poorly written subject matter, resulting in losses both for the Government and for the participants in the bid. It is not unusual to find suppliers that deliver products or services that are not exactly what the Government intends to acquire or contract, often due to erroneous interpretation of the subject matter of the bid invitation.

In this context, the present work proposes a combined use of the problem-structuring method and the FITradeoff method to support the definition of the object, helping the decision maker to evaluate the important criteria and avoid possible inconsistencies that could compromise the hiring process. To establish a reasonable methodological framework, Section 2 presents aspects of normative and methodological references. Section 3 presents an example case study, while Section 4 details the results. Finally, a brief conclusion is presented in Section 5.

2 THEORETICAL AND NORMATIVE REFERENCE

2.1 The Bidding Regulatory Framework

Bidding, within the scope of the Federal Government, is intended to ensure compliance with the basic principles of public administration, as set forth in the main section of Article 37 of the

Constitution of the Federative Republic of Brazil (CRFB) (Brasil, 1988), and Subsection XXI of the same article.

Bidding at the federal level in Brazil is regulated by a set of laws and secondary legislation. In addition to the General Procurement Act, the Reverse Auction Act and the Differentiated Procurement Act are secondary pieces of legislation that establish the legal framework for public procurement. Moreover, the Ministry of the Economy oversees adopting "Instruções Normativas", or Regulatory Instructions, that complement the legal framework of public procurement.

Federal Law No. 8.666/1993 (General Procurement Act) (Brasil, 1993) governs the general regime of public procurement of services, goods, and works at the national level, covering federal, state, and municipal entities. It is, however, possible for states and municipalities to adapt the provisions of the General Procurement Act to their local needs.

There have been many attempts to modify the General Procurement Act. A draft bill from 1995 was being considered by the Federal Senate during the drafting process. This led to the adoption of the new law 14.133/2021 (Brasil, 2021) will become fully effective from the December 30, 2023. In the interim, legislation was passed in 2002 and 2011, which sought to fill in the gaps and regulate specific procurement processes. However, its scope remains limited. Federal Law No. 12.462/2011 (Differentiated Procurement Act), originally intended for specific engineering projects.

The Reverse Auction Act permits procurement online via Comprasnet, a Brazilian e-procurement platform, and is only subject to the General Procurement Act subsidiarily. Reverse auctions use the lowest price as the award criteria. Qualifying bidders occurs after the bidding has finished. Reverse auctions are used more frequently in Brazil, despite being designed for common goods and services procurement. The Reverse Auction Act is broadly understood by public-procurement entities. They consider all goods and services that are eligible for award under the lowest price criterion to be common.

The Differentiated Procurement Act has seen its application expand since its inception in 2011. The Differentiated Procurement Act was originally created to procure works for the 2014 World Cup and 2016 Olympic Games. It is now more broadly applicable to engineering works and services in other sectors such as public health, penitentiaries, and urban mobility. Recent authorizations of the act have been granted for urgent purchases in connection with the COVID-19 pandemic.

Electronic procedures are possible under the Differentiated Procurement Act. Before or after qualification of bidders, the opening and evaluation of technical and economic offers can be done electronically. Offers may be submitted in sealed envelopes or encrypted electronic means or via the reverse auction system.

The Ministry of the Economy adopted regulations to improve processes and make them more efficient. However, the procurement community believes that this type of regulation is too restrictive and that a new law would be better. This new law would harmonize existing laws and

regulations. As a compromise, the new law 14.133/2021 was approved at the time this report was being drafted. Two major innovations in the draft bill are:

- A chapter dedicated to public procurement officers (Title IV, Chapter IV);
- A particular focus on tender preparation, with the explicit requirement to prepare a preliminary technological report (estudo técnico preliminar; Title II, Chapter I), which is the document that can use multicriteria method for choosing a viable solution for requested product or service.

All procurement processes can be divided into three stages:

1. pre-tender;
2. tender, which includes the publication of notice and contract award;
3. post award.

For the purposes of the model to which this paper refers, the pre-tender phase is the most relevant stage, since it is when the multicriteria analysis is applied to define object besides, among other fundamental parameters for the success of the bidding.

2.1.1 Pre-tender phase

Pre-tender, also known as internal phase or preparatory phase (Brasil, 2010), is the stage that defines the parameters and characteristics of the bidding process. This includes establishing the entity's requirements and assessing potential supply markets, to deciding on the best tender methods.

Federal entities must create an annual contracting program (Plano Anual de Contratações or PAC) every year. This plan must include the contracts for the next financial year. It must be based on the federal entity's budget and should contain pre-defined fields from Comprasnet.

In accordance with PAC, the requesting department(or unit), supervised by the director, initiates the bidding process by filing a form with a request for a service or product (Documento de Formalização da Demanda or DFD).

The technical department, which may be separate to the requesting department, creates a preliminary technical report (Estudo Técnico Preliminar or ETP) that evaluates the requesting entity's need, under the approaches of available solutions on the market, general and specific characteristics of the object, prospecting for potential suppliers and technical and economic-financial viability of the hiring.

Preparation of preliminary technical report is the first step in planning a bidding (preliminary planning) and aims to objective:

1. to ensure the technical feasibility of the contract, as well as the treatment of its impact environmental;

2. support the term of reference (Termo de Referência or TR) or the basic project (Projeto Básico or PB), which is only elaborated if the hiring is considered feasible, as well as the plan of work (Plano de Trabalho or PT), in the case of services.

All federal entities are required to create a preliminary technical report (ETP) prior to the purchase of goods, services, or public works. This requirement was previously only applicable to the purchase of information and communication technology (ITC) and services. This preliminary study helps the unit to better understand their needs and find market solutions.

Public agencies must also conduct price research to determine the acceptable price at which an offer is unacceptable. In this paper, that consider Brazilian Navy organizational structure, it'll be considered that Purchase Department (or sector) is responsible for that task instead of Technical Department, how use to happen in some structures.

The above information is used to determine the terms of reference (TP) for goods or services, or the main terms (the project's terms) for public works. A public purchaser will then define the procurement method, the object of the contract and the quantities. The tender notice for public works procurement will include detailed specifications.

2.1.2 Object Definition

According to Vareschini (2013), the best way to avoid the most frequent failures in contracting processes occurs through thorough planning, which allows the Administration, in summary:

- identify its main needs;
- adequately define the quantities that will be necessary to meet the demand;
- determine the periodicity of the contracting;
- adequately delimit the object, defining specific characteristics that meet the institution's needs, but with due caution so as not to unduly restrict competitiveness;
- carry out a broad market survey to estimate the price of the contracting.

To achieve these objectives, it is essential to prepare the Terms of Reference, which will serve as a parameter for the preparation of the Tender Protocol and must describe, in a precise and adequate manner,the Administration's needs and the terms of the desired contract.

2.2 Problem Structuring Theoretical Reference

The legal constraints for this problem implicitly transform the problem, which could be first understood as a hard OR problem where a multicriteria method could be directly applied in order

to choose the best alternative, into an ill-structured problem, where the public interest appears as a hidden stake holder.

Soft OR methods appear as a viable way to deal with this kind of problem. and its roots date from Ackoff (1979a,b) . Among the problem structuring methods are Soft Systems Methodology (SSM), proposed by Checkland (1981), and Strategic Options Development and Analysis (SODA), proposed by Eden (1989).

Nevertheless, such a problem is not intended, for every public bidding contract, to be solved through stakeholders compromise and accommodation and reaching an acceptable solution for all involved stakeholders. Even because the public interest is a diffuse stakeholder. In contrast, this study uses problem structuring techniques to structure how the intended bidding is adequate to legal principles.

In fact, a multimethodological approach is widely used. Howick and Ackermann (2011) presented a review of case studies that combine different methodologies and used a set of interests to classify these methodologies. In addition, the combined use of soft and hard OR techniques is considered to produce better results.

For that, an instrument based on cognitive mapping, is used on the study.

The term “cognitive map” has been used for distinct meanings (Doyle and Ford, 1999). The first reference of the term cognitive map is found in Tolman (1948). A brief presentation of distinct interpretations of cognitive map can be found in Pessôa et al. (2015b). It is necessary to highlight the contributions of Axelrod (1976), creating a cognitive map theory as a tool to analyze social systems in the real world graphically. Also it is noteworthy the introduction of fuzzy cognitive maps (FCM) (Kosko, 1986) as a tool to model the behavior of qualitative systems, assessing the causal relationships as degrees of causality between the concepts.

However, the instrument used in this paper is detailed in Pessôa et al. (2015a), and uses na adaptation of SODA Eden (1989) to provide a way to overcome sequential communication for language and help create a quantitative model. In addition, it also stimulates a metacognitive approach to the problem (Lins, 2014).

The proposed approach is expected to benefit the organization by providing a deeper understanding of the bidding object in a similar way. Moreover, it provides a link of the bidding object to the bidding law requirements, which is helpful for the bidding process and also for audits. Because the bidding processes are devoted to more expensive purchases of goods and services, and subject to higher scrutiny.

The original structuring approach, Pessôa et al. (2015a) was not considered a strict SODA application, because it uses a simplified form of causal cognitive mapping and does not explore a negotiated decision Eden (1989) It consisted of the following steps:

- Mission definition: the problem to be solved
- Key personnel selection: relevant stakeholders

- Interviews: semistructured interviews to generate the cognitive maps
- Cognitive mapping: constructed through the compilation and structuring of the factors (Primary Evaluation Concepts), that must be brief, and may be complemented by contrasting items to better characterize the core idea.

The development of the cognitive map used the following rationale: "The ensuing question 'How?' (meaning 'what actions can lead to this concept?') is proposed to obtain the means to achieve a concept. Thus, the links between concepts are initially derived from the mission to form other concepts.(...) To organize the concepts, the facilitator asked: 'Why is this concept important?' This also allowed for interconnections among different concepts."

This study intends to adapt this technique. However, due to the intended mandatory connections to the bidding law principles, in this adaptation some concepts will be necessarily present on the map, and some questions used to produce the connections will be a default on the interview process.

It is also important to note that interviews and maps, despite considered separated steps, are a cyclical activity, and the cognitive map depends on the approval of the interviewee to be considered finished.

The organizational structure considered for this model may vary from institution to institution in the Brazilian Federal Government. This implies that some role assigned to one department can be played by another. However, this does not disqualify the model, but requires some adaptations.

2.3 FITradeoff Theoretical Reference

The multicriteria decision model, according to De Almeida and Costa (2003) consists of a decision problem in which certain basic elements are observed, such as the decision maker, the objectives, the preferences and the alternatives to be chosen by such.

According to Vieira (2016) the multicriteria decision process is based and focused on the decision maker. It can be an executive, a manager, who presents the problem of choosing between alternatives with conflicting objectives, and that the decision may impact the organization. Such decisions are inherent to business and organizational activity, which makes the use of a decision model so relevant, since it starts to base such decisions using rational and transparent criteria.

The FITradeoff method (Flexible and Interactive Tradeoff) (De Almeida et al., 2016) as one of its great potentialities is its peculiar way of eliciting information of preference from the decision maker, with a reduction of cognitive effort required by the decision maker to establish the scale constants.

The establishment of scale constants is precisely a point of great sensitivity and impact on the decision model. Over time, the model, which contemplates support solutions, dedicated to the choice and ordering modalities, has been constantly improved to contemplate behavioral aspects,

with improvements in its graphical presentation, aiming at a more intuitive and easy interface for interaction.

The present work uses the choice mode, supported by a Web-Based Decision Support System (DSS). The most recent version of the FITradeoff DSS includes the combination of two types of preference modeling in its structure(De Almeida et al., 2021): elicitation by decomposition and holistic evaluation, so that the decision maker can alternate between these two types, in a flexible way, according to his own wishes. This version also has the advantage of presenting both modes of choice and ordering, and the possibility of using nonlinear value functions in the intracriteria evaluation step.

The choice of FITradeoff for this work comes from this potential, coupled with its employment in procurement contexts (Frej et al., 2017; Rodrigues et al., 2020; Fossile et al.,2020), in technology assessment (Kang et al., 2018), and also in military contexts, in which the present work is inserted (Pessôa et al., 2018; Silva et al., 2020; Botelho et al., 2017; Pessôa et al., 2016).

The execution of the method can be separated into two steps. The first provides for the ordering of the criteria scale constants by the decision maker, in a decreasing manner of relative importance, taking into account the criteria ranges of consequences.

The choice problematic with FITradeoff (De Almeida et al., 2016) is based on a Linear Programming Problem, where m alternatives ($j \in \{1,\ldots,m\}$) are evaluated according to n criteria, each criterion $i(i = 1,\ldots,n)$ having its scale constant ki. Its formulation is as follows (De Almeida et al., 2021):

$$maxv(aj) = \int_{i=1}^{n} kivi(yij) \tag{1}$$

In which yij is the consequence of alternative j in criterion i. Subject to a constraint on the scaling constants, consequential to an ordering performed by the DM:

$$k1 \geq k2 \geq \cdots \geq kn-1 \geq kn \tag{2}$$

The second step presents the decision maker with two hypothetical consequences, which diverge in only two criteria (i and j), and presents the decision maker with the option to choose one of them or consider them indifferent or even express their impossibility of evaluation.

Gradually, as a result of the choices made, the space of alternatives that can be chosen may be reduced, due to additional restrictions on the scale constants, resulting from the decision maker's response.

The process continues until the moment when, in addition to an established tolerance, a winning alternative is determined, or a subset of alternatives, in a tie, whose differentiation is smaller than the established tolerance.

The question-answer process is carried out interactively and the decision maker can also choose to perform holistic judgments between alternatives whenever he/she wants (De Almeida et al., 2021).

The DM may also interrupt the process when the set of alternatives is narrow enough to make a decision. The FITradeoff Decision Support System used in this article is available at http://www.cdsid.org.br/fitradeoff.

3 METHOD

This section enumerates the steps applied in the modeling. The details about modeling processing are presented in the next section (case study), where we apply the stages and steps described here to a hypothetical realistic military situation decision. Figure 1 presents a representation of the connections of the methods and the expected contribution for the actual process.

1. Mission Definition: The mission definition in this study is to be the intended bid object.
2. Key personnel selection – the personnel selected for the process, with different roles, to comply with "segregation of duties" principle:
   (a) the Director, responsible for the approval of the administrative process;
   (b) the Purchase incumbent (Intendente); and
   (c) the related technical sector head.
3. Interviews: in this study, interviews are intended both to construct cognitive maps and to perform the MCDA evaluation. Separated interviews are meant to ensure this process, generating different cognitive maps for the Director, Technical Sector, and Purchase sector, while the evaluation is performed by the Director only, pre-serving the decision autonomy. Therefore, it protects the personnel involved from the authority constraints.
4. Cognitive maps: in the original approach, developed by Pessôa et al. (2015a), the mission was represented as a top concept, which meant the problem to be solved, and the factors relevant to the solution of the problem, called Primary Evaluation Concepts (PECs), were constructed freely by the interviewees.

   In this study, the initial alternatives are meant to be present on the Cognitive Map of the Technical Department. Additionally, the maps will have mandatory PECs, representing the legal principles, to respond accordingly to the roles of the interviewees.

   - Director – The first concept to be explored is the motivation, obtained directly from the top of the map, using a support question (Why is it necessary?). Here, the complementing negative concept, as presented in Subsection 2.2, hás an additional purpose: to provide an estimate of the impacts if the bidding is not attended. Public interest, and the derived concepts are found through a direct question: (How the public interest is affected?). The concept of transparency is explored through the following questions:
     – "Is the decision process supported by method ?"
     – "Is the process publicly available?"

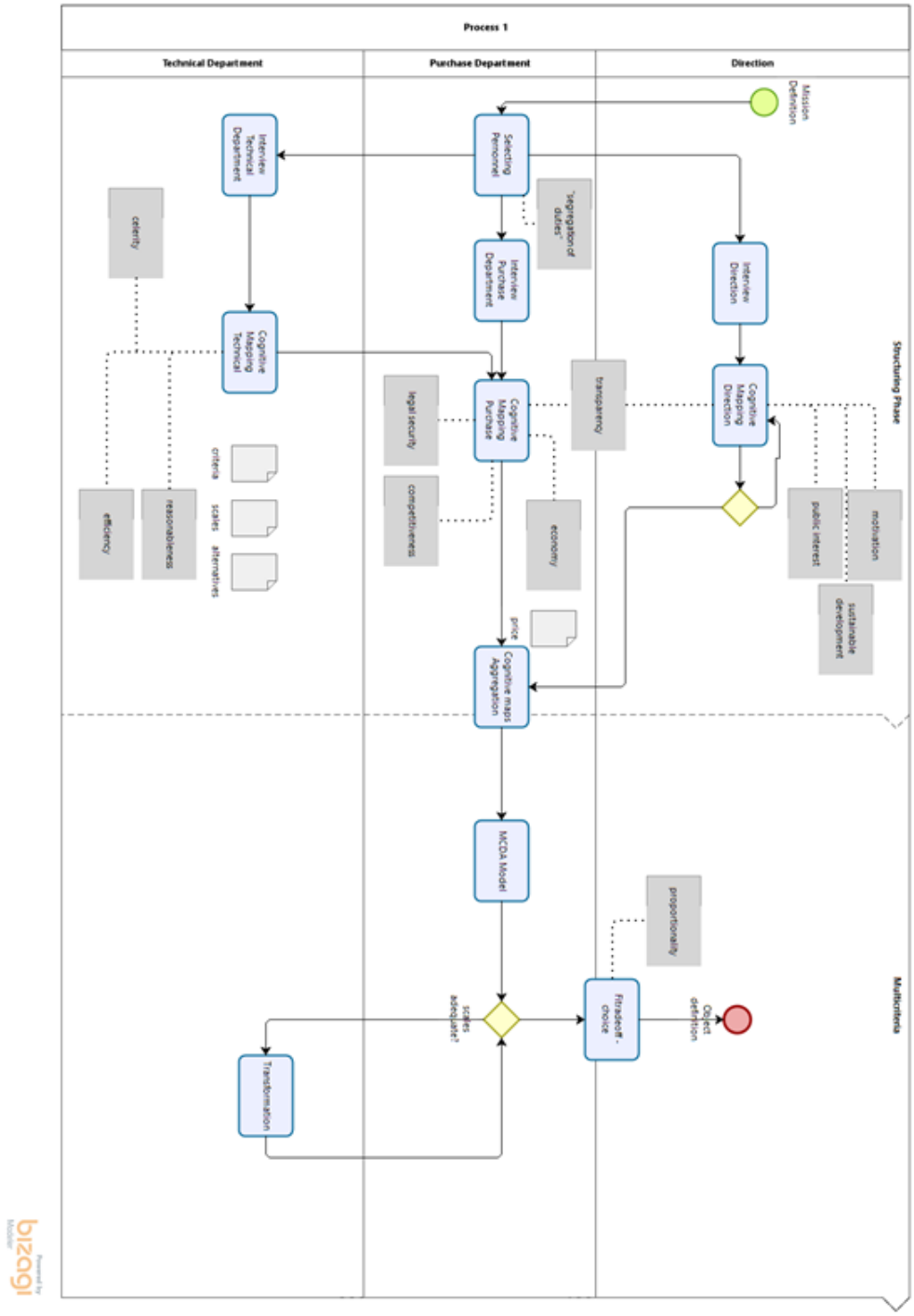

Figure 1 – Flux.

Finally, through the "motivations" and "public interest" derived concepts, it is possible to verify if the "sustainable national development" is somehow connected to the graph.

- Technical Department – The technical Department will be responsible for responding on how the "mission" can be done. Therefore, its map shall contain the imagined alternatives and connect it to the principles of effectiveness, reasonableness, and celerity. Thus, it presents evaluations of feasibility, adequateness, and valid criterion to evaluate the alternatives;
- Purchase Sector – The purchase sector cognitive map derives the transparency and legal security, concerning the normative adequateness of the bidding process. While the competitiveness analysis analyses the inexistence of monopoly for each alternative. This represents a veto to alternatives that do not allow for viable competition. Finally, to evaluate economy, alternative data regarding the cost/price is obtained as an element to the MCDA model. Public agencies must also conduct price research to determine the acceptable price at which an offer is unacceptable. In this paper that considers the organizational structure of the Brazilian Navy, it will be considered that the Purchase Department (or sector) is responsible for that task instead of the Technical Department, which happens in some structures.

5. Maps Consolidation – Gathering and synthesis of elements that must be included into the MCDA model.

6. Validation of alternatives – From the cognitive map of the Technical Department, the selected alternatives will have a relationship to the concepts of effectiveness, reasonableness and proportionality, to verify their adequateness to the object. While the Purchase department will provide an evaluation regarding competitiveness.

7. Definition of criteria from the Technical Department map, elements related to the effectiveness concept will be considered as technical object criteria; from the Purchase sector map, concepts derived from the economy concept will be regarded as economy criteria.

8. Scale definition and adequation – How the criteria will be measured. The direction may consider the need to adequate a criterion scale for a better non-expert judgement.

9. FITradeoff evaluation, performed by the Director using the freely available FITradeoff web application, to evaluate the alternatives.

10. Definition of object – consolidating the result and the elements for each legal principle, so as to justify the decision.

After the definition of the object, the Technical Department will be able to establish a detailed planning to estimate the time and cost to subsidize the object bidding.

Note that there is a critical dependence of the Cognitive Map of the Purchase Department on the alternatives produced by the Technical Department. It occurs due to the need to have adequate alternatives listed to evaluate the economy and competitiveness. Despite the aforementioned dependence, the segregation of roles is preserved.

The following section presents an example of a hypothetical case for a Brazilian Navy organization. It is intended as a more complete depiction of the method outcome to a practical situation.

4 CASE STUDY

The research problem was contextualized in the public administration environment and the hypothetical choice of roof tiles for the structural coverage of a building of a Military Organization, given the need for maintenance of the existing installation, without the need for structural changes.

The existing installation consists of a system to close the upper part of the building, its frame made of wood, and depending on the floor plan of the covered building, the roof has the configuration of the so-called three-span roof as shown in Figure 2.

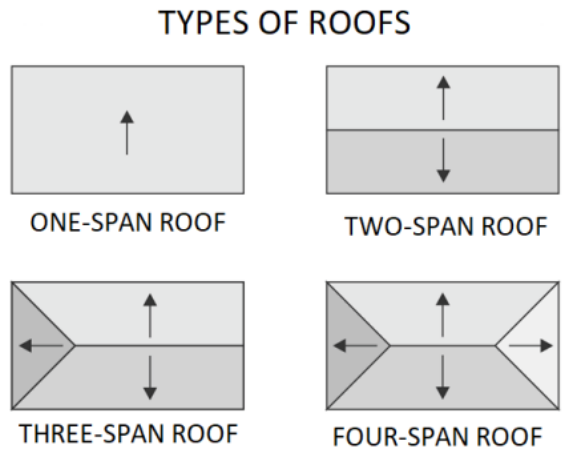

Figure 2 – Scheme in plan of roof types.

Source: Pereira (2016).

The roof is a mixed method of coverage with a support system and its main function is to protect the internal area, preventing the entry of rainwater, sun rays, winds, and animals, being composed of tiles inclined so as to conduct the rainwater to the gutters and then to the ground. Can be built with different types of tiles, which is essential for the choice of material that is resistant, waterproof, unalterable in terms of shape and weight, it needs to be lightweight, easy to maintain, with good durability and reasonable cost.

Following the model

1. Mission Definition – Using the method, the first step is to define the mission. ”Structural covering of a Military Organization building”

2. Key personnel selection – the personnel selected for the process, with different roles, so as to comply with “**segregation of duties**” principle:

   (a) the Director, responsible for the approval of the administrative process;

   (b) the Purchase incumbent (Intendente); and

   (c) the related technical sector head.

3. Interviews Interviews are conducted to generate elements for the construction of cognitive mapping. The mandatory concepts are already present in the interview to ensure their evidence on the respective cognitive map.

4. Cognitive Maps:

   - Director – The motivation, the answer to the question “Why is it necessary?” according to the Director map (Figure 3) is:
     – “to provide protection to the building, equipment and people working there” and
     – “If not fixed may deteriorate the building”
     Thus, affecting the performance of the organization and the achievement of its necessary activities. Public interest, and the derived concepts are found through a direct question: (How the public interest is affected?). The transparency concept is explored through the following questions: “Is the decision process supported by the method?” and “Is the process publicly available ?”. Finally, through the concepts derived from “motivations” and “public interest” derived concepts, it is possible to verify if the “sustainable national development” is somehow connected to the graph, as presented in Figure 3.

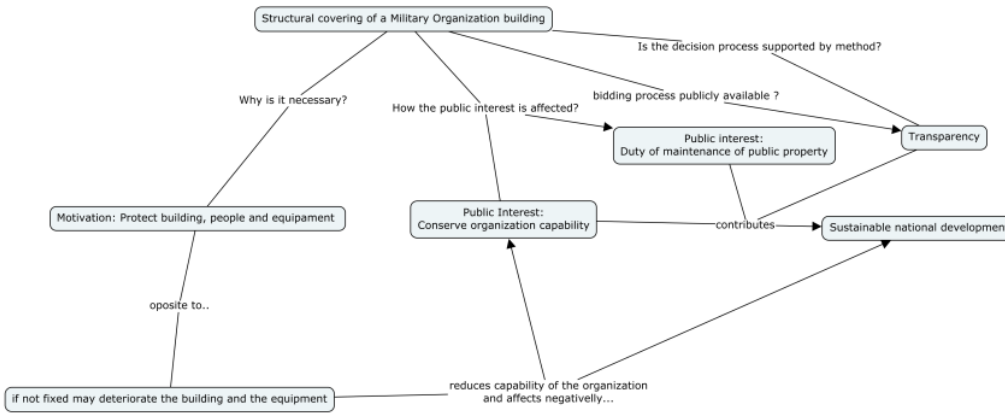

Figure 3 – Director Cognitive Map.

- The Technical Department perspective uses the assumption that the top concept, that is, the definition of the mission, is already justified, but explores the principles of effectiveness, reasonableness and celerity, as presented in Figure 4.

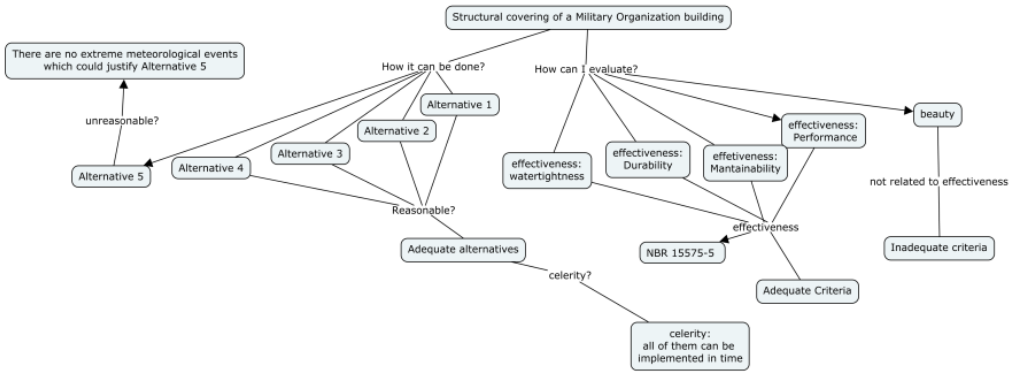

Figure 4 – Technical Department Map.

- Purchase Sector maps explore the principles of transparency, legal security, competitiveness; economy, as shown in Figure 5.

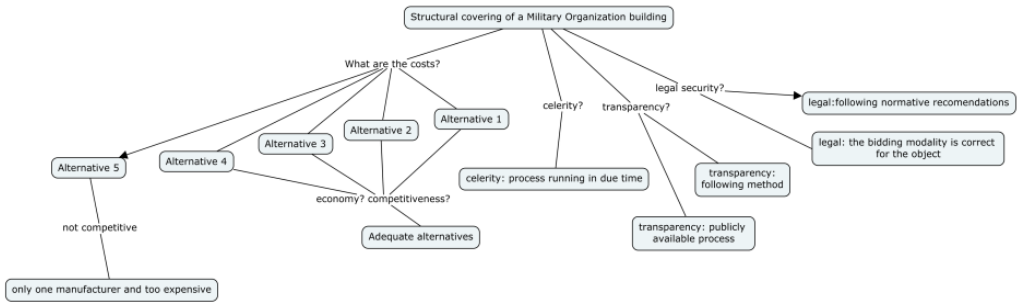

Figure 5 – Purchase Department map.

5. "Maps Consolidation" represent the elements that were included in the MCDA model. The building roof can be built with different types of roof tiles, where the choice of material that is resistant, impermeable, unalterable in shape and weight needs to be light, easy to maintain, with good durability and reasonable cost.

6. Definition of criteria

   From the Technical Department map, the elements related to the effectiveness concept will be considered as technical object criteria; from the Purchase sector map, the derived concepts from the economy concept will be regarded as economy criteria.

   The Brazilian Association of Technical Standards establishes in the Brazilian Standard NBR 15.575 which addresses the topic of roofing systems. The technical requirements that

will serve as parameters to exemplify how the decision of this model could be structured, considering the following critical aspects to be analyzed:

(a) Durability – Durability is understood as the ability to meet the functions it is intended for during the useful life specified in the project as long as the indicated periodic interventions and maintenance are carried out.

(b) Maintainability criterion evaluates the ease with which these maintenance are carried out

(c) Watertightness – It is associated with the ability to be impermeable to rainwater impermeable to rainwater, avoiding the formation of humidity and the proliferation of insects and microorganisms.

(d) Thermal performance. As for the issue of thermal performance, it is associated with the realization of a project that offers adequate thermal performance for the region where the building is or will be built.

Sometimes, a problem is prone to be solved with different solutions. So there are distinct objects which could be established as a basis for the bidding process.

It is important to highlight that the model purpose is to help on the definition of the bidding object, and not to choose among the suppliers' proposals, which will be evaluated in later phases of the bidding process, normally selecting the lowest price proposal.

Therefore, the alternatives do not represent the contractor's offers, but the feasible bidding objects to become the reference to the proposals.

In this step, the economy criterion refers to an evaluation of the different types of cost for each alternative, such as the expected purchase cost, maintenance cost, and so on. It involves an evaluation of compatible alternatives for the available budget.

The economic aspects may be composed of technical department concepts, in order to provide a complete assessment of maintenance costs, which will not be evident on the final offers from the competitors.

7. Alternatives validation – from the Technical Department cognitive map, the selected alternatives will have their relationship to effectiveness, reasonableness, and proportionality concepts, in order to verify their adequateness to the object For the analysis of this problem, four alternatives are analyzed.

   There are some possible veto decisions regarding the principle of reasonableness, with respect to the technical department, as shown in Figure 4, where Alternative 5 is discarded because it was not a reasonable solution. (e.g. a roof designed to resist to hurricanes where such phenomena does not occur).

   In the presented case study, the Purchase Department also rejects alternative 5, since there is a monopoly for the alternative, to comply with the competitiveness principle.

The four alternatives, Alternative, 1, 2, 3 and 4 are the viable alternatives which have passed the minimum technical requirements, on the Technical Department perspective, and also the competitiveness evaluation, regarding the Purchase Department Cognitive map accordingly to the aforementioned criteria.

8. Scale Definition – This step defines how the criteria will be measured. The direction may consider the need to adequate a criterion scale for a better non-expert judgement. The original technical criteria establish categories M (Minimum), I (Intermediate), and S (Superior). To present a scale closer to the decision maker's evaluation, numerical scales were established in the range of zero to ten. As a limitation, the use of a numerical evaluation scale of 0-10 was characterized as a linear approximation of the correspondence of the performance indicators in each criterion.

   Table 1 establishes a correspondence between the indicators used and the corresponding linguistic variables defined for each criterion on the evaluation scale.

Table 1 – Correspondence between Linguistic Variables and Numerical Scale.

Linguistic Variable	Numerical Scale
Excelent	10
Very Good	8
Good	6
Regular	4
Weak	2
Very weak	0

   It was considered that the benefit of an easier elicitation for the decision maker would have more benefits for the process than the problems arising from this linear approximation.

   At the same time, it presents greater discrimination between alternatives inserted in the same category. Table 2 presents the alternatives performances using the transformed scale.

Table 2 – Consequence matrix.

	Durability	Mantainability	Watertightness	Thermal Performance
Alt1	8	6	8	6
Alt2	10	8	8	4
Alt3	10	8	8	6
Alt4	10	8	8	8

9. FITradeoff evaluation, performed by the Director using the Web application, brings the "proportionality" of the alternatives, which corresponds to the trade-off among the criteria.

The Intercriteria Evaluation process is initiated by ordering the scale constants of the criteria. Figure 6 presents the FITradeoff screen with alternatives before the ordering process of the scaling constants.

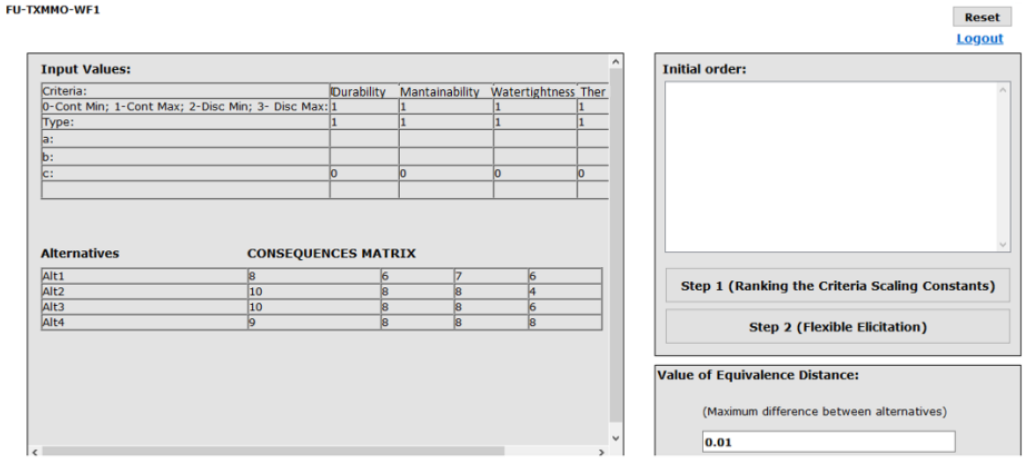

Figure 6 – FITradeoff ordering step.

Equation 1 presents the following result in the decision maker's opinion:

$$kdurability \geq kmaintainability \geq kwatertightness \geq kthermal \tag{3}$$

After ordering the criteria scale constants in descending order of preference, we proceeded to the flexible elicitation process of the scale constants. This step is considered one of the differentials of FITradeoff, because this elicitation is done in a flexible way and gradually narrows the space of scale constants.

In each step, the decision maker chooses between two presented consequences that differ only in two criteria. Importantly, for the decision maker, the competing alternatives themselves are not presented for intercriteria evaluation.

Figure 7 shows the first question the software asks the decision maker.

The DM is asked to compare two consequences, considering tradeoffs between criteria. Consequence A in the left side of the figure presents an internediate outcome in criterion C1 – Durability" and worst outcome in all other criteria; Consequence B represents the best outcome in criterion "C4 – Thermal Performance" and the worst outcome in all other criteria.

The software presents additional information, such as the number of questions answered; the number of potentially optimal alternatives; the ordering of the criteria weights; and the maximum difference between the potentially optimal alternatives.

In this very first interaction, one of the four alternatives available to the decision maker was considered dominated.

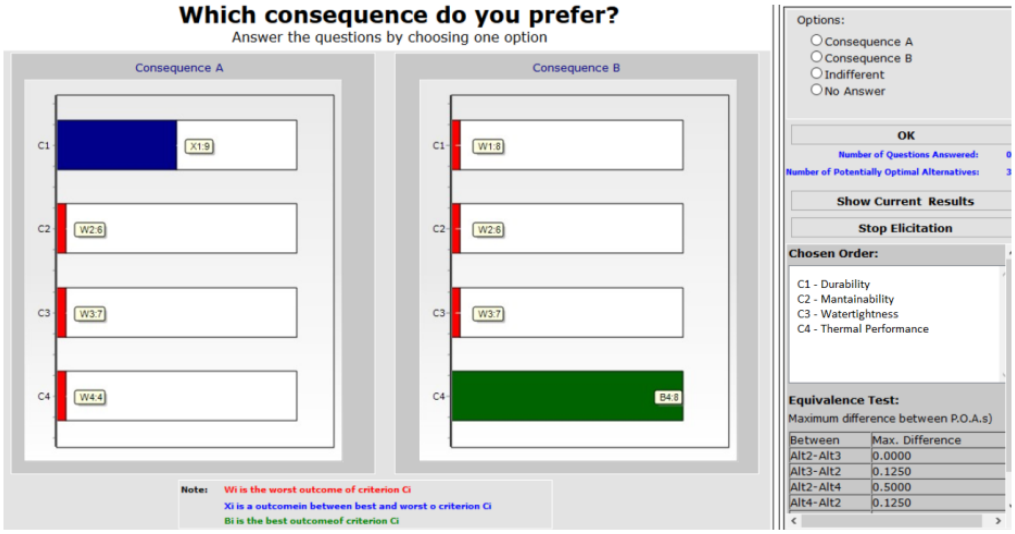

Figure 7 – First Elicitation Question.

Since the intercriteria evaluation does not present actual alternatives in the elicitation process, the DM bias is reduced at this step.

After answering the first question, the number of potentially optimal alternatives was reduced to two, as shown in Figure 8. Its difference is a maximum tolerance of 0.10.

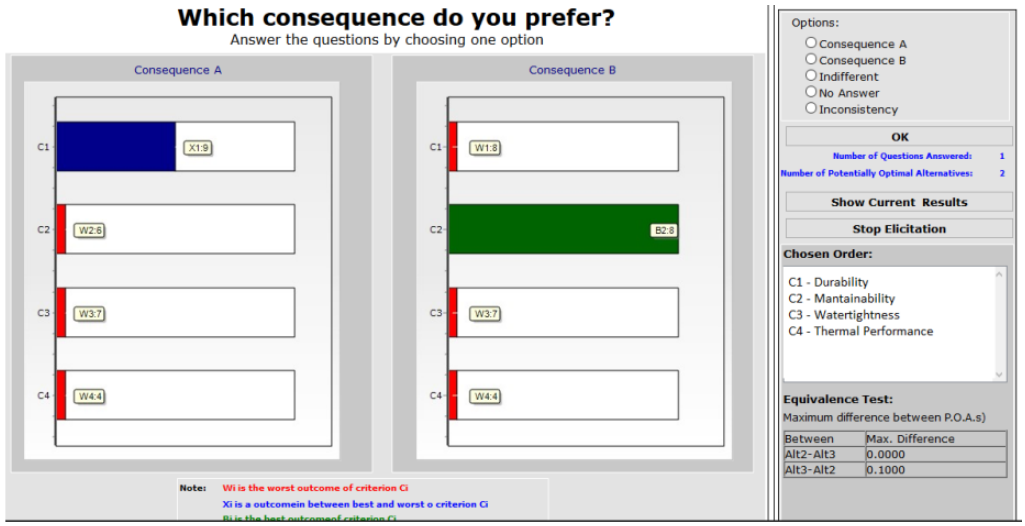

Figure 8 – Second Elicitation Question.

FITradeoff presents the holistic evaluation feature, allowing the DM to interrupt the elicitation process, assess the potentially optimal alternatives, and analyze their performance. For example, Figure 9 presents an example of holistic evaluation.

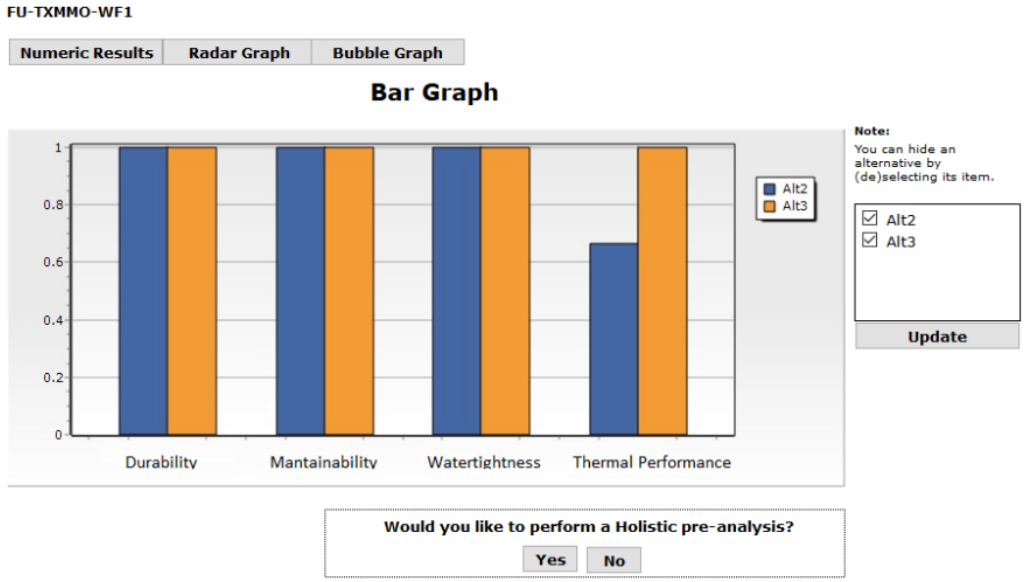

Figure 9 – Bar graphic comparing alternatives Alt2 and Alt3

Therefore, the decision maker can, when analyzing these sources of information, interrupt the process if he is confident to finalize his decision.

The height of the bar represents the consequence of the alternative on a given criterion, normalized on a ratio scale from 0 to 1. In this graph, the alternatives present the same performance in the first three criteria, but the alternative Alt3 presents a slight advantage in the last criterion (thermal performance).

It is noteworthy that FITradeoff did not eliminate the alternative Alt2. It occurs because the range of scaling constant values, presented in Figure 10, allow a very small magnitude of the scale constant of the "Thermal performance" criterion.

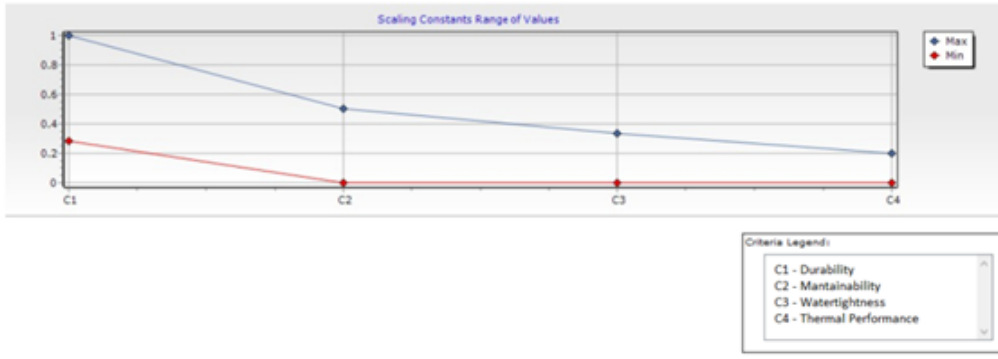

Figure 10 – Scaling Constants range of values.

If it becomes very small (close to zero), the two alternatives may be considered indifferent, since they would be "tied" in terms of overall value, according to the equivalence threshold defined at the beginning of the process.

10. Definition of object – Looking closely at Figure 9, the decision maker made a holistic judgment, declaring a preference for the alternative Alt3. The result and the elements collected for each legal principle are documented to justify the decision.

Then, after the definition of the object, the Technical Department will be able to provide planning guidance for the bidding process.

5 CONCLUSION

As the majority of public bidding in Brazil is related to the "lowest price" type, a great deal of Operations Research methods, including MCDA, are not adherent to the law constraints for alternative selection.

This work makes a practical contribution to bidding processes in the Brazilian public context. The described approach may be used for the "lowest price" type, and other modalities as well, aimed at the bidding object definition.

Moreover, the proposed approach establishes a connection of the object definition with the principles of Brazilian bidding law, through the cognitive maps. This can be interesting not only for a better bidding execution, but as a way to ease the execution of control.

In fact, the poor definition of objects is regarded at least as harmful as corruption, leading to waste and poor use of public resources.

In a way to present an use example, a fictional, yet close to reality,a study case is presented. The study case shows a hypothetical bid for the roof replacement of a military building. It shows some of the valid tradeoffs that the decisor may face, and the need of "scale adjustment".

In its evaluation, the functionality of a combined use of FITradeoff holistic evaluation shows how the process can be simplified to translate the DM preference about the object alternatives. With the use of the holistic assessment tool, the decision maker was able to finalize the elicitation process by answering only one question in the decomposition elicitation process and making only a holistic judgment. In this way, it is concluded that the possibility of making holistic judgments in the process reduces, even more, the time and cognitive effort spent by the decision maker.

As an academic contribution, the study builds a multimethodology approach, using a cognitive mapping adaptation, preserving the separation of roles of the people involved in the bidding process, using their roles as a way to connect the Brazilian bidding law to multicriteria elements.

The interpretation of the Brazilian laws as a "hidden" public stakeholder to be represented in a Soft OR context and its connection to a MCDA method seems to be novel and may extend the combined use of soft OR and Hard OR to a broader range of public applications.

Another contribution is to provide a "translation" for technical aspects to be evaluated by directors who are not familiar with specific jargon or detailed elements. The object alternatives are meant to be judged by the DM on knowledgeable terms for a proper decision.

In addition, the approach produces a "metacognitive" feature about the justification of the process. This element can help the documentation of the process in a way that eases bid control, even for audits.

Future works can explore adaptations to specific public contexts, due organizational differences and needs. On the methodological perspective, a development could use weights of relationships between concepts, or even fuzzy logic, to enhance the interpretation power of the cognitive maps. Another interesting point for development could comprise a deeper exploration for services, materials and contracts procurements guided by specific procurement legislation, so as to incorporate other legal constraints elements in the presented framework, and enhance its potential.

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