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ARTICLES

A FITRADEOFF-BASED APPROACH FOR STRATEGIC DECISIONS ON MILITARY BUDGET

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ABSTRACT. This paper presents an actual application of the FITradeoff method to support strategic decisions on military budgets. Using Optimization Techniques and a particular Multicriteria Decision Aid method to assess budget allocation efficiency, a model was built for the Brazilian Defense Ministry. A case study of the Brazilian Navy is described in this paper, whereby this model was used. The focus is on the adaptations of FITradeoff necessary to make it suitable for different groups of decision-makers and staff, performing different tasks on the process. The FITradeoff proposal allowed a group decision with different levels suitable to the military context and high-level strategic decisions. The use of multicriteria in this approach provides a meaningful utility measure. This provides a score value representing the desirability of an alternative, in terms of its attainment of the institution´s strategic objectives. The approach contributed to an approximate gain of 15% in budget efficiency in 2022.

Keywords: FITradeoff, military, strategic decisions.

1 INTRODUCTION

This article presents an approach to using FITradeoff (Almeida et al., 2016) to address a real case of assessing strategic decisions on the Brazilian Navy's budget allocation. This approach is part of a hybrid model that uses optimization and multicriteria to assess the allocation of funds among investment alternatives. It was placed first in the Brazilian Contest for Defense Budget (Pessôa et al., 2021).

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For a successful result, it was essential to provide a meaningful measurement of the performance of alternatives, comprising the Navy Commander's and the Admiralty's perspectives along with valid scaling constants, which was the aim of FITradeoff use.

It is fundamental to measure aspects aligned to the strategic objectives, along with a thorough evaluation of the alternatives, and the most efficient use of the time made available by high-level decision-makers. FITradeoff results, coupled with budget information, is present in a current system developed for budget assessment for the Brazilian Navy, named SADORC (Sistema de Apoio à Decisão Orçamentária).

Multicriteria methodologies applied to military problems are not novel. There are diverse uses, encompassing mainly the logistical and administrative aspects in the military context, (Pessôa & Costa, 2020). The FITradeoff has also been used in the Brazilian Navy by high-level decision-makers (Pessôa et al., 2018).

The purpose of this study is to support a new type of application of the FITradeoff method, adapting the aforementioned procedure to military strategic decision-making.

The main contribution of this study is to support a new approach to the application of the FITradeoff method, adapting it to military strategic decisions. This study is dedicated to circumventing the following challenges:

- using only the available time of the high-level decision-makers
- extracting relevant information independently from different decision-makers of the group
- reducing the cognitive effort to obtain consistent information
- communicating processes and results in a simple manner
- gaining confidence regarding the facilitation process

The structure of the article comprises the introduction, followed by the background presentation in Section 2. Section 3 presents the case study and Section 4 discusses the results with a brief conclusion.

2 BACKGROUND

Analysis of governmental expenditure through a political focus (Amara, 2008; Bruneau & Tollefson, 2006; Jaskoski, 2012; Candreva & Jones, 2005; Frederiksen & Looney, 1994) is often found in the literature but is not directly connected to the purpose of this work.

Practical applications aimed at contributing to budgetary allocation use different methodologies, such as fuzzy logic (Johnson et al., 2004), Transaction Costs Economy (TCE) (Melese et al., 2007), and hybrid or multi-methodological approaches (Hernandez, 2015). Some of these methods combine optimization techniques with multicriteria.

Brown et al. (2004), used an optimization model which guides the purchase of weapon system units, using the Portfolio Selection Model (Knapsack Problem). It is an integer programming problem with a linear objective function, and a model that gradually adds complexity to represent reality in a more detailed manner. The model uses a valuation parameter provided by the weapon system's measure of effectiveness (MOE). The author established value-focused thinking (VFT), a multicriteria analysis approach to understanding and structuring problems, as the framework for developing these MOEs.

This paper also mentions other works related to resource allocation in the military environment. Brown et al. (2003) used an integer linear programming model, and Salmeron et al. (2002) used an optimization-based decision support system for naval platform replacement.

The contribution of Robert F. Dell in the treatment of Base Realignment and Closure (BRAC) (Dell & Tarantino, 2005) and especially Dell et al. (2008) also stands out. These studies detail mathematical programming for selecting alternatives in models that contemplate multiple periods.

However, the aspect of valuation of the military unit is superficially referenced, except in Dell et al. (2008), who mentioned the use of the procedure established in Ewing et al. (2006), a multicriteria additive method, using the SWING approach for weight elicitation.

Roy & Bouyssou (1993) detail a classical taxonomy of four categories for the Multicriteria Problematics (α, β, γ and δ). This study uses a multicriteria ranking problem (γ) to define a preference function. This function calculates alternatives investment's utilities for a branch of the military. Considering budget constraints, it is possible to optimize the allocation of funds.

Multicriteria decisions that are applied to military problems are not novel. According to Pessôa & Costa (2020), the examples are diverse, encompassing mainly the logistical and administrative aspects of the military context, most of which are produced by researchers linked to institutes in China and the United States, commonly using AHP methodology (Crary et al., 2002; Nikou & Moschuris, 2016; Nikou et al., 2017; Cheng et al., 1999; Fan et al., 2015; Linkov et al., 2010; Alomair et al., 2016). As exceptions to the use of AHP, are VFT (Austin & Mitchell, 2008), DEMATEL (Gazibey et al., 2015) and MOOT and MAUT (Dewispelare & Sage, 1980).

In the context of Brazilian Navy, other methods such as Coppe-Cosenza (Cosenza et al., 2015; Taranti et al., 2022), Electre (Roy, 1968), and especially FITradeoff (Almeida et al., 2016) have been highlighted (Pessôa et al., 2016; Botelho et al., 2017; Pessôa et al., 2018; Silva et al., 2019).

Since the idea is to present a preference function, a compensatory method is suitable for solving the problem.

Other compensatory methods can be used for this purpose. However, this approach is meant to represent a strategic assessment. Therefore, high-level decision-maker's preferences must be represented, subject to limited time interaction and information.

The FITradeoff method has the potential to enable the modeling of decision-maker's preferences based only on partial information (Frej et al., 2019). The evaluator requests only the definition of preference relations between two consequences. This eliminates the need to expose indifference relations, which is cognitively more challenging to establish, and leads to a high rate of inconsistency (Borcherding et al., 1991).

2.1 FITradeoff method

As discussed by Almeida et al. (2016), the flexible and interactive procedure of the FITradeoff method provides a good solution through an elicitation process. Figure 1 presents a schema of the procedures used to help us better understand the methodological process.

In FITradeoff, the DM establishes an order of criteria scaling constants, and then a flexible elicitation procedure is carried out based on a question-answering process in which the DM compares consequences considering tradeoffs amongst criteria.

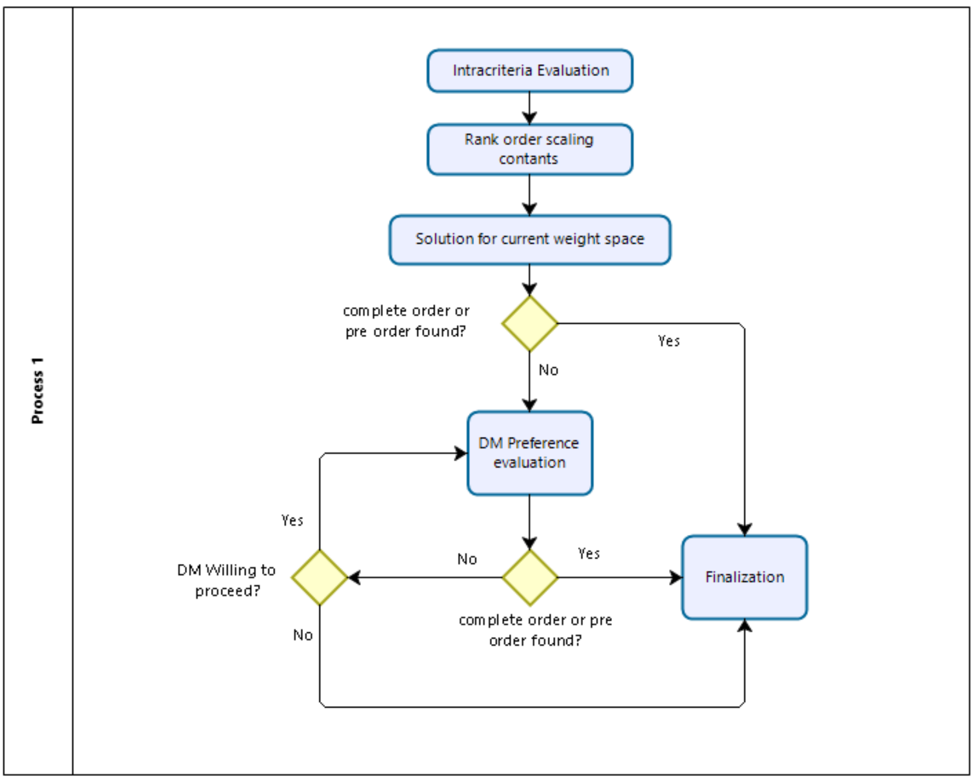

Figure 1 – FITradeoff Fluxogram. Adapted from Frej et al. (2019).

Each comparison produces an inequality that gradually narrows the space of weights to a point where it is possible to obtain an ordering for the dataset.

Thus, it is possible to establish a set of scaling constants bounded by comparison constraints.

This set of scaling constants, arbitrated between the limits defined by FITradeoff, defines the decision-maker's space of weights. Within this space, linear programming (LP) models attempt to determine a solution to the problem. For the choice problematic (Almeida et al., 2016), a subset of potentially optimal alternatives is obtained after each interaction, based on the LP model results. For the ranking problematic (Frej et al., 2019), a partial or complete ranking of the alternatives is obtained for each interaction, based on the dominance relations found by the LP models.

Recently, Almeida et al. (2021) proposed a new approach for the FITradeoff elicitation process based on the combination of two preference modeling paradigms in preference modeling: elicitation by decomposition and holistic evaluation. Performing holistic evaluation during the process enables the possibility of speeding up the decision process, without the need to answer a high-level elicitation questions during the decomposition process.

This study uses the FITradeoff multicriteria method (Almeida et al., 2016) in its ordering version (Frej et al., 2019), exploring the potential of flexible elicitation with the decision-maker, reducing its cognitive load and the use of discrete scales.

2.2 Problem Context

The Brazilian Navy comprises almost to 80000 members. It is dedicated to "prepare and employ Naval Power in order to contribute to the Defense of the country; guarantee the constitutional powers and, by the initiative of any of these, law and order; fulfill the subsidiary attributions provided by Law; and to support Foreign Policy." (Brasil, 2020b,a, 1988, 1999).

One important subsidiary attribution is the Brazilian Maritime Authority, which is responsible for ensuring the safety of human life and navigation in the open sea and inland waterways, and for preventing environmental pollution from ships, platforms or their support facilities.

Hierarchy and discipline are the bases of the Brazilian Navy as a military service, and its view of the future is

> "The Brazilian Navy will be a modern, ready and motivated Force, with a high degree of technological independence, of a dimension compatible with the political-strategic stature of Brazil in the international arena, capable of contributing to the defense of the country and safeguarding national interests, at sea and in inland waters, in tune with the yearnings of society." Brasil (2017).

Performing such a critical mission and pursuing its vision is a challenge, considering that there is a vast amount of littoral, along the 7400 km coastline; a maritime economic exclusive zone of over 3500000 km^2 and 60000 km of rivers under the Brazilian Navy's authority. In a scenario with restrained funds, efficient budget planning is vital for accomplishing the mission objectives.

Owing to the diversity of attributions, budget investment planning must comply with strategic guidance. The multicriteria evaluation will provide a "utility measure" of the budget investment options and, combined with the cost, will make it possible to find the most efficient way to invest.

The most important stakeholders to guide strategic development towards its future vision are the Brazilian Navy's Command and the Brazilian Admiralty.

> "The Navy Command, an organ integrating the Regimental Structure of the Ministry of Defense and directly subordinated to the Minister of State of Defense, has the purpose of preparing the Navy for the fulfillment in its constitutional purpose and subsidiary attributions." Brasil (2015)

Among its duties, the Navy Command plans naval policy and naval military doctrine, formulates strategic planning and employs the Naval Forces for the defense of the country. The Admiralty advises the Navy Commander in his duties of direction and management of the Force (Brasil, 2015).

Therefore, the highest-level decision-makers must guide the budget-planning. However, this raises another constraint: the time available to conduct the process.

To deal with the time constraint, they should perform the most important tasks, while their staff perform the most time-consuming tasks. Moreover, the independent execution of the tasks is desirable.

The intent is long-term guidance that must encompass both the Admiralty and the Navy Commander's perspectives. The strategic aspects must then orient themselves with criteria. Additionally, different sets of annual decisions should reuse the scaling constants.

Despite being the most important authority, the Navy Commander is in a medium-term position, depending on the political factors. An ideal approach must consider both perspectives.

The acceptance of this method is also crucial for a successful assessment. Therefore, stakeholders should easily understand the approach to accept the results.

A considerable part of the facilitation process is present the method's characteristics and steps for a deeper integration of stakeholders into the process.

3 ASSESSING STRATEGIC DECISIONS ON THE BRAZILIAN NAVY'S BUDGET ALLOCATION

3.1 Adaptations proposal

The adaptations proposal intends to fulfill the following requirements for the multicriteria evaluation:

- reduce the interaction time with the high-level decision-makers
- make the approach easy to understand and accept
- consider both the Navy Commander's and Admiralty's perspectives
- use the weights to different annual sets of alternatives

Strategic policy guidelines have defined these criteria. Due to confidentiality purposes, the paper does not detail them, but their number is between 8 and 15, and their definition involves the staff of the Admiralty members and the Navy Chief of staff (EMA).

To exemplify the criteria, Pessôa et al. (2021) described the criteria for a broader context (Defense) based on the publicly available Brazilian national strategy. Mobility, Cybernetics Strategy, Surveillance, and Monitoring are among mentioned examples.

The FITradeoff method uses intra-criteria and inter-criteria evaluations. This process separation allowed us to define the most time-consuming (intra-criteria) evaluation for the staff, and the proposed approach allowed both methods to run simultaneously, once the scale, the criteria, and the investment alternatives were available.

Figure 2 details the adapted proposal, showing that several tasks are to run independently, saving the time of the high-level decision-makers for critical tasks.

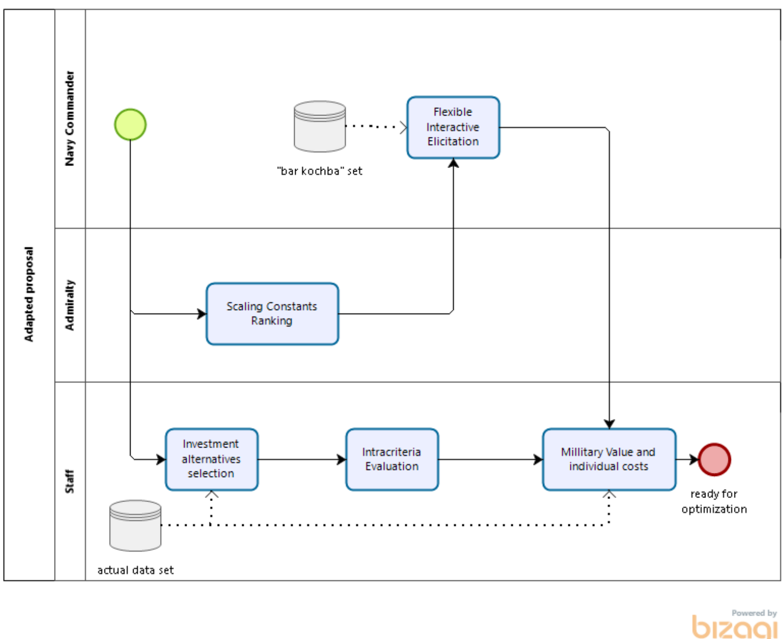

Figure 2 – Adapted proposal. Source: Authors caption.

The traditional use of FITradeoff requires an actual set of alternatives. However, when such alternatives are provided, all normalizations are performed for that set of alternatives. Therefore, the weights provided were inadequate for reuse.

In our proposal, an artificial set of alternatives was provided to comprise the complete range of each criterion evaluation scale. Therefore, it is possible to use the same weights, over several years, for distinct alternative sets. This feature allows a strategic direction based on the FITradeoff. Furthermore, the use of a special set allows the sharing of different tasks (intra-criteria evaluation and inter-criteria evaluation) for different actors.

All investment options must be evaluated in light of each criterion. These evaluations are subject to Bounded Rationality (Simon, 1955; Sent, 2018), and a limit on the cognitive effort to do so.

The focus on the investment options is due to the impossibility of not complying with mandatory expenses.

As the criteria represent the higher-level objectives, they are primarily qualitative and aligned with the strategic policies of the Navy.

The evaluation scale is numeric, ranging from 0 to 10, and is associated with linguistic variables for easy understanding, describing the contribution degree for a defined criterion:

- 0 Does not contribute
- 2 Contributes very little
- 4 Contributes a little
- 6 Contributes reasonably
- 8 Contributes a lot
- 10 Outstanding contribution
- 1, 3, 5, 7, 9 Intermediate values

To define a relative degree for each investment option within each criterion, the staff defines a magnitude for each element based on the numeric scale. A normalization process of the respective magnitudes assigned to each element was used to carry out this procedure, where max $a_{ij} = 10$, representing the maximum scale level.

While the staff performs the intra-criteria evaluation, the high-level decision-makers perform the inter-criteria evaluation. This process defines the scaling constants for a broad horizon. It intends to evaluate different annual sets of alternatives and reevaluate them only when the decision-makers demand it.

The inter-criteria process in FITradeoff consists of two steps: ordering the criteria and flexible elicitation. Again, this approach assigns different stakeholders to perform each task.

This proposed use of the method can be described as a group decision because the Admiralty is responsible for the ordering and the Navy Commander for flexible elicitation, so it involves two or more decision-makers responsible for the decision (Almeida et al., 2012).

First, the Admiralty members order the scaling constants using the statistical mode and reach a consensus. This process can be carried out independently by each Admiralty member, allowing more flexibility.

The simple ranking of criteria scaling constants is an essential guideline for defining weights. It also serves as a system of checks and balances for the Navy Commander's decision because it acts as a series of constraints.

The paper will not present the actual results, because of confidentiality issues, but will show a numerical example to depict how the proposed approach works.

The example considers twelve criteria, ordered:

$$k_1 \geq k_2 \geq k_3 \geq k_4 \geq k_5 \geq k_6 \geq k_7 \geq k_8 \geq k_9 \geq k_{10} \geq k_{11} \geq k_{12} \tag{1}$$

Figure 3 presents the limits for each scaling constant produced by such ordering. Note that no elicitation was performed, but it already presents a general constraint on the results.

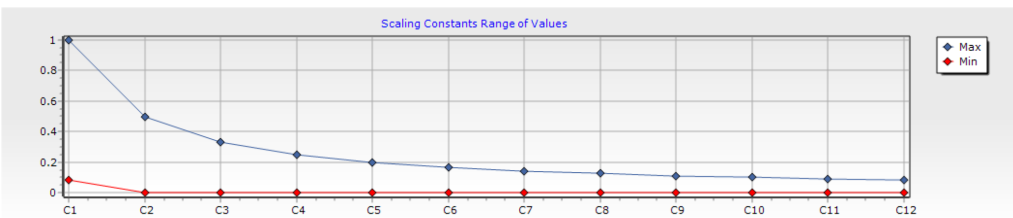

Figure 3 – Scaling Constants - ordering. Source: Authors.

The evaluation must cover all decision spaces to achieve long-term reuse or it will be subject to inconsistent results. Because FITradeoff uses normalization based on the maximum and minimum values of alternative sets.

As a methodological contribution, in very high-level decisions which involve many alternatives, the decision-maker is not available to follow the entire process and, in particular, has very little time available for preference elicitation.

The facilitator must use the time wisely, according to the decision-maker's availability. This study uses an approximate elicitation approach, with only 24 alternatives, allowing the representation of maximum and minimum values for all criteria, as well as an intermediate value, allowing a faster relative comparison, as presented in Table 1.

The experience of the Brazilian Navy's decision-makers and their staff supports the definition of the consequence space, and thus, the range of evaluation of the criteria. This is an advantage of the MAVT methods, since they create a synthesis function, that depend only on the consequence space.

Table 1 – Set of Artificial Alternatives.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
A1	10	0	0	0	0	0	0	0	0	0	0	0
A2	5	0	0	0	0	0	0	0	0	0	0	0
A3	0	10	0	0	0	0	0	0	0	0	0	0
A4	0	5	0	0	0	0	0	0	0	0	0	0
A5	0	0	10	0	0	0	0	0	0	0	0	0
A6	0	0	5	0	0	0	0	0	0	0	0	0
A7	0	0	0	10	0	0	0	0	0	0	0	0
A8	0	0	0	5	0	0	0	0	0	0	0	0
A9	0	0	0	0	10	0	0	0	0	0	0	0
A10	0	0	0	0	5	0	0	0	0	0	0	0
A11	0	0	0	0	0	10	0	0	0	0	0	0
A12	0	0	0	0	0	5	0	0	0	0	0	0
A13	0	0	0	0	0	0	10	0	0	0	0	0
A14	0	0	0	0	0	0	5	0	0	0	0	0
A15	0	0	0	0	0	0	0	10	0	0	0	0
A16	0	0	0	0	0	0	0	5	0	0	0	0
A17	0	0	0	0	0	0	0	0	10	0	0	0
A18	0	0	0	0	0	0	0	0	5	0	0	0
A19	0	0	0	0	0	0	0	0	0	10	0	0
A20	0	0	0	0	0	0	0	0	0	5	0	0
A21	0	0	0	0	0	0	0	0	0	0	10	0
A22	0	0	0	0	0	0	0	0	0	0	5	0
A23	0	0	0	0	0	0	0	0	0	0	0	10
A24	0	0	0	0	0	0	0	0	0	0	0	5

Using this principle, the approach performs an approximate elicitation, where the number of alternatives is equal to twice the number of criteria, representing the maximum and minimum values for all criteria as well as an intermediate value.

This would allow relative comparison in a consistent manner for reuse and independent elicitation of the actual set of alternative intra-criteria evaluations. The actual set of alternatives comprises hundreds of alternatives. The use of a reduced set makes the elicitation time reasonable for the highest decision-maker's elicitation.

This approach explores the consequence space to define a preference function capable of ordering future strategic alternatives. Nevertheless, defining the scaling constants is still a challenge in actual usage, as it demands high cognitive effort; FITradeoff eases decision-maker interactions.

The first place is already defined by the ordering of criteria. Thus, the approach uses the ranking version of FITradeoff. The elicitation proceeds until a pre-order is achieved, providing the necessary trade-off of the criteria scaling constants.

Additionally, it prevents a ranking reversal because the normalization uses the scale min and max, so the withdrawal of an irrelevant alternative will not impact the decision process.

The “Bar Kochba game” and the version of integer guessing by ’Yes and No’ questions (Ellis et al., 2008) inspires this artificial set of alternatives. It divides the set into two subsets with approximate boundary intervals, and thereby providing a more efficient elicitation.

It is also necessary to reconcile this efficiency with a straightforward interpretation. FITradeoff software provides an accessible presentation for each elicitation question, as shown in Figure 4.

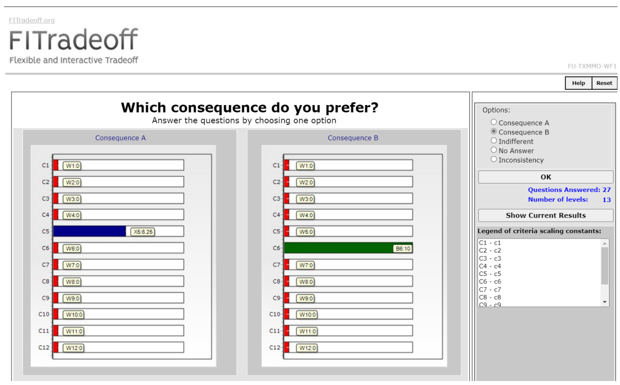

Figure 4 – Elicitation. Source: Authors.

With only two consequences presented, such a presentation reduces the cognitive load for the decision-maker and makes the understanding of the process easier.

If the decision-maker considers that partial elicitation suffices to define the scaling constants boundaries, the holistic comparison feature of FITradeoff can be used to shorten the elicitation process.

After elicitation, the FITradeoff software shows the the final weight limits, as shown in Figure 5. It was possible to define an intermediate value for each scaling constant. However, the chosen scaling constants were normalized to sum constant.

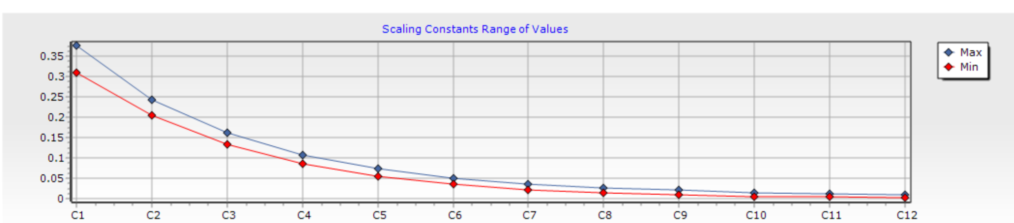

Figure 5 – Weight. Source: Authors.

Subsequently, it is possible to obtain the actual set utility values by aggregating the weighted intra-criteria evaluation values, so each investment alternative has a utility value combined with individual cost and budgetary limits, and is prone to optimization.

Finally, the weights encompass both the Navy Commander's and Admiralty's perspectives, and different annual sets can reuse them, as intended. If demanded by decision-makers, the facilitator can update the weights by performing new evaluations.

4 CONCLUSION

With regard to the practical contributions, the FITradeoff approach defines a utility measure for investment alternatives dedicated to 2022, comprising the Navy Commander's and the Admiralty's perspective with valid scaling constants.

Such results, coupled with budget information for each alternative, and budgetary constraints, using optimization techniques are present in a current system developed for budget assessment for the Brazilian Navy, named SADORC (Sistema de Apoio à Decisão Orçamentária).

Only for 2022, they estimate positive results for the Brazilian Navy for 15% of the Navy's investment budget. The defined scaling constants remain valid for reuse in 2023. A new version of the system intends to assess medium-term (4 year) budget planning for the Navy.

Other public and private institutions can benefit from the adaptations to the method. It allows semi-independent task completion at different levels of organization. The most time-consuming tasks are assigned to the staff.

One impression derived from the implementation, is that a considerable effort to get a successful practical result comes from the high-level stakeholders' commitment. Therefore, it is vital to use their available time in the most efficient way. It is paramount to increase trust in the method.

Another important observation is that the facilitation team must be available for every time window and plan the interaction for a focused and productive outcome.

The approach also provides a group decision, using both perspectives of the organization director's board (in our case study, the Admiralty) and the CEO (Navy Commander). It defines scaling constants for reuse in multiple periods and, provides strategic guidance on investment and budgetary planning.

The approach defines constraints on the CEO but allows flexibility aligned to the board's directions. This approach may provide a portfolio decision using the FITradeoff method coupled with Optimization Techniques.

The "Bar Kochba" alternative set is efficient to reduce the elicitation time. Firstly, it has a limited set of alternatives, despite representing all the "consequence spaces". However, this is not dependent on the actual set of alternatives. Therefore, the elicitation process can occur even before the intra-criteria evaluation. It allows the reuse of weights as long as it is convenient for decision-makers.

Moreover, it also prevents a ranking reversal because the normalization uses the scale min and max, so the withdrawal of an irrelevant alternative will not affect the decision-making process.

Future studies could incorporate a probabilistic chance of success in investments. Another interesting perspective would be the development of criteria at distinct organizational levels and how to aggregate them from operational to strategic levels, while preserving adherence to high-level alignment.

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