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ARTICLES

# A SUMMARY ON FITRADEOFF METHOD WITH METHODOLOGICAL AND PRACTICAL DEVELOPMENTS AND FUTURE PERSPECTIVES

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**ABSTRACT**. This paper presents a broad overview of main contributions related to the FITradeoff (Flexible and Interactive Tradeoff) method. FITradeoff is a multicriteria method developed within the scope of the Multiattribute Value Theory (MAVT), considering partial information from the decision maker (DM) in the preference modelling process. Over the last few years, several methodological developments on this method have been published in the literature, as well as practical applications to a wide range of multicriteria decision problems. The most recent methodological advances are related to preference modelling process, which now integrate the two paradigms of elicitation by decomposition and holistic evaluation. Furthermore, contributions from behavioral studies, some of them including decision neuroscience, have enhanced the DSS free available for FITradeoff. In this paper, all previously developed works related to the FITradeoff method are approached, considering both methodological developments and practical applications. A summary on the different modeling approaches for solving different decision problematics (choice, ranking, sorting and portfolio) with FITradeoff is presented. The recently proposed combination of preference modeling paradigms - elicitation by decomposition and holistic evaluation - within the FITradeoff decision process is explained, as well its potential advantages for the elicitation process. Moreover, a brief review on the practical applications of the method in different contexts is presented. In addition, this work also brings a summary on the results of behavioral experiments conducted using neuroscience tools with the FITradeoff method, as well the methodological insights resulted from them, and future perspectives of potential research topics related to the FITradeoff method.

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## 1 INTRODUCTION

The Flexible and Interactive Tradeoff method (FITradeoff) consists of a Multicriteria Decision Making-Aiding (MCDM/A) technique for solving decision problems under multiple and conflicting criteria in additive models within the scope of the Multiattribute Value Theory. This method works based on partial information about the decision maker's preferences, in such a way that the elicitation of preferences becomes less cognitively demanding for the decision maker, with less time and effort spent in the preferences modeling process (De Almeida et al., 2016; De Almeida et al., 2021).

When dealing with additive aggregation models, alternatives are scored straightforwardly according to (1). In (1), $v(a_i)$ represents the global value of alternative $a_i$, $k_j$ represents the scaling constant (or commonly called weight) of criterion j (j = 1, ..., m), and $v_j(x_{ij})$ is the value of consequence $x_{ij}$, which consists of the evaluation of alternative $a_i$ in criterion j, measured in a 0-1 scale according to the marginal value function of criterion j. Criteria scaling constants are normalized and sum up to 1, according to (2).

$$v(a_i) = \sum_{j=1}^{m} k_j v_j(x_{ij}) \tag{1}$$

$$\sum_{j=1}^{m} k_j = 1 \tag{2}$$

In multicriteria additive models, a critical issue is the elicitation of criteria scaling constants, since these parameters should reflect the range of consequences of the actual set of alternatives in each criterion, and defining them based on importance level of the criteria may cause critical distortions within the model (Keeney & Raiffa, 1976). Hence, structured procedures for eliciting the values of these parameters considering the consequences space are necessary. The most well-known procedures for elicitation of criteria scaling constants in additive models are the classical tradeoff procedure (Keeney & Raiffa, 1976) and the swing procedure (von Winterfeldt & Edwards, 1986). The first one was developed based on a strong axiomatic structure under the concepts of the Multiattribute Value/Utility Theory, and allows nonlinear value functions to be considered for intracriterion evaluation. However, a critical disadvantage of this procedure is the difficulty presented for decision makers in the preferences elicitation process, since exact values that makes the decision maker indifferent between two consequences when considering tradeoffs between criteria are requested. This information is considered to be high cognitively demanding, which lead to a high inconsistency rate when this procedure is applied, according to behavioral studies (Borcherding et al., 1991). The swing procedure, on the other hand, carries the elicitation process in an easier way, but modeling steps are simplified (Edwards & Barron, 1994), in such a way that only linear value functions are considered in the intracriterion evaluation, which may also cause distortions in the model.

Multicriteria methods that consider partial information about preferences have been developed in order to facilitate the elicitation process for decision makers, lowering the cognitive effort spent and, consequently, tightening the gap between theoretical models and practical applications (Weber, 1987; Salo & Hamalainen, 1992; Kirkwood & Sarin, 1985). Over the years, several partial information methods have been developed in the literature, such as the PAIRS method (Salo & Hamalainen, 1992); PRIME method (Salo & Hamalainen, 2001); RICH method (Salo & Punkka, 1995); Interval SMART/Swing method (Mustajoki, Hamalainen & Salo, 2005); SMARTER method (Edwards & Barron, 1994); among many others (Malakooti, 2000; Park & Kim, 1997; Ahn & Park, 2008). According to De Almeida et al (2016), these methods differ in terms of the form in which the decision maker provides preferential information, which can be interactively or all at once; the type of information provided (rankings of criteria weights, bounds, holistic judgments, arbitrary inequalities), and the synthesis step (linear programming, decision rules, surrogate weights, simulation and/or sensitivity analysis).

Da Silva et al (2022) performed a systematic literature review on partial information methods, which addresses different types of information, elicitation structure and synthesis step that different methods use. In their review, the authors point out that most partial information methods consider a nonstructured protocol for the elicitation, or consider the swing procedure for doing so, in a simplified manner. In this context, the FITradeoff method differs from other partial information methods in a sense that it carries out the whole structure of the classical tradeoff procedure in the elicitation protocol, including the possibility of using nonlinear value functions in intracriterion evaluation (De Almeida et al., 2016), but considering partial information about the DM's preferences. Moreover, the FITradeoff method has flexibility features that enable the process to be adapted to different circumstances, including graphical visualization of partial results and possibility of conducting holistic judgments to accelerate the process.

The purpose of this paper to conduct a summary on the main contributions related to the FITradeoff method, both in methodological and practical perspectives. Different decision problematics that can be addressed with the FITradeoff method are approach in this paper, as well as the combination of preference modeling paradigms conducted in this method. Moreover, this paper will also present an overview of neuroscience studies and behavioral experiments conducted with a view to bring methodological developments on the FITradeoff method. Practical decision situations in several contexts in which the FITradeoff method was applied are also presented in this paper, as well as the future perspectives expected within this research line.

This paper is structured as follows. Section 2 is devoted to describing the FITradeoff method in light of the four decision problematics: choice, ranking, sorting and portfolio. Section 3 presents results of neuroscience and behavioral studies related to the FITradeoff method. In Section 4, the combination of paradigms in preference modeling and its potential advantages for the decision process are highlighted. Section 5 gives a summary on the applications conducted using the FITradeoff method, and Section 6 finally presents the conclusions and future perspectives.

## 2 SOLVING DIFFERENT DECISION PROBLEMATICS WITH FITRADEOFF

The FITradeoff method was originally developed by De Almeida et al (2016), for solving multicriteria decision problems for choice problematic. Few years later, Frej et al (2019) developed a different variant of FITradeoff for dealing with the ranking problematic. Kang et al (2020) expanded the method for the sorting problematic. More recently, Frej et al (2021) proposed a benefit-to-cost ratio based approach for dealing with the portfolio problematic with FITradeoff. The portfolio problematic was also approached by Marques et al (2022) from a different perspective, considering the classical combinatorial approach.

All those variants of the FITradeoff method are operationalized by means of a Decision Support System (DSS), in which the whole elicitation process is carried out in an interactive manner, alternating steps of interaction with the DM and computational steps. It is important to highlight that, for all problematics, the interaction steps – steps in which the DM provides preferential information - are extremely similar. What differs from one problematic to another is the mathematical model formulation, which is specific for each problematic, and the results obtained.

In a generic way and summarized way, the FITradeoff method works as follows. After an intracriterion evaluation is performed (in which both linear or nonlinear value functions can be considered), the DM ranks criteria scaling constants according to his own preferences, considering the ranges of consequences in each criterion. After that, a ranking of criteria scaling constants (3) is obtained.

$$k_1 > k_2 > \ldots > k_j > k_{j+1} > \ldots > k_m \tag{3}$$

Then, the elicitation process continues with questions put for the DM, in which he/she should answer considering tradeoffs between criteria. Two consequences are put for the DM: Consequence A, with the worst outcome for all criteria and an intermediate outcome for criterion j; and Consequence B, with the worst outcome for all criteria and the best outcome for criterion j+1. Depending on the value stablished for criterion j (let us say, $x'_j$ ), the DM may declare preference for Consequence A over Consequence B, in such a way that $v(A) > v(B)$ and the inequality in (4) is obtained; or, for other values of $x_j$, let us say, $x''_j$, Consequence B might be preferred to Consequence A, so that $v(B) > v(A)$ and the inequality in (5) is obtained.

$$k_j v\left(x'_j\right) > k_{j+1} \tag{4}$$

$$k_j v\left(x''_j\right) < k_{j+1} \tag{5}$$

Inequalities in (3), (4) and (5), together with equation (2), form the so-called space of weights; i.e., the set of weights vectors compatible with the preferences of the decision maker. For each decision problematic, a different mathematical model is run searching for a recommendation, considering the current space of weights. In general, the FITradeoff method works based on linear programming models, and the space of weights act as part of the constraints of such models. Different LP models are considered depending on the decision problematic being dealt. Such models will be further detailed in the following subtopics.

The FITradeoff process is carried out in an interactive manner, so that after each preference statement given by the DM in the comparison of consequences, the space of weights is updated with the new information obtained, so that LP model runs in order to refine the results obtained. Partial results can be displayed for the DM at any time during the process, as a flexibility feature of the FITradeoff DSS, including the possibility of graphical visualization. Different types of visualization are provided in the DSS, and it is also possible for the DM to perform holistic judgments during the process, providing additional information to the model (this issue will be detailed explored in Section 4). In this sense, if the DM feels satisfied with such partial results, then he/she may interrupt the process even before the end of the elicitation, saving time and effort.

The following subtopics are devoted to give a brief explanation on how the FITradeoff method works for each decision problematic.

### 2.1 FITradeoff for Choice problematic

When dealing with choice problems, the FITradeoff method works based on a progressive reduction of the set of Potentially Optimal Alternatives (POA). Considering an MCDM problem with n alternatives, an alternative $a_i$ can be considered to be Potentially Optimal if the global value of $a_i$, according to Equation (1), is greater than the global values of all other n-1 alternatives for at least one vector of weights within the feasible weights space. I.e., an alternative is considered potentially optimal if it can be the optimal alternative of the problem, considering the actual space of weights (De Almeida et al., 2016). In this sense, for an alternative $a_i$ to be considered potentially optimal, the inequality in (6) must hold for all z = 1, . . . , n; z ≠ i.

$$\sum_{j=1}^{m} k_j v_j\left(x_{ij}\right) \geq \sum_{j=1}^{m} k_j v_j\left(x_{zj}\right) \tag{6}$$

Therefore, the mathematical model of FITradeoff for choice problematic seeks for the verification of the potential optimality of an alternative. And the model is run for all alternatives, in order to form the subset of potentially optimal alternatives. At each interaction step, the following LP model runs (7).

$$Max\ v\left(a_i\right) = \sum_{j=1}^{m} k_j v_j\left(x_{ij}\right) \tag{7}$$

$$s.t: k_1 > k_2 > \ldots > k_j > k_{j+1} > \ldots > k_m$$

$$\sum_{j=1}^{m} k_j v_j\left(x_{ij}\right) \geq \sum_{j=1}^{m} k_j v_j\left(x_{zj}\right), for\ all\ z = 1,\ \ldots,\ n;\ z \neq j.$$

$$k_j v\left(x'_j\right) \geq k_{j+1} + \varepsilon$$

$$k_j v\left(x''_j\right) \leq k_{j+1} + \varepsilon$$

$$\sum_{j=1}^{m} k_j = 1$$

If the LPP model (7) has at least one feasible solution - i.e., if for at least one vector of weights it is possible to maximize the global value of $a_i$ considering the current space of weights (formed by inequalities of type (3), (4) and (5) according to the preferential information given by the DM and Equation (2)) and satisfying the potential optimality constraints in (6) -, then alternative $a_i$ is a potentially optimal alternative for the problem. In (7), a small number $\varepsilon$ is incorporated in order to turn inequalities in (4) and (5) computationally treatable in LP models.

It should be highlighted that each time the DM gives a new preference information, the weight space is updated with new inequalities of type (4) and (5), which are incorporated into the LP models, that run again searching for the updated subset of potentially optimal alternatives. In this sense, the interaction steps continue until a unique alternative is found to be potentially optimal (i.e., this will be the optimal alternative for the problem); or until the DM feels satisfied with the actual set of potentially optimal alternatives (De Almeida et al., 2016).

### 2.2 FITradeoff for Ranking problematic

Since the concept of potential optimality is no longer enough to deal with the ranking of alternatives, Frej et al (2019) developed a new model for solving ranking problems with FITradeoff based on the verification of pairwise dominance relations. The LP model in (8) is run for all pairs of alternatives $a_i, a_k$ in order to compute the maximum difference between their global values, subjected to the current space of weights formed by the inequalities in (3), (4) and (5) and Equation (2).

$$Max \sum_{j=1}^{m} k_j v_j\left(x_{ij}\right) - \sum_{j=1}^{m} k_j v_j\left(x_{kj}\right) \tag{8}$$

$$s.t:$$

$$k_1 > k_2 > \ldots > k_j > k_{j+1} > \ldots > k_m$$

$$k_j v\left(x'_j\right) \geq k_{j+1} + \varepsilon$$

$$k_j v\left(x''_j\right) \leq k_{j+1} + \varepsilon$$

$$\sum_{j=1}^{m} k_j = 1$$

Frej et al (2019) define the possibilities of preference relations between alternatives $a_i, a_k$ considering the optimal solution of (8). In summary, A dominance relation for $a_i$ over $a_k$ is defined if the global value of $a_k$ cannot be greater than the global value of $a_i$ for any vector of weights within the current weight space. At each interaction, the LPP in (8) runs for all pairs of alternatives in order to test dominance relations between them. Once a dominance relation is stablished between a pair of alternatives, this relation remains until the end of the process, and such pair needs no longer to be tested.

When dealing with the ranking problematic, the FITradeoff DSS also provides a graphical visualization of the partial (or complete) ranking, through a Hasse diagram of the alternatives, in which the dominance relations can be visualized. Figure 1 illustrates the graphical visualization of the ranking. Depending on the level of information obtained, the ranking may be still partial, with pairs of alternatives still being incomparable according to that level of information. An incomparability relation between two alternatives $a_i$, $a_k$ can be verified when the level of information provided by the DM is not sufficient to stablish a dominance relation between then, because a subspace makes the value of $a_i$ greater than the value of $a_k$, and another subspace makes the value of $a_k$ greater than the value of $a_i$ .

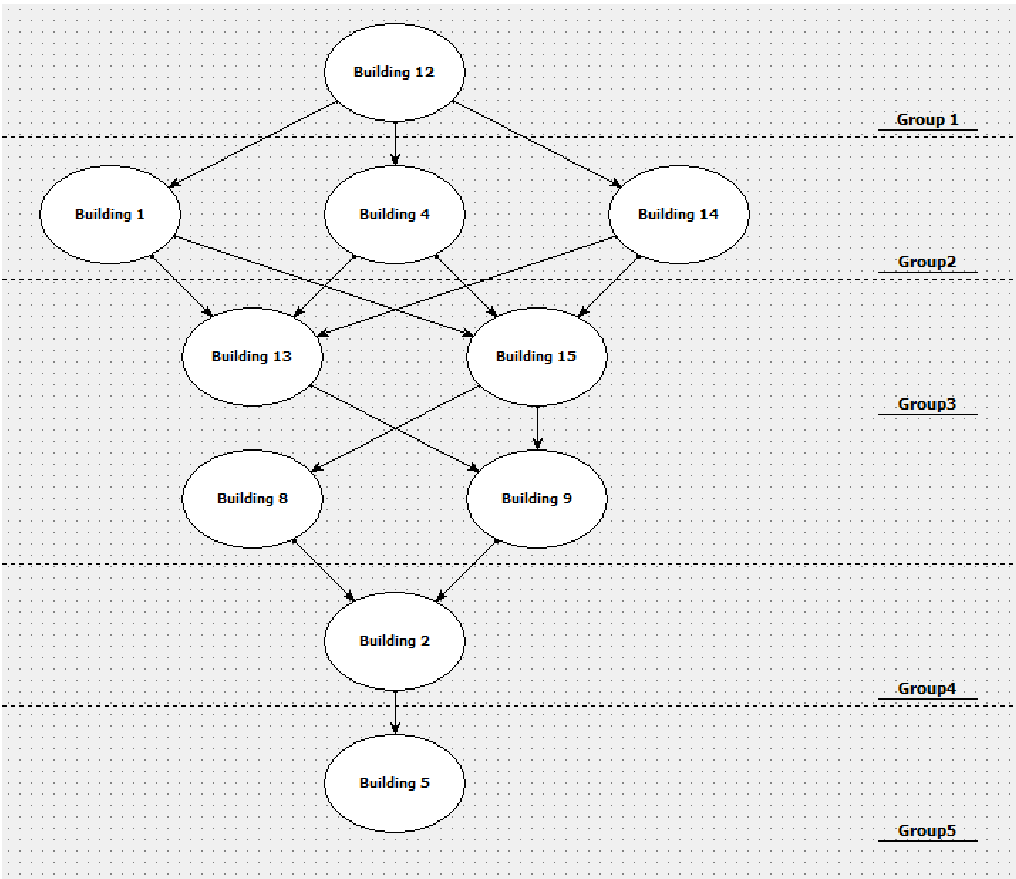


**Figure 1 –** Hasse diagram of the alternatives.

When two alternatives are considered to be incomparable for the current level of information provided, there is the possibility to conduct holistic evaluations in order to solve such incomparability relations in a faster way. This issue is further discussed in Section 4. Each time the DM answers an elicitation question, a new inequality of types (4) or (5) is obtained, in such a way that the weight space is updated, and the LP models run again in order to search for new dominance relations between alternatives and therefore refine the ranking. The process finishes either when a complete ranking of the alternatives is obtained or when the partial ranking is enough for the DM's purposes (Frej et al., 2019).

### 2.3 FITradeoff for Sorting problematic

Sorting problems can also be solved with the FITradeoff method, based on a decision rules approach proposed by Kang et al (2020). Categories are defined a priori by the decision maker, with global values profiles that act as boundaries for them. The preferences elicitation is identical to what was previously explained for the choice and ranking problematics, in which the DM answers questions considering tradeoffs between criteria, comparing hypothetical consequences. The space of weights now serve as constraints for two LP models, which run at each interaction searching for the maximum (9) and minimum (10) global value of each alternative $a_i$, i = 1, ..., n.

$$Max\ v(a_i) = \sum_{j=1}^{m} k_j v_j(x_{ij}) \tag{9}$$

$$s.t:$$

$$k_1 > k_2 > \ldots > k_j > k_{j+1} > \ldots > k_m$$

$$k_j v\left(x'_j\right) \geq k_{j+1} + \varepsilon$$

$$k_j v\left(x''_j\right) \leq k_{j+1} + \varepsilon$$

$$\sum_{j=1}^{m} k_j = 1$$

$$Min\ v(a_i) = \sum_{j=1}^{m} k_j v_j(x_{ij}) \tag{10}$$

$$s.t:$$

$$k_1 > k_2 > \ldots > k_j > k_{j+1} > \ldots > k_m$$

$$k_j v\left(x'_j\right) \geq k_{j+1} + \varepsilon$$

$$k_j v\left(x''_j\right) \leq k_{j+1} + \varepsilon$$

$$\sum_{j=1}^{m} k_j = 1$$

The optimal solution of (9) consists on the maximum overall value, according to (1), that alternative $a_i$ can assume, considering the current space of weights, while the optimal solution of (10) indicated the minimum overall value that alternative $a_i$ can assume, considering the current space of weights. Based on these two values, Kang et al (2020) propose a set of decision rules in order to allocate each alternative $a_i$ to a predefined specified category. Basically, an alternative $a_i$ is allocated to a certain category if the minimum value of $a_i$ is greater that the minimum value of the lower profile value for that category and if the maximum value of $a_i$ is lower than the upper profile value for that category. The process is carried within an interactive way with partial allocations displayed for the DM whenever he/she wants to visualize partial results. The process finishes either when all alternatives are allocated into a single category or when the DM feels satisfied with the partial allocation.

### 2.4 FITradeoff for Portfolio problematic

For dealing with portfolio selection problems, two approaches have been developed with the FITradeoff method. First, Frej et al (2021) developed an approach that consists of a heuristic that ranks projects according to their benefit-to-cost ratio, and select those projects that fit within the budget constraints. The second one was proposed by Marques et al (2022), which treats the portfolio selection problem in a combinatorial manner, based on complete enumeration. The following subtopics are devoted to explain each of them in a brief manner.

#### 2.4.1 Using Benefit-to-Cost Ratio (BCR)

Frej et al (2021) proposed a heuristic to solve portfolio selection problems with the FITradeoff method in a simpler manner, without the need to treat the portfolio problematic in a combinatorial way, since the computational effort to do so is relatively high. In this sense, the authors proposed an adaptation of the model presented by Frej et al (2019) for the ranking problematic, detailed in Section 2.2, to rank projects based on decreasing order of their Benefit-to-Cost ratio (BCR). The BCR of an alternative – or project - $a_i$ is defined by the ratio between its global value (calculated according to 1), which is a measure of its benefit, and the cost of implementation of this project, $c_i$ (see Equation 11).

$$BCR_i = \frac{v(a_i)}{c_i} \tag{11}$$

The main issue that arises from this model is that, since FITradeoff works based on partial information, $v(a_i)$ is not exactly known, since criteria scaling constants are not exactly determined, and the FITradeoff method works considering a space of weights. Therefore, Frej et al (2021) proposed the computation of dominance relations between candidate projects with an LP model similar to that in (8), but considering their BCR instead of their global value in the objective function of the LP model (see 12). The constraints remain the same of the model in (8), which consist basically of the space of weights formed by equations (2), (3), (4) and (5).

$$Max \sum_{j=1}^{m} k_j v_j(x_{ij})/c_i - \sum_{j=1}^{m} k_j v_j(x_{kj})/c_k \tag{12}$$

Based on the dominance relations found, a ranking of projects is built; this ranking may be partial or complete, depending on the level of information obtained. An available budget B should be defined by the organization, in a sense that projects are selected to be part of the portfolio according to the ranking obtained, until budget B is built (Frej et al., 2021).

### 2.4.2 Using complete enumeration

Different from the approach proposed by Frej et al (2021), which consists of a simplified heuristic to deal with the portfolio problematic in order to avoid the combinatorial optimization problem, Marques et al (2022) treats the portfolio problematic with FITradeoff considering complete enumeration of all possible portfolios.

The authors propose an approach to verify the efficiency and feasibility of each portfolio generated, in order to reduce the computational complexity in the explicit generation of portfolios. The process is divided into two phases: a preparation phase, which is conducted without interaction with the DM, and in which a high computational effort is spent to generate all possible portfolios; and the preferences elicitation phase, in which the DM plays an active role by answering preference questions of comparison of consequences to model the space of weights.

The preferences elicitation process is extremely similar to the one for the choice problematic detailed in section 2.1. The main difference is that, in this approach, each alternative $a_i$ consists of a combination of projects; i.e., a candidate portfolio. The performance of each portfolio $a_i$ in each criterion is evaluated considering an aggregation of the performances of each project in each criterion. The mathematical model presented in (7) is run to verify the potential optimality of an alternative $a_i$ ; i.e., the potential optimality of portfolio $a_i$. The model works based on a progressive reduction of the subset of potentially optimal portfolios.

## 3 DEVELOPING METHODOLOGICAL ASPECTS OF FITRADEOFF METHOD WITH RESULTS FROM NEUROSCIENCE AND BEHAVIOURAL EXPERIMENTS

The Neuroscience is considered a multidisciplinary approach which can be integrated to several areas of knowledge in order to investigate human behavioural (Glimcher & Rustichini, 2004; Dimoka et al., 2007; Fehr &Camerer, 2007; Morin, 2011; Khushaba 2013; Riedl et al., 2014). Regarding to MCDM/A approach, a few numbers of studies which use neuroscience tools to investigate Decision-Makers (DMs) preferences have been found in literature (Trepel et al., 2005; Özerol & Karasakal, 2008; Barberis & Xiong, 2009; Hunt et al., 2014; Chuang et al., 2015; Nermend, 2017, de Almeida et al., 2020a).

According to Korhonen & Wallenius (1997) behavioural aspects involved in decision processes should be considered into methods or techniques in order to modulate (transform) those methods. Hence, motivated by this gap in literature, several behavioural studies have been performed using neuroscience tools to investigate DMs preferences when they use the FITradeoff method.

Based on these behavioural studies, methodological aspects have been developed on the FITradeoff. The transformations made on the FITradeoff method, or its modulation, as suggested Korhonen & Wallenius (1997), bring improvements for this method.

The most important transformation made in the FITradeoff regards the combination of two paradigms of preference modelling – elicitation by decomposition and holistic evaluation – during the FITradeoff decision process. This new feature proposed for the FITradeoff (de Almeida et al., 2021) is possible from behavioural studies concerning holistic evaluation. In the previous version of the FITradeoff method (de Almeida et al., 2016) the holistic evaluation was used only to finalize the decision process. Now, preferences expressed during the holistic evaluation are included in Linear Programming Problem (LPP) model (de Almeida et al. 2021). Hence, using the FITradeoff method, DMs can express preferences for pairwise comparisons in the elicitation by decomposition or they can express dominance relations between alternatives in the holistic evaluation, at any moment of process.

In addition, this feature has been applied in the FITradeoff Decision Support System (DSS) for choice and ranking problematics. In the previous version of FITradeoff method, the holistic evaluation is presented only in choice problematic (de Almeida et al., 2016). Now, it is included in ranking problematic (Frej et al., 2019; de Almeida et al., 2021). For ranking problems, the use of holistic evaluation paradigm presents a special role since DMs can express dominance relations between alternatives which are in the same level of the ranking.

It is worth to mention that graphical and tabular visualization are presented in the FITradeoff DSS to support DMs during the holistic evaluation. Based on behavioural studies, another improvement is the inclusion of tables to support the evaluation of alternatives during the holistic evaluation. Firstly, only graphical visualizations are considered in the DSS, but behavioural results suggested that tables are as good as bar graphs to support DMs during the holistic evaluation (Roselli et al., 2018; Roselli et al., 2019, Roselli & de Almeida 2022).

Another important methodological aspect is the inclusion of the elimination process during the holistic evaluation. In the previous version, the DM can only select the best alternative, i.e., those that dominates the others. Now, DMs can select the best one, or the worst one in the group of Potentially Optimal Alternatives (POA). This feature is very interesting for choice problems, since provides flexibility during the holistic evaluation. Some DMs prefers to select the best, and other judges as most simple to eliminate the worst.

Two decision tools have also been developed from the studies. The first one is named Alpha-Theta Diagram (Roselli & de Almeida 2022) which uses Alpha and Theta brain activities to classify DMs behavioural. The other is the Success Based Decision Rule (SBDR - Roselli & de Almeida 2021) which indicates the probability of success for several patterns of visualizations used to support DMs during the holistic evaluation.

Moreover, behavioural studies suggested that cognitive effort and time were demanded in the decomposition process. This result confirms that the elicitation has been made in adequate way, since it is expected that DMs spend time and effort during making the preference modelling by decomposition. Moreover, the studies suggested that the use of quantitative and qualitative criteria demanded more cognitive effort to proceed in the FITradeoff method (Silva et al., 2019).

In addition, aspects related to the design of the FITradeoff DSS have been suggested from behavioural studies. Inclusion of messages, buttons, graphs, and tools have been made to improve DMs' experience in using the DSS. In special, the Eye-Tracking tool brings important improvements related to design of the DSS. This equipment measure eye-movements on computer screen, thus it can be used to suggest if DMs is really looking to the elements on the screen. Some adjusts are made in the design of the FITradeoff DSS based on these studies.

All these features are possible from behavioural studies. These studies are performed in the NSID (NeuroScience for Information and Decision) laboratory at the Federal University of Pernambuco (UFPE), Recife, Brazil. Several experiments have been made, focusing on the investigation of the two paradigms of preference modelling (Roselli & de Almeida 2022). These experiments were approved by the university's Ethical Committee and used two neuroscience tools, in particular the Electroencephalography with 14 channels, to capture brain activities, and the X120 Eye-Tracking to capture eye-movements.

For instance, for studies that focused on the elicitation by decomposition the main task was to solve a multi-criteria decision problem using the decomposition process. The problem solved by each DM was personal, elaborated by their own in MCDM/A classes. The experiments are extra-classes activities (Silva et al., 2021; Silva et al., 2019, Roselli et al. 2019).

For holistic evaluation experiments, the main task was to evaluate graphical and tabular visualizations and express dominance relations between alternatives. The experiments present different visualizations patterns. Moreover, involves different decision tasks - selection of the best alternative or elimination of the worst (Pessoa et al., 2021; Roselli & de Almeida 2020a, Roselli & de Almeida 2020b, Roselli et al., 2018; Silva et al., 2022)

Based on physiological variables, DMs behavioural have been investigated and modulations are done in the FITradeoff method. The modulations are done concerning to methodological aspects and design aspects (de Almeida et al., 2021). These modulations bring improvements for the method since integrates behavioural aspects to technical aspects (Wallenius et al., 2008; Wallenius & Wallenius, 2020). As commented by Ruben et al. (2020), studies in decision neurosciences as an interesting direction for the development of effective decision support systems. Therefore, the FITradeoff method has been modulated in order to improve the preference modelling process as the way to bring more flexibility for DMs, and it DSS is also improved in terms of design. The FITradeoff DSS is available for free at www.fitradeoff.org.

## 4 COMBINING PREFERENCE MODELLING PARADIGMS IN FITRADEOFF METHOD

The flexibility of the FITradeoff method is one of its main bullet points compared to other methods, and the flexibility features of the FITradeoff DSS enable DMs to conduct the decision process in different manners, according to their own wishes and perspectives. Recently, a new flexibility feature was incorporated within the DSS: the possibility of conducting holistic judgments between alternatives to help solving undefined relations between them. This new feature was incorporated based on the ideas proposed by De Almeida et al (2021), who bring the possibility of combination of preference modeling paradigms within the decision process with FITradeoff: elicitation by decomposition and holistic evaluation. With these two types of preference modeling put together within the FITradeoff DSS, significant improvements to the decision process can be observed.

The elicitation by decomposition consists of the classical elicitation proposed by Keeney & Raiffa (1976), through a cartesian process in which the DM compares elements in the consequences space. In this preference modeling type, two consequences are put for the DM to compare, as exemplified in Figure 2, which illustrates a problem with four criteria: C1, C2, C3 and C4.

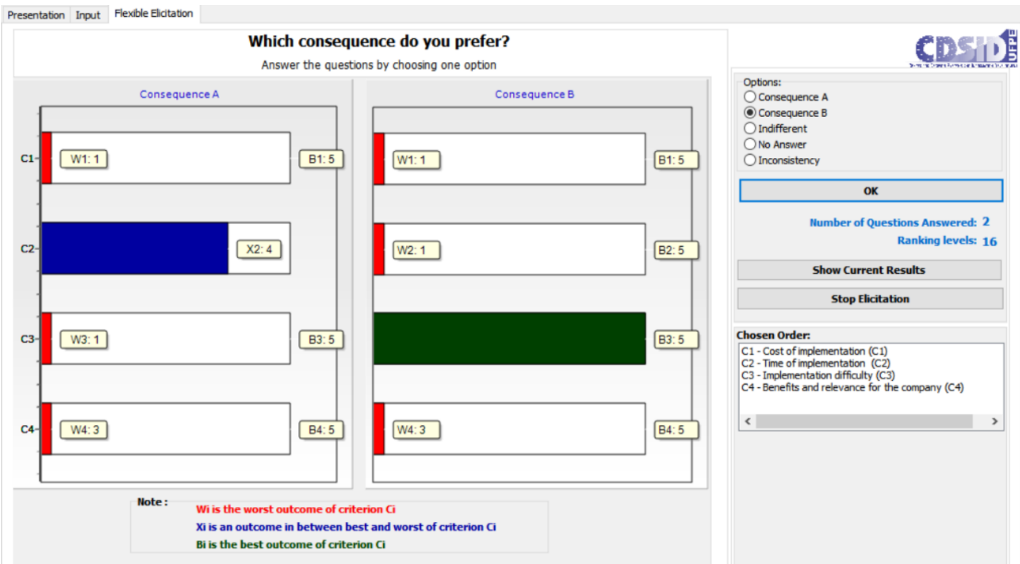


**Figure 2 –** Elicitation by decomposition.

In Figure 2, the consequences displayed are similar to those described in Section 2. Consequence A has the worst outcome in all criteria (except for C2), denoted by small red bars, and an intermediate outcome for criterion C2 denoted by the blue bar. Consequence B has the worst outcome in all criteria (except for C3), and the best outcome in criterion C3. The DM should analyze those consequences by considering tradeoffs between criteria C2 and C3, and choose which one he/she prefers. If the DM chooses preference for Consequence A, an inequality similar to (4) is obtained; if Consequence B is preferred, and inequality similar to (5) is obtained.

The great novelty proposed by De Almeida et al (2021) was actually the possibility of incorporating holistic judgments during the process, in such a way that the preferential information obtained by the holistic evaluation could be incorporated into the model and accelerate the process. Holistic evaluations consist on comparison of elements within the alternatives space, in a direct manner. For instance, the DM says directly that alternative $a_i$ is preferred to alternative $a_z$, such that the inequality in (13) is obtained.

$$\sum_{j=1}^{m} k_j v_j(x_{ij}) \geq \sum_{j=1}^{m} k_j v_j(x_{zj}) \tag{13}$$

This inequality is incorporated to the mathematical model of the FITradeoff method, tightening the space of weights according to this information. It may happen that the information provided in holistic judgments are inconsistent with the information obtained in the elicitation by decomposition. In this case, the FITradeoff DSS puts the DM to choose which of the two conflicting judgements is actually correct, in such a way that the other one is discarded (De Almeida et al., 2021).

The FITradeoff DSS provides graphical visualization of the alternatives to order to aid the DM when analyzing them to perform the holistic judgments. Three types of graphics are available: bar graphic, bubble graphic and radar graphic, as Figure 3 shows. In those graphics, each color represents an alternative, and the performance of the alternatives are displayed in each criterion, in a ratio 0-1 scale, so that the DM can visualize them in a comparative manner. It should be highlighted that the DM can analyze the graphics during any time of the process and then decide whether he/she is willing or not to perform a holistic evaluation at that point, according to the confidence level. In case the DM does not feel confident (or does not want to) perform a holistic evaluation, he/she can go back to the elicitation by decomposition to answer tradeoff questions. The key issue here is the possibility to alternate between the two types of preference modeling within the FITradeoff decision process.

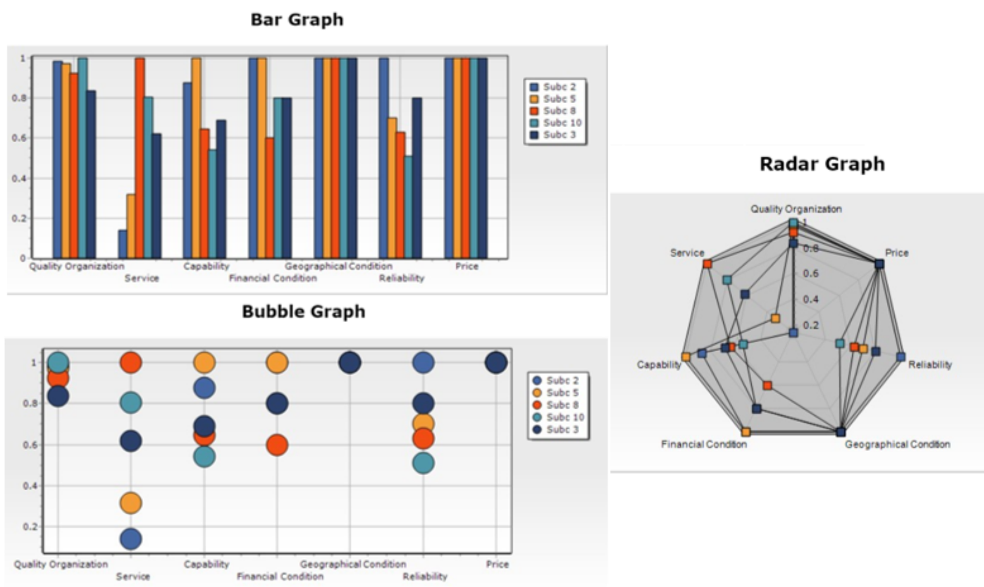


**Figure 3 –** Graphics for Holistic Evaluation.

Holistic judgments can be useful in the choice problematic either to select the best alternative amongst a subset of the Potentially Optimal Alternatives set, or to eliminate an alternative from this subset (De Almeida et al., 2021). As for the ranking problematic, holistic judgments are useful to define dominance relations between pairs of alternatives that are still incomparable for the current level of information obtained. Generally speaking, holistic judgments are useful to provide additional information to the mathematical model of FITradeoff, with the incorporation of inequalities of type (13). In some cases, however, the information provided in holistic judgments may be enough to finalize the decision process with a satisfactory result obtained for the DM (De Almeida et al., 2021).

According to De Almeida et al (2021), inequalities that come from holistic judgments have great potential to cause a significant reduction in the space of weights, accelerating the decision process in a sense that the final solution can be obtained faster. This is a potential advantage of conducting holistic evaluations during the process, since the DM can save effort and time that he/she would spend answering several questions in the elicitation by decomposition process, with only few holistic judgments. It should be highlighted that the two preference modeling types are available for the DM in the FITradeoff DSS, in such a way that he/she can alternate between them during the process, guided by an analyst with well background in MCDM.

## 5 PRACTICAL APPLICATIONS

This section intends to summarize several practical applications in which the FITradeoff method has been applied to support MCDM/A problems in different areas.

### 5.1 Supplier Selection

Santo et al. (2020) used the FITradeoff method to rank suppliers of in a Wholesaler and Retailer Company. In this study, twenty suppliers have been evaluated against five criteria. The preference modeling process have been conducted using the elicitation by decomposition and the holistic evaluation. In this application, bar graphics and spider graphics have been used to support the DM.

Rodrigues et al. (2020) used the FITradeoff method to support a ranking problematic involving supplier of a textile company. In this study, a problem structuring method is also used to identify hidden criteria, before the FITradeoff method. As result, the supplier which had the best position is not those that the company works.

Frej et al. (2017) used the FITradeoff method to select the best supplier for a food industry. The problem is composed of five suppliers which have been evaluated against seven criteria. These criteria represent the objectives of the company. In this study, a choice problematic has been considered. Also, the decision process was very fast, after only two elicitation questions a supplier had been selected. An interesting point is that the supplier which had been selected does not had the best price, which in general is the only attribute considered by companies.

### 5.2 Location Problem

Sousa Ribeiro et al. (2021) used the FITradeoff method to support a shopping mall location problem in the northeast countryside of Brazil. Ten cities of the northeastern countryside have been evaluated against seven criteria which represent conflicting objectives. This problem is interesting since discuss investments in the countryside of Brazil, stimulating economic growth in northeastern region.

De Lacerda et al. (2021) used the method to solve a site selection problem for a station of natural gas. DMs from a company which distribute natural gas participated in this study.

Oppio et al. (2020) discussed the integration of Geographic Information Systems (GIS) and Multi-Criteria Decision Analysis (MCDA), in special the FITradeoff method, to addressing decisions about the location of healthcare facilities. In the same context, Dell'Ovo et al. (2018) used the FITradeoff method to support a healthcare facility location problem in the city of Milan, Italy. In this problem, six potential areas had been considered to site a new hospital.

### 5.3 Health Systems

In the context of health systems, Dos Santos et al. (2022) used the FITradeoff method to prioritize response activities for *Aedes Aegypt* control in the city of Natal/RN. In this study several actors are involved in the decision model. The study considered eleven alternatives which had been evaluated against six criteria. As result, the study supports DMs to minimize effects and risks associated to Aedes Aegypt proliferation.

Frazão et al. (2021) discussed the gap in literature of studies to prioritize victims in the Emergency Medical Service. Hence, this study uses the FITradeoff method to prioritize victims of SAMU/192, considering the scarcity of resources and conflicting objectives. In this study, twenty-five criteria had been considered. As result, protocols that guide regulatory physicians have been discussed considering strategic criteria.

Moreover, Camilo et al. (2020) discussed triage system in emergency healthcare units. Thus,in this study, the FITradeoff was used to select the best protocol of triage for emergency healthcare units in Natal-RN. As result, the Spanish Triage System has been considered the most suitable protocol for the emergency care units.

### 5.4 Energy, Agricultural and Urban contexts

Kang et al. (2018) used the method to evaluate electric power generation technologies to be included in the electricity matrix. In this study, eight technologies had been evaluated in terms of financial, technical, environmental, and socio-economic dimensions.

Fossile et al. (2020) investigated which type of renewable energy is the most viable for Brazilian ports using the FITradeoff method. The study considered three alternatives (wind energy, photovoltaic energy, and wave energy) against twenty criteria. The criteria have been defined in terms of sustainability, management, national standards, legislation, and previous data. As result, the photovoltaic energy was considered the most viable energy source.

Monte & Morais (2019) investigated a water supply system of an urban area which was deficient since the population growth and equipments become old. Thus, the FITradeoff method was applied to indicate actions to deal with an urban water supply system. The study also considered a problem structuring method to support objectives identification.

Martins et al. (2020) used the method to prioritize road sections, based on their criticality and the risks faced by the user. This study considered twenty-two road sections against different attributes. As result, the most critical sections had been identified.

Rodriguez et al. (2021) used the method to support buying a laboratory equipment for a colombian agricultural research company. In the same context, Carrillo et al. (2018) used the method to select the best agricultural technology packages.

Morais et al. (2022) presented a group decision process in which the DMs of an agribusiness organization needs to evaluate which variety of mango should be plant in new farms concerning mango variety agricultural farms. Thus, the FITradeoff method had been applied to collect individual preferences of each DM. After that, a voting procedure had been applied to obtain the solution.

### 5.5 Management and Industrial Context

Pessoa et al. (2022) applied the method to rank options to support a compliance-program problem. This study discussed decision-making in time of crisis, reinforcing actions in the context of anticorruption law. In this paper, twenty-eight alternatives were evaluated against five criteria.

De Oliveira et al. (2022) used the method to prioritize indicators to monitor the development of plastering supply chains. As result, a set of indicators had been defined to provide competitiveness and sustainability for the company.

Shukla & Dubey (2021) used the FITradeoff method to support a celebrity selection for a brand or campaign. This study considered a group decision process with DMs from different sectors (brand, marketing communication agency and brand's customers). This study supports DMs to make effective decisions on celebrity selection for their brands.

Correia et al. (2021) used the FITradeoff method to solve a workstation problem concerning ergonomics interventions in the footwear industry. This study also used problem structuring methods to structure the hierarchy of fundamental objectives. As result, the ranking of workstations which need ergonomic interventions had been obtained.

Fernandes et al. (2021) used the method for managing Waste from Electrical and Electronic Equipment (WEEE). In this study, ten alternatives had been considered, and the DM is a federal public agency. The study also presented recommendations to manufacturers in terms of design and traceability of products.

Pergher et al. (2020) used the FITradeoff method to support schedule decisions in a manufacturer of ladies' shoes. These decision concerns due date assignment, order release and priority dispatching. Previous job-shop studies do not explore DM preferences. Thus, in this study the FITradeoff method is used to consider DM's preferences concerning due date assignment, order release and shop dispatching rules.

Poleto et al. (2020) used the method to support information technology outsourcing decisions. This study also considered a problem structuring method to support the identification of strategic and fundamental objectives in ITO decisions.

De Macedo et al. (2018) applied FITradeoff to support a motor replacement in a chemical industry. The study focused on develop a replacement plan in order to have a minimum energy performance in accordance to the Brazilian Energy Efficiency Law.

Gusmão & Medeiros (2018) to select the best strategic information system for a glass packaging factory. The factory needs to select a unique information system from a set of systems considered as relevant.

As illustrated in this section, the FITradeoff method can be applied to support several MCDM/A problems. The next section remarks conclusions and future perspectives of the study.

## 6 CONCLUSIONS AND FUTURE PERSPECTIVES

This paper presented an overall perspective of the FITradeoff method, with a summary on all methodological developments and applications developed in the literature. It could be seen that this MCDM method is suitable for solving multicriteria decision problems in all the four main decision problematics: choice, ranking, sorting and portfolio. The preferences elicitation process is carried out in a similar manner for all of them, with differences on the mathematical models and results obtained. Even though there are differences within the mathematical models, all variants of the FITradeoff method work with linear programming models, which is one of the most used approaches for dealing with partial information in MCDM, according to Da Silva et al (2022).

All variants of the FITradeoff method are operated by means of a Decision Support System, freely available for users at www.fitradeoff.org. It should be highlighted that, when using the DSS, the decision maker should be guided by an analyst with well background on MCDM and on the FITradeoff method, in order to better explore all the functionalities and flexibility features of the system. With regards to future perspectives in this line of research, some major topics can be highlighted.

First, the conduction of behavioral experiments with the use of neuroscience tools to analyze how decision makers think and act within the elicitation process considering its aspects. A key issue that shall be investigated though behavioral experiments is the combination of preference modeling types (elicitation by decomposition and holistic evaluation) in FITradeoff, and the DM behaves within this perspective.

Moreover, the extent into which the holistic judgments indeed improve the decision process in terms of reducing the number of total questions the DM has to answer should be explored in future studies; this could be conducted considering a simulation approach. Mendes et al (2020) conducted a preliminary simulation study with the FITradeoff for the choice problematic, and concluded that the method presents a relatively high convergence speed in the reduction of the set of potentially optimal alternatives. This study should be complemented considering the other decision problematics, as well as the incorporation of the holistic evaluation element and how does this type of preference modeling indeed contribute to fasten the elicitation process. When analyzing the holistic evaluation, it is also possible to investigate how the elimination of worse alternatives and selection of best ones contributes to the process, and which of these two are more effective to aid a satisfactory result to be found.

Still regarding the holistic evaluation and its potential benefits, future studies should also explore the use of this type of preference modeling also in sorting and portfolio problematic, since it is currently incorporated for choice and ranking, with the possibilities of selection of the best alternative or elimination of worst alternative for choice problematic, and establishment of a dominance relation for the ranking problematic. For sorting problematic, holistic judgments between alternatives and profiles should be explored. As for the portfolio problematic, holistic judgments between projects and/or between portfolios may be interesting to consider.

In addition to methodological focus studies, the application of the FITradeoff method to practical decision problems should be continuously explored, in order to tighten the gap between these methodological developments and real-world applications. Both public and private organizations can use the method on its multiple variants to aid the solution of complex decision problems with multiple objectives.

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