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ARTICLES

OUTSOURCING LABORATORY SERVICES FROM A COLOMBIAN AGRICULTURAL RESEARCH COMPANY USING THE FITRADEOFF METHOD UNDER MULTIPLE STAKEHOLDERS ANALYSIS

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ABSTRACT. Since most of the studies about outsourcing are focused on mathematical models, this paper seeks to support from theoretical bases the use of partial information to ease the decision-making process; the practical contribution is to apply the FITradeoff method for solving a multicriteria problem of an agricultural research company that seeks to decide about the need to outsource the operation in case to overhead the limited capacity of the analysis services. After the FITradeoff method was applied to elicit preferences from each decision-maker (DM), the results show whether or not it would be feasible to outsource a given service, and what the most promising options are. The method required the DMs to answer in less time only a few questions, which avoided placing an unnecessary cognitive burden on them and proved to be useful in assisting DMs in the decision-making.

Keywords: decision analysis, multicriteria, partial information, outsourcing, FITradeoff method.

1 INTRODUCTION

Despite outsourcing organizations' activities to some degree is a strategy that is being increasingly adopted (Gao & Driouchi 2018), research on outsourcing in the public sector or government companies it still limited or focused on American cases (Jansson et al. 2020). Companies seek the greatest number of diverse benefits in terms of less price and risk or better quality that may

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arise from adopting such a policy (Pankouska 2019; Handfield et al. 1999). Organizations may decide to outsource non-core business to reduce costs, to increase efficiency and to improve their services (de Felice et al. 2015). Outsourcing may also result in making better use of time, energy, labor, technology, capital and resources (Kara 2011). An additional motivation for adopting an outsourcing strategy is to alleviate companies' capacity shortages and to increase the flexibility of production (Chang et al. 2008).

On the other hand, when relating outsourcing and performance, Hsuan & Mahnke (2011) point that those benefits should increase to a threshold, after which the returns will decrease. In addition, there may be adverse effects such as loss of core competences and service debasement (Modak et al. 2018). With regard especially to pure outsourcing (Buck-Lew 1992), organizations should take care when sharing essential products and process knowledge with their suppliers, or transferring those to them, since this may bring risks for companies (Wu et al. 2013). Dolgui & Proth (2013) list some advantages and disadvantages of outsourcing and also provide an analysis of the state of the art in this area. Furthermore, it is noteworthy that the quality of an organization's services and its performance in delivering these are strongly influenced by its outsourcers, especially when a significant part of its business is outsourced (Araz et al. 2007).

According to the foregoing, outsourcing decisions are not trivial, since different questions may arise, such as: to outsource or not? What to outsource? Outsource from whom? In this context, tradeoffs need to be analyzed to balance benefits and risks (Martínez-Noya & García-Canal 2011). For these reasons, managers responsible for outsourcing decisions are encouraged to select suppliers who are able to protect their clients' intellectual property rights. To Leng et al. (2014), outsourcing decisions which are taken based on previous experiences are neither effective nor scientific, because these will use subjective judgments and suffer from a lack of systematic analysis. Therefore, this kind of decision needs to be conducted using a well-structured process, aided by an appropriate method that best matches the DM's rationality and characteristics. Also, one must take into account that there are often multiple decision makers involved in this type of problem, who have limited time and scarce information (López & Ishizaka 2017).

When dealing with outsourcing issues, it is important to evaluate tradeoffs between benefits and drawbacks through a structured process that is suitable for multiple DMs and that meets their rationality and limitations. In this study, these aspects are present in the following context: A Colombian agricultural research company wishes to conduct a structured process in order to decide if it is going to outsource services and, in an affirmative case, what suppliers are the most suitable to provide the laboratorial analysis. In order to do so, we analyzed the situation of seven research laboratories and interviewed the leaders of each of them. Each laboratory has its own manager and particularities, which means that different DMs and alternatives must be considered for each laboratory when tackling this outsourcing problem. Therefore, it is a situation in which multiple decision problems are involved and conflicting in nature criteria.

The goal of our work is to aid a company's managers to decide on which laboratory activities are worth outsourcing, and which of the available suppliers should be chosen. We focused on seven laboratories whose services are subject to outsourcing: analytical chemistry, vegetal microbiology, molecular analysis, entomology, vegetal production, animal microbiology and animal nutrition. The outsourcing questions are modelled through the preferences of the manager of each of the seven laboratories, which are modelled based on the Flexible and Interactive Tradeoff (FITradeoff) method (de Almeida et al. 2016). This is an MCDM/A method that has a structured elicitation process based on tradeoffs (Keeney & Raiffa 1976) for eliciting criteria weights, with the advantage of making use of partial information about the DM's preferences, in such a way that less cognitive effort is required in the elicitation process (de Almeida-Filho et al. 2017).

This paper is structured as follows. In Section 2, a brief literature review is conducted. Section 3 is divided into four subsections: first, in 3.1, a background on the FITradeoff method is presented; in 3.2, the context of the Colombian agricultural research company's problem is described; 3.3 presents the characterization of the DMs and in 3.4 a detailed analysis about the criteria of the problem is conducted. Section 4 presents and discusses the results obtained in the application, and in Section 5 the main conclusions are presented.

2 PREVIOUS WORK

Taking advantage of mathematical decision-making tools may help DMs to obtain realistic results for their problems (Kara 2011), and that is the reason why outsourcing decisions are usually dealt with based on approaches that consider multicriteria methods and/or group decision-making techniques (Nazari-Shikouhi et al. 2011). The task of selecting suppliers from a wide set of potential suppliers with different performances is not an easy task, since multiple, conflicting objectives are inherently involved in these decision-making problems (Araz et al. 2007).

Several earlier studies in this field make use of Multi-Criteria Decision-Making/Aiding (MCDM/A) methods to support outsourcing decisions. Nazari-Shikouhi et al. (2011) proposed a group decision-making approach based on Fuzzy Analytic Hierarchy Process (AHP) for selecting an information system outsourcer which took seven criteria into account. Wadhwa and Ravindran (2007) model the problem of selecting outsourcers by considering three conflicting objectives in a multiple sourcing network, and they compared three different multi-objective techniques, of which goal programming appeared to be the most suitable one for this problem. The Analytic Balanced Scorecard Model was developed by de Felice et al. (2015), who integrated the Balanced Scorecard with the AHP, in order to analyse strategic performance in the context of outsourcing a supply chain.

Hybrid approaches in which more than one MCDM/A method is applied are also common in the literature on outsourcing. Araz et al. (2007) developed a system that evaluates and manages outsourcers for a textile company based on two phases: first, the outsourcers are evaluated in terms of multiple objectives by the PROMETHEE method; then, fuzzy goal programming is applied so as to select strategic outsourcing partners and to determine the quantities to be ordered from each outsourcer. The ELECTRE method was combined with the utility function in order to evaluate alternatives of an outsourcing contract problem from a cost-quality perspective by de Almeida (2007). Kara (2011) integrated Fuzzy AHP and the PROMETHEE method to solve an outsourcing problem of a mid-size firm in the field of electrical and electronic equipment. Wang and Yang (2007) also developed a hybrid MCDM/A method based on AHP and PROMETHEE in order to aid outsourcing decisions on information systems; in their approach, the weights of the criteria are found based on AHP, and the PROMETHEE method is used to rank the alternatives and to conduct a sensitivity analysis based on varying the values of weights. More recently, López and Ishizaka (2017) have used fuzzy cognitive maps combined with AHP in order to select a location to outsourcing activities on the supply chain.

There is variety of MCDM/A methods (Belton and Stewart 2002; Ishizaka and Nemery 2013) that can be applied for evaluating alternatives. These methods should be selected by considering aspects regarding the nature of the problem and the process for building a model (de Almeida 2007). Another issue that should be considered when choosing a method is the rationality of the DM regarding compensation amongst criteria: the DM may or may not allow the compensation of good or bad performance among criteria. This aspect is crucial in order to define whether or not a compensatory or non-compensatory rationality will be used in the preference modelling (de Almeida et al. 2015).

In order to address the outsourcing problem described in this paper, the FITradeoff method is applied. This method uses partial information about decision makers' preferences, and it was originally developed for dealing with choice problems in the scope of the Multiattribute Value Theory by De Almeida et al (2016). Then, the method was extended for dealing with ranking problems (Frej et al., 2019a), sorting problems (Kang et al., 2020) and portfolio problems (Frej et al., 2021). This method has been applied in a wide range of application areas. Gusmão & Medeiros (2016) applied it to aid the decision on selecting a strategic information system. Frej et al. (2017) explored the FITradeoff method to solve a supplier selection problem of packaging material in a food industry. This method has also been applied to deal with problems in the energy sector (Kang et al., 2018; Fossile et al., 2020); scheduling rules selection (Pergher et al., 2020), agricultural sector (Alvarez Carrillo et al., 2018); textile sector (Rodrigues et al., 2020), among other application fields. Recently, de Almeida et al. (2021) proposed a different approach for the FITradeoff decision process which combinates two preference modeling paradigms: elicitation by decomposition and holistic evaluation, in order to improve the decision process. All those applications have shown that satisfactory results are obtained by this method, and a simulation study performed by Mendes et al (2020) highlight the potential of the FITradeoff method to solve the problem with few questions answered, enhancing the advantages of reducing the time and effort that the DM needs to devote to the elicitation process.

As an extension of the research made by Rodriguez et al. (2021) and Rodriguez et al. (2018) and where cases of purchasing of laboratory equipment were evaluated, under the same conditions and scenarios for all the DM, in this study the singularity and independence in each laboratory and DM is evaluated. At the end of the decision-making process, only a unique and group solution should be selected. Since different case analysis are necessary to validate and the generalization from a single case is not enough to develop a scientific knowledge (Flyvbjerg 2006), from a practical perspective the situation presented in this paper is a more complex situation because of the inequity in the number of alternatives and criteria available for each DM. Even considering the limited time for the decision-making process, the FITradeoff method application allows validating the possible advantages found in the literature using partial information and, at the same time, thinking about the standardization of the decision-making process through a DSS not only for outsourcing problems but in general, for all the processes in the company.

3 METHODOLOGY

The FITradeoff method, which is described in Section 3.1, was applied in this study in order to find the most promising alternatives for outsourcing laboratory services from a Colombian agricultural research company. The context of the outsourcing decision problem is described in Section 3.2, and the remaining sections describe the preference modelling of the decision process.

3.1 FITradeoff Method

In order to find solutions that satisfy the preferences of each DM, we based our analysis on the additive model in the scope of Multi-Attribute Value Theory (MAVT) (Keeney & Raiffa 1976), according to which a global value v_j is given to each alternative j by Eq. (1), which sums the normalized performances $v_i(x_{ji})$ of j in each criterion i, $i = 1,\ldots,n$, weighted by the scaling factors k_i. In order to calculate the values of $v_i(x_{ji})$, an intracriteria evaluation should be performed, in which linear or non-linear value functions can be considered. For simplification purposes, in the present case, a linear value function was considered for all criteria, and therefore a normalization procedure was applied according de Almeida et al., (2015), creating a new scale as shown in Eq. (2), in which $\mathrm{B_i}$ and $\mathrm{W_i}$ are, respectively, the best and worst consequences for criterion i. Finally, the weights are normalized according to Eq. (3).

$$v_j = \sum_{i=1}^{n} k_i v_i(x_{ji}) \tag{1}$$

$$v_i(x_{ji}) = (x_{ji} - W_i) / (B_i - W_i) \tag{2}$$

$$\sum_{i=1}^{n} k_i = 1; k_i > 0 \tag{3}$$

The Flexible and Interactive Tradeoff (de Almeida et al. 2016; Frej et al. 2019a) is an MCDM/A method based on the additive model with the axiomatic structure of the tradeoff procedure (Keeney and Raiffa 1976). It has the advantage of using partial rather than complete information regarding the scaling constants of the criteria, which leads to reducing the information required from the DM and the level of cognitive effort that he/she needs to make. The flexible elicitation process is based on strict preference statements rather than indifference and can be adapted for different conditions and applications. Using the flexible Decision Support System (DSS) available online at www.fitradeoff.org, the elicitation procedure with the DM is conducted in such a way that he/she does not necessarily need to follow all the steps in a rigid way. Instead, he/she may skip doubtful questions and reflect on the problem by analyzing the results found so far at each interaction.

After an intracriteria evaluation is performed, the DM ranks the criteria scaling constants. Thereafter, an interactive question-answering process starts, in which the DM compares two hypothetical consequences in each question: consequence A, with an intermediate outcome of a certain criterion and the worst outcome for all other criteria; and consequence B, with the best outcome for a lower ranked criterion (compared to the one with intermediate outcome in consequence A) and the worst outcome for all other criteria. More details about the questions made in the FITradeoff method can be found in De Almeida et al. (2016). Then, by answering questions concerning strict preferences between consequence vectors, inequalities of type (4) and (5) are obtained. For each indifference point x_i^I, there is an upper ($x_i^{'}$) and lower ($x_i^{''}$) bound around it, which gives rise to inequalities as shown in Eqs. (4) and (5). As the DM gives more information, the interval ($x_i^{''}$, $x_i^{'}$) is narrowed, thus limiting the values that the scaling constants can assume.

$$v_i\left(x_i^{'}\right) > k_{i+1}/k_i \tag{4}$$

$$v_i\left(x_i^{''}\right) < k_{i+1}/k_i \tag{5}$$

The FITradeoff method works based on a so-called space of weights (φ^n) (Eq. (6)), which is used to build the constraints of a Linear Programming Problem (LPP), with a view to identifying the potential solutions for each updated space of weights (de Almeida et al. 2016).

$$\varphi^n = \begin{bmatrix} k_1 > k_2 \ldots > k_n; \sum_{i=1}^{n} k_i = 1; k_i > 0; \\ k_1 v_1\left(x_1^{''}\right) < k_2 < k_1 v_1\left(x_1^{'}\right); \ldots; \\ k_i v_1\left(x_i^{''}\right) < k_{i+1} < k_i v_1\left(x_i^{'}\right); \ldots; \\ k_{n-1} v_1\left(x_{n-1}^{''}\right) < k_n < k_{n-1} v_1\left(x_{n-1}^{'}\right) \end{bmatrix} \tag{6}$$

The elicitation process finishes when the DM is not willing to continue the process or when a final solution is found. Figure 1 shows the steps of the FITradeoff DSS.

3.2 Problem description

The institution in which this study was conducted is a semi-private Colombian firm which conducts research, transfer of technology activities and innovation for the agricultural sector. This company counts on several research laboratories throughout the country, the aim being to satisfy all the requirements of its agricultural projects. Actually, the current challenge for its Laboratories Department is to improve the productivity of the laboratories in terms of generating results from laboratory analyses, in accordance with quality standards, thus contributing to the emergence of technological solutions. However, given the constant increase in the demand for their services, the capacity of the laboratories is being over-stretched, and this has led company managers to consider outsourcing some services in order to ensure research projects are developed.

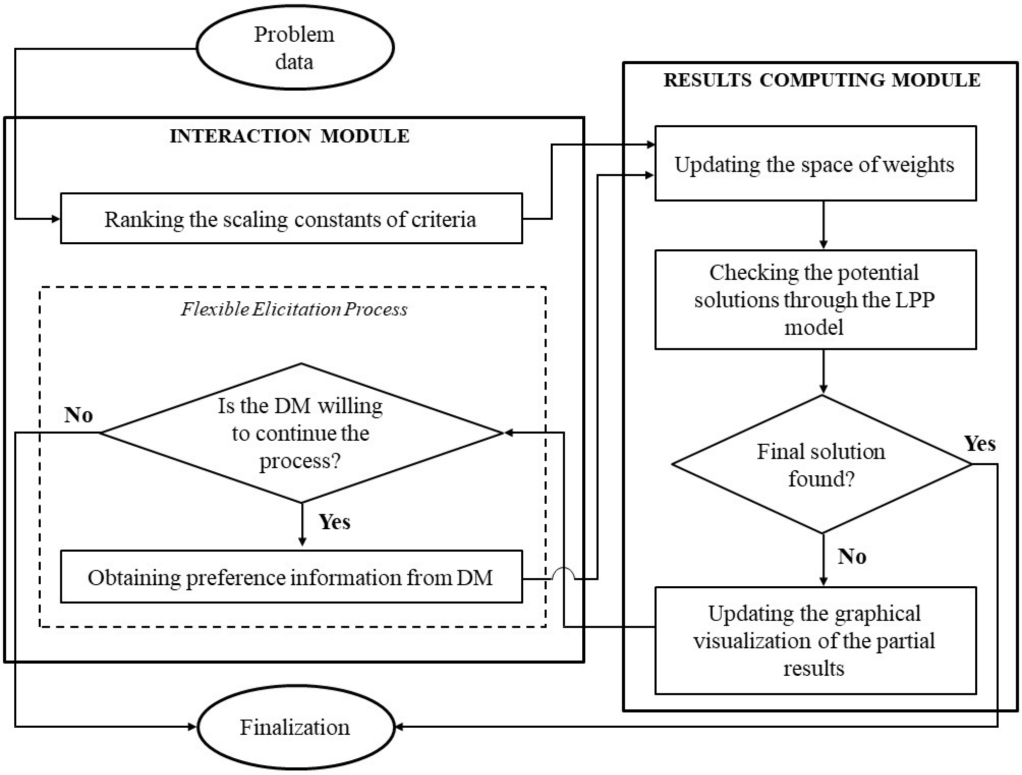

Figure 1 – FITradeoff DSS.

In this study we focused on seven laboratories whose services are subject to outsourcing: analytical chemistry, vegetal microbiology, molecular analysis, entomology, vegetal production, animal microbiology and animal nutrition. A first class of laboratories consists of those able to develop all tests related to their analysis independently of other laboratories. A second class refers to those requiring results from other laboratories as input for their analysis. And the remaining laboratories are auxiliary, developing tests the results of which are later used as input for analysis from other laboratories. Figure 2 illustrates the flow of analysis between laboratories, starting from the receipt of the work order.

The company has identified nine potential external partners to which it could outsource laboratory services, represented by the set $L = \{A,B,C,D,E,F,G,H,I\}$. Since the services developed by each laboratory have different requirements and there is not a single external partner able to supply all the analyses, there is a set of alternatives for each laboratory and DM, which consists of a subset of L and the alternative *OWN*, that corresponds to the option of keeping the analysis currently in the company's laboratory. This sub-set is used to verify whether it would be feasible to outsource the service. Table 1 shows the availability of alternatives for each laboratory.

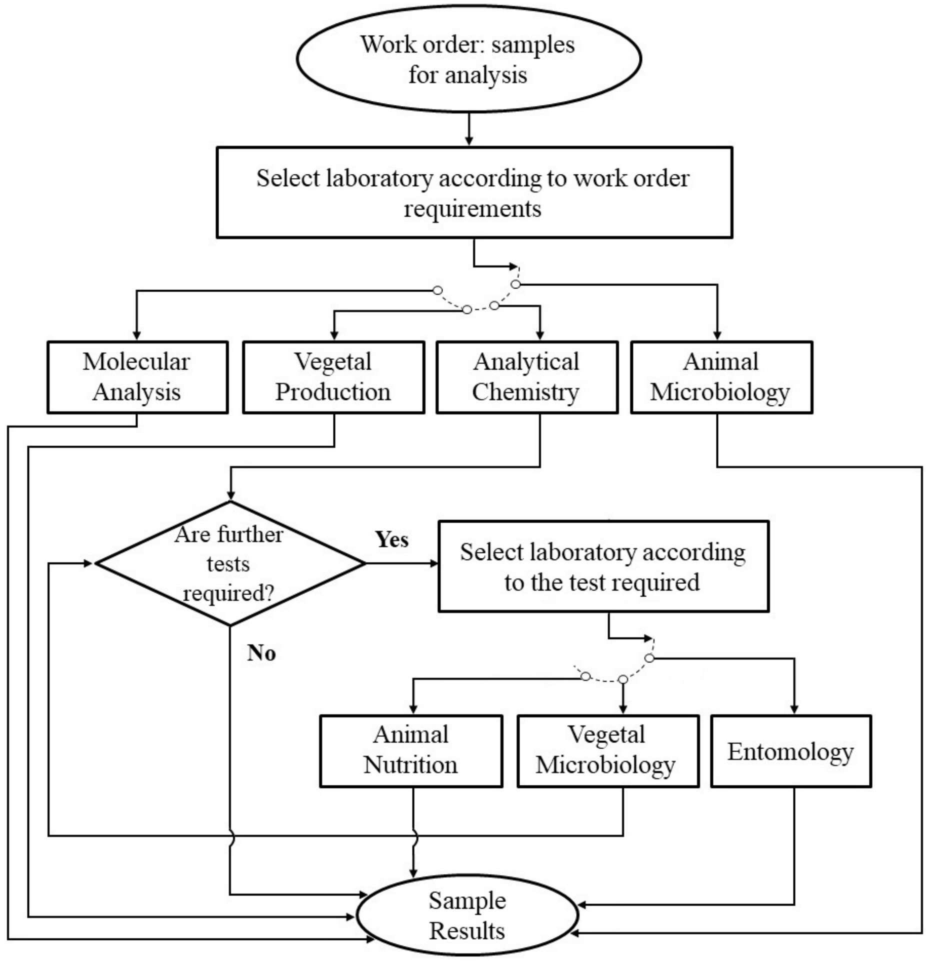

Figure 2 – Procedure for sample analysis.

Table 1 – Viable alternatives for each laboratory.

Laboratory	Alternatives
Analytical Chemistry	OWN, A, B, C, D, H
Animal microbiology	OWN, A, B, D, G
Animal nutrition	OWN, A, B, D, F
Entomology	$OWN, A, B, C, D, E, F, G, I$
Molecular analysis	OWN, A, B, C, E
Vegetal microbiology	OWN, A, B, C, D, E, F
Vegetal production	OWN, A, E

Table 2 – DMs description.

Laboratory	Educational background	Position in the firm	Experience in the field (years)
Chemistry	Chemistry	Technical coordinator	15
Animal Nutrition	Food engineer	Laboratory manager	15
Animal Microbiology	Microbiologist	Technical coordinator	10
Entomology	Biologist	Technical coordinator	5
Molecular Analysis	Veterinary	Technical coordinator	7
Vegetal Production	Agronomist	Researcher	5
Vegetal Microbiology	Microbiologist	Technical coordinator	7

3.3 Characterization of the decision makers

For each laboratory there is a DM whose preferences should be taken into account when making decisions about outsourcing a laboratory service. The DMs interviewed are composed by seven people who are the technical leaders for each laboratory. Their qualification and experience are descripted in Table 2. A decision must be taken on whether outsourcing should be carried out and, if so, on selecting what company will be in charge of performing the service. Moreover, on account of the interactions between laboratories, the decisions made by one of the laboratories may impact on the performance of the others.

3.4 Criteria definition

In order to guide DMs and managers in their task, five performance objectives were defined by a group of consultants belonging to the area of project management in the same organization: Dependability, Flexibility, Speed, Cost and Quality. Each objective was established considering the strategic drivers and goals to keep the sustainability of the operation of the organization. In the same context, each objective generated one or more criteria against which the alternatives for each laboratory should be evaluated, leading to a final set consisting of ten criteria. The use of additive models requires preferential independence between criteria to be verified; the use on an additive aggregation function to evaluate alternatives (Eq. 1) is conditioned to the satisfaction of the preferential independence condition (de Almeida et al., 2015). The criteria of this problem were analyzed by the DMs to ensure the satisfaction of such independence condition. In case of the occurrence of dependence between criteria, it would affect the decision model in a sense that Eq. 1 would not be possible. According to Keeney & Raiffa (1976), the occurrence of preferential dependence may be due to missing criteria in the problem; in this sense, a better analysis on the set of criteria would have to be performed in order to revise the criteria of the problem.

- Reliability on the Result (C1): This is the perception related with the quality, reproducibility and precision in the result of the analyses performed. Sometimes it is influenced by the results obtained in international or interlaboratory proficiency tests.

- Acceptance Level (C2): Level of approval of researchers and partners regarding outsourcing.
- Know How (C3): Percentage of technical knowledge that can be lost with outsourcing.
- Technology (C4): Related to the physical infrastructure and the quantity of available equipment of the alternative.
- Capability (C5): Number of samples analyzed per day.
- Flexibility to Change (C6): Ability to change methodologies and adapt to new requirements.
- Innovation (C7): Competence of a company to propose procedures and evaluate other methodologies in order to improve the activities.
- Time (C8): Delivery time of the result of the analysis, measured in number of days.
- Cost (C9): Total cost of analyzing just one sample. The value is expressed in USD.
- Quality System (C10): Evaluates whether or not there is a quality management system in the laboratory and/or accredited tests according to technical standards. Two evaluation levels: 1, if there is a quality management system and 0 if there is not.

Thus, to reach the Dependability objective, an alternative should be well evaluated in criteria C1, C2, C3 and C4; similarly, to achieve Flexibility, criteria C5, C6 and C7 should be considered; finally, to comply with the Speed, Cost and Quality objectives, it is important to have good performances in criteria C8, C9 and C10, respectively. Table 3 presents the evaluations of each alternative in each criterion, made by company experts who took into account the specificities of each laboratory activity. Scores of an alternative in criteria C3, C8 and C9 should be minimized, whereas those in the other criteria should be maximized. It is important to highlight that constructed criteria (C1, C2, C6 and C7) were measured on a five-point Likert scale, ranging the performance between 1 as very bad, 2 bad, 3 regular, 4 good and 5 very good. The judgment about the desirable result of each criteria was set according the goals the firm expect to achieve.

4 RESULTS AND DISCUSSION

Since the real-life decision-making processes inside the companies are usually made in a subjective way, without an appropriate methodological support, at the beginning the principles of multicriteria decision-making were presented and explained, and a consensus was finally reached on the objectives and criteria to be considered in the problem. Then, with the support of the analyst, the FITradeoff DSS was applied to elicit the preferences of each DM separately.

In the first step of the FITradeoff method, the DMs ranked the scaling constants. Then, during the flexible elicitation process, the DMs expressed their preferences by answering questions with respect to consequence vectors. The final rankings are shown in Table 4.

Table 3 – Consequences matrix.

Laboratory	Alternative	Criteria									
		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
Analytical Chemistry	*OWN*	5	2	23.01	10	100	5	5	21	13	1
	A	5	5	14.62	2.7	70	3	4	7	15	1
	B	5	5	13.45	3.8	50	5	3	9	14	1
	C	4	4	7.67	4.5	40	5	4	12	14	1
	D	4	4	9.55	2.5	30	3	3	12	14	0
	H	3	1	2.60	1	20	1	2	15	14	0
Animal Microbiology	*OWN*	4	2	23.01	10.0	100	5	5	21	12	1
	A	3	5	14.62	2.7	60	3	4	7	20	0
	B	5	5	13.45	3.8	75	5	3	9	18	1
	D	3	4	9.55	2.5	40	3	3	12	15	1
	G	2	2	13.18	5.0	20	4	5	14	12	1
Animal Nutrition	*OWN*	4	2	23.01	10	40	5	5	21	20.0	1
	A	5	5	13.45	3.8	80	5	3	9	18.4	1
	B	3	5	14.62	2.7	70	3	4	7	17.6	1
	D	4	3	3.76	2.5	40	1	2	17	18.0	0
	F	4	4	5.07	1.4	20	2	3	10	19.5	0
Entomology	*OWN*	4	2	23.01	10	100	3	5	21	20	1
	A	3	4	14.62	7	80	4	5	7	15	0
	B	4	4	13.45	9	35	3	4	9	16	1
	C	5	3	7.67	10	100	2	3	12	18	1
	D	3	3	9.55	5	20	4	4	12	18	0
	E	4	3	4.49	7	75	3	3	10	18	1
	F	2	3	5.07	5	30	4	5	12	17	0
	G	4	4	3.18	8	70	3	3	14	16	1
	I	3	2	3.91	4	35	3	3	18	15	0
Molecular Analysis	*OWN*	4	2	23.01	10	100	5	5	21	12.5	1
	A	3	5	14.62	2.7	50	3	4	7	13.0	0
	B	3	5	13.45	3.8	50	5	3	9	12.0	1
	C	2	4	7.67	4.5	40	5	4	12	12.0	0
	E	4	2	23.01	10	100	5	5	21	12.5	1
Vegetal Microbiology	*OWN*	5	2	23.01	10	100	5	5	21	18.5	1
	A	4	5	14.62	2.7	60	3	4	7	17.5	1
	B	5	5	13.45	3.8	80	5	4	9	17.0	1
	C	4	4	7.67	4.5	60	5	4	12	18.5	1
	D	3	4	9.55	2.5	70	3	3	12	17.5	1
	E	5	3	4.49	4.1	80	2	4	10	18.0	0
	F	3	4	5.07	1.4	20	2	3	10	18.7	0
Vegetal Production	*OWN*	5	2	23.01	10	80	5	5	21	5.5	1
	A	3	5	14.62	2.7	30	3	4	7	3.9	0
	E	3	3	4.49	4.1	100	2	4	15	4.0	0

Table 4 – Ranking of criteria scaling constants.

DM	Laboratory	Ranking of criteria scaling constants
DM$_1$	Analytical Chemistry	$k_1 > k_4 > k_5 > k_8 > k_9 > k_2 > k_6 > k_{10} > k_3 > k_7$
DM$_2$	Animal Microbiology	$k_4 > k_1 > k_{10} > k_2 > k_3 > k_7 > k_5 > k_6 > k_8 > k_9$
DM$_3$	Animal Nutrition	$k_{10} > k_5 > k_8 > k_4 > k_9 > k_1 > k_6 > k_3 > k_7 > k_2$
DM$_4$	Entomology	$k_1 > k_5 > k_{10} > k_4 > k_2 > k_6 > k_7 > k_3 > k_8 > k_9$
DM$_5$	Molecular Analysis	$k_4 > k_1 > k_5 > k_9 > k_8 > k_3 > k_7 > k_6 > k_{10} > k_2$
DM$_6$	Vegetal Microbiology	$k_4 > k_1 > k_5 > k_3 > k_7 > k_6 > k_8 > k_9 > k_{10} > k_2$
DM$_7$	Vegetal Production	$k_4 > k_1 > k_5 > k_3 > k_7 > k_6 > k_8 > k_9 > k_{10} > k_2$

In the FITradeoff method, the subspace of weights for the scale constants is expressed in the minimum and maximum limits that each constant can assume (Table 5).

Table 5 – Limits of the subspace of weights obtained.

DM		C$_1$	C$_2$	C$_3$	C$_4$	C$_5$	C$_6$	C$_7$	C$_8$	C$_9$	C$_{10}$
DM$_1$	Min k	0.286	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Max k	1.000	0.100	0.077	0.333	0.129	0.091	0.071	0.118	0.111	0.083
DM$_2$	Min k	0.147	0.000	0.000	0.418	0.000	0.000	0.000	0.000	0.000	0.000
	Max k	0.333	0.085	0.081	0.800	0.038	0.018	0.078	0.018	0.018	0.102
DM$_3$	Min k	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.222
	Max k	0.071	0.056	0.063	0.167	0.364	0.067	0.059	0.182	0.077	1.000
DM$_4$	Min k	0.296	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Max k	1.000	0.112	0.089	0.124	0.225	0.108	0.098	0.078	0.075	0.160
DM$_5$	Min k	0.167	0.000	0.000	0.200	0.085	0.000	0.000	0.000	0.000	0.000
	Max k	0.427	0.050	0.063	0.599	0.333	0.056	0.059	0.067	0.143	0.053
DM$_6$	Min k	0.500	0.083	0.167	0.667	0.200	0.125	0.143	0.111	0.100	0.091
	Max k	0.143	0.000	0.000	0.167	0.000	0.000	0.000	0.000	0.000	0.000
DM$_7$	Min k	0.000	0.000	0.000	0.100	0.000	0.000	0.000	0.000	0.000	0.000
	Max k	0.500	0.100	0.250	1.000	0.333	0.167	0.200	0.143	0.125	0.111

For most DMs, the alternative placed first in the ranking was the company's laboratory where the activities are currently carried out. In these cases, DMs considered it relevant to also obtain information about the second alternative in their rankings, as those ranked second could be taken into consideration as possible suppliers to outsource activities. For the DMs for whom the first place alternative in the ranking was not the company's laboratory itself, the elicitation process was concluded based on the first place information.

Table 5 shows the results obtained for each DM. The alternative placed in the first position of the ranking answers the question "to outsource or not?". For those DMs who ranked the 'own' alterative in first place, Table 6 shows which alternative was placed in the second position of the ranking, so as to give an option for outsourcing in case a backup supplier is necessary, thus answering the question "outsource from whom?". This question is also answered in cases in which the alternative ranked in first position is an external supplier. While in the choice problems, the potential optimality alternative is verified, this study showed a ranking problem, applying the

Table 6 – Results and ranking of the alternatives.

DM	Laboratory	Number of Answered Questions	Position on Final Ranking 1st	2nd
DM_1	Analytical Chemistry	5	*OWN*	*B*
DM_2	Agricultural Microbiology	3	*OWN*	*B*
DM_3	Molecular Analysis	5	*OWN*	*E*
DM_4	Entomology	11	*C*	
DM_5	Vegetal Production	0	*OWN*	*E*
DM_6	Animal Microbiology	11	*OWN*	*B*
DM_7	Animal Nutrition	4	*B*	

concept of pairwise dominance relations among the alternatives within the subspace of weights, finding preferential relations among the alternatives obtained from partial information provided by the DMs (Frej et al. 2019b). Table 6 presents the number of questions that each DM answered during the process and the top alternatives obtained in the final ranking.

According to the defined objectives and the corresponding set of criteria, as well as the preferences of DMs from the seven laboratories, the alternative most preferred to perform the research activities are the company's own laboratories, where activities have already been developed, indicating that for these cases outsourcing would not be the best option. Actually, DMs might have a tendency to not outsourcing the activities, since it somehow could affect their own jobs; these aspects may have influence on the results found. Nevertheless, as the laboratories' capacities are overloaded, which makes it impossible to meet the demand, other organizational strategies must be considered, and those alternatives should be aligned with the organizational objectives. Taking this into account, the alternatives placed second in the ranking were also computed. It can be observed in Table 6 that supplier B appears in the second position for the analytical chemistry, agricultural microbiology and animal microbiology laboratories. Similarly, E is the second best positioned supplier for the molecular analysis and vegetal production laboratories. Therefore, an option for the company could be to ask these suppliers to improve in the criteria identified with weak performance, thereby strengthening their proficiency.

On the other hand, of course, a company would prefer its own services because ideally, they are aligned with "the business". However, for the other two laboratories the main alternative that should be considered is not the 'own' one, meaning that even if the capacity is not over-stretched, it is more profitable to contract a supplier rather than to keep the operations internally in these laboratories.

Table 6 also indicates the number of questions each DM needed to answer during the FITradeoff elicitation process to obtain a result. In fact, there is a reduction of the total of answers needed compared with compensatory methods (de Morais Correia et al. 2021). For example, using the classical tradeoff procedure proposed by Keeney & Raiffa (1976), a benchmarking for the number of questions would be a minimum of 3*(n-1), in which n is the number of criteria of the problem (de Almeida et al., 2016). This is due to the fact that it is hard for the decision maker to go straight to the indifference point, and therefore it would be reasonable to make at least one question above the indifference point and one question below the indifference point, which would lead to 3 questions for each criterion. Considering this benchmarking, a total of 27 questions would be necessary. The results in Table 6 show that for all laboratories the number of questions was significantly lower than that. The higher value was a total of 11 questions, for the Entomology and Animal Microbiology laboratories. In contrast, for the Vegetal Production laboratory, for example, no question needed to be answered, since for this case the space of weights obtained after ranking the scaling constants was enough to find a solution. Moreover, it should be highlighted that the FITradeoff method works with partial information, in such a way that only strict preferences need to be answered. From the 27 questions that would be made considering the classical tradeoff procedure, at least 9 of them would be indifference questions, which are more difficult for the DM to answer. In this sense, a lower cognitive burden is spent in FITradeoff, when compared to other approaches.

The application of the FITradeoff method in this real case of an agriculture research company confirms that it can be an advantageous tool for solving multicriteria situations found in practice such as the outsourcing problem. This method is based on a compensatory rationality in the scope of MAVT, but it uses partial information about DMs' preferences in order to deal with the challenging task related to eliciting the scaling constants. The flexibility of the method allows DMs to adapt it to any conditions and circumstances, and it does not necessarily follow all the steps of the traditional trade-off procedure (de Almeida et al. 2016), and therefore DMs need to spend less time and effort on it. Moreover, to reduce the inconsistencies found within compensatory methods (Borcherding et al, 1991), applying FITradeoff method provide the reliability of the results obtained, because of the need to systematize the decision-making process through long-term strategies (Poleto et al. 2020).

5 CONCLUSIONS

In this paper we applied the FITradeoff method to solve different multicriteria decision problems by eliciting preferences from seven leaders of agricultural research laboratories in a real-life application. The results obtained helped to answer for each laboratory whether it would be feasible to outsource its services, and which would be the most appropriate supplier according to different criteria. For those cases where it would be preferable to keep the activities being developed internally, the results also indicated which external suppliers could be taken into account by the company for future negotiations, thereby complying with its strategic objectives.

The selection of partner or supplier for the case organization in complex cases that require a decision-making approach results in a positive benefit-cost ratio when a decision-making tool is introduced. The FITradeoff method proved to be useful for assisting DMs and managers in this context. Its elicitation process required DMs to answer few or no questions. Moreover, as the method is based on partial information, defining exact parameter values was not necessary, thus easing to DMs a cognitive process with less effort and saving time on the decision-making process.

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